Australian Government

Department of Sustainability, Environment, Water, Population and Communities

Narran Lake Nature Reserve Ramsar Site

Ecological Character Description

May 2011

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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 *Environment Protection and Biodiversity Conservation Act 1999* (Cth), 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.

Note: There may be differences in the type of information contained in this ECD publication, to those of other Ramsar wetlands.

Cover photos (left to right):
Aerial photo Narran Lake Nature Reserve – Dragi Markovic (SEWPAC), Water bird at Narran Lake Nature Reserve – Dragi Markovic (SEWPAC), Sunset at Narran Lake Nature Reserve – Dragi Markovic (SEWPAC), Water bird at Narran Lake Nature Reserve – Dragi Markovic (SEWPAC), Aerial photo Narran Lake Nature Reserve – Dragi Markovic (SEWPAC)

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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".
Biodisparity	The range of morphologies and reproductive styles in a community. The biodisparity of a wetland community is determined by the diversity and predictability of its habitats in time and space.
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).
Change in ecological character	Defined as 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; 159 as at March 2010. Membership in the Convention is open to all states that are members of the United Nations, one of the UN specialised agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice.
Critical stage	Meaning 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	Include 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	The changes or reactions which occur naturally within wetland

processes	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 (Australian Heritage Commission 2002).
Ecosystem services	The benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (for example food and water), regulating (for example flood control), cultural (for example spiritual, recreational), and supporting (for example nutrient cycling, ecological value). (Millennium Ecosystem Assessment 2005). See also "Benefits".
Endemic	*endemic species* (Guidelines for Criterion 7) - a species that is unique to one biogeographical region, i.e., it is found nowhere else in the world. A group of fishes may be indigenous to a subcontinent with some species endemic to a part of that subcontinent (Ramsar 2009).
Endemism	The ecological state of being unique to a geographic location – see endemic.
Fluvial geomorphology	The study of water-shaped landforms (Gordon et al. 1999).
Geomorphology	The study of the evolution and configuration of 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 ("the 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 related 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*.
Wetlands	Are 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/ris/key_ris.htm#type].

List of Abbreviations

CAMBA	China Australia Migratory Bird Agreement.
CEPA	Communication, Education, Participation and Awareness.
BONN	Bonn Convention on Migratory Species.
CPS	Components, processes and services.
DEWHA	Department of the Environment, Water, Heritage and the Arts (Commonwealth).
DIWA	Directory of Important Wetlands in Australia.
ECD	Ecological Character Description.
EPBC Act	Environment Protection and Biodiversity Conservation Act, 1999 (Commonwealth).
IUCN	International Union for Conservation of Nature.
JAMBA	Japan Australia Migratory Bird Agreement.
LAC	Limits of Acceptable Change.
RIS	Ramsar Information Sheet.
ROKMBA	Republic of Korea Australia Migratory Bird Agreement.
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities, formerly DEWHA.

Executive Summary

Narran Lake Nature Reserve Ramsar site is located in the central north of New South Wales approximately 70 kilometres south west of Lightning Ridge, 75 kilometres north west of Walgett and 50 kilometres east of Brewarrina. The site is located on the terminal wetland system of the Narran River, a distributary of the Balonne River in the Condamine-Balonne catchment of the Murray Darling Basin (Figure E1). The site was listed as a Ramsar site in 1999 covering an area of 5343 hectares. In 2011 an extension of the site was proposed to capture additional waterbird breeding and feeding habitat adding a further 3104 hectares. This Ecological Character Description includes both the original area and proposed extension.

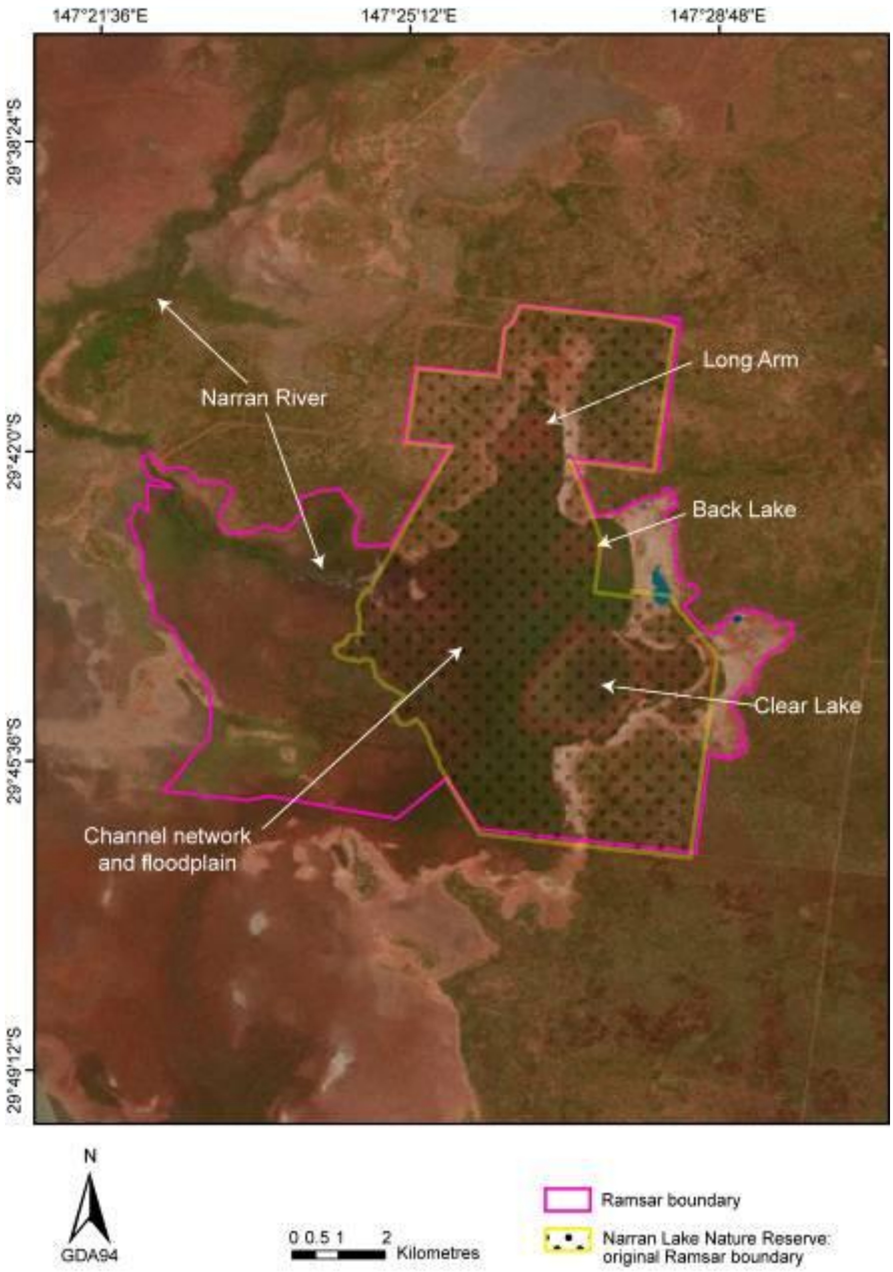


Figure E1: Location of the Narran Lake Nature Reserve Ramsar site (data supplied by SEWPaC and DECCW 2010).

Narran Lake Nature Reserve Ramsar site meets the following Ramsar criteria:

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***.
This criterion was judged to be met at designation in 1999 using New South Wales as the scale for assessment. The site also meets criterion 1 under the current bioregional assessment, that is it is a representative example of a near natural terminal inland wetland system in relatively good condition at the Murray Darling Drainage Division scale. The juxtaposition of the channelised floodplain against open water lake habitat is unique within the Murray Darling.

Criterion 2: ***A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.***
The site supports three nationally or internationally listed species:

- Murray cod (*Maccullochella peelii peelii*) listed as vulnerable under the EPBC Act and critically endangered on the IUCN Red List (IUCN 2010).
- Australasian bittern (*Botaurus poiciloptilus*) is listed as endangered under both the EPBC Act and the IUCN Red List (IUCN 2010).
- Winged peppercress *(Lepidium monoplocoides*) is listed as endangered under the EPBC Act.

Criterion 4: ***A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.***
Narran Lake Nature Reserve supports a significant number of migratory species including 14 species listed under international migratory species treaties and a further 26 species which are migratory within Australia. In addition the site is important for the critical life stage of breeding. The site supports substantial breeding of waterbirds with 44 species having been recorded breeding at the site since listing. Significant breeding populations of colonial breeding species including great eastern egret (*Ardea modesta*), glossy ibis (*Plegadis falcinellus*), Australian white ibis (*Threskiornis molucca*) straw-necked ibis (*Threskiornis spinicollis*), and royal spoonbill (*Platalea regia*) are supported at the site (RIS 1999). Narran Lake terminal wetland ecosystem has been identified as one of a handful of wetlands which retain water for a period of time after flooding and therefore act as a drought refuge in the Murray Darling Basin (Scott 1997).

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. A total of five critical components and processes were identified which contribute significantly to the sites ecological character: hydrology, productivity, vegetation, fish and waterbirds. The hydrology of the site has highly variable flows, driven by summer rainfall in the upper catchment. The Narran River is a losing system due to high evaporation. Flows of 100 000 megalitres have been identified as a threshold for most large waterbird breeding events, the exception being the 2008 flood. Annual return rates for floods greater than 50 000 and 100 000 megalitres at the time of listing were 1.85 and 2.6 years respectively. Considered an intermittent river, the historical records indicate flow in 90 percent of years; however since 1992 there has been a significant reduction in frequency and magnitude of floods reaching the Ramsar site. The 2000 to 2010 decade is the driest on record.

The Narran Lake Nature Reserve Ramsar site is a boom and bust wetland in a semi-arid environment and as such it was considered that productivity is a critical process for the site, with high primary production underpinning the support of fish and waterbird populations. However, whilst no site specific data exists, the loss of reactive floodplain upstream of the Ramsar site may influence productivity in the Ramsar site.

Vegetation of the Ramsar site is characterised by three main associations: lignum shrublands, riparian open forest and ephemeral herbfields. Lignum condition at the time of listing and in 2004 was considered good. Tree health in 2004 was poor with a high mortality and low recruitment. Seed banks remain viable and diverse especially on the edges areas of inundation. Fish are also considered critical to the ecological character of the site in that the site supports a high proportion of native species. Eleven native, including Murray cod, and four introduced species have been recorded at the site. The lowland reaches of the Condamine valley has a high degree of fish nativeness which is unusual within the Murray Darling Basin: native fish species dominate in terms of species richness and abundance (MDBA 2008). Thoms et al. (2007) reported that in 2004 more than 90 percent of the fish caught in per unit effort were native.

The site is highly significant for waterbirds. The site supports a total of 68 species, 14 international migrants and 26 species that migrate within Australia. The site is considered critical as a drought refuge for waterbirds within the Murray Darling Basin and supports 44 breeding species including large colonial waterbird breeding events of ibis, spoonbills and cormorants.

The critical services for the site include cultural and ecological supporting services. Narran Lake Nature Reserve is a significant site for Indigenous people, with contemporary use of the site for intergenerational transfer of traditional knowledge, and the presence of artefacts and middens. The site is also important spiritually for the local Indigenous people with several Dreamtime Paths converging at Narran Lake. The cultural economy and value of the site is closely linked to the ecological integrity of the site with the boom and bust ecology having a strong influence on Indigenous use of the site. Maintaining the near natural condition of the wetland is fundamental to maintaining the cultural services of the site.

The ecological supporting services provided are that the site supports near natural wetland types, physical habitat for waterbird breeding and threatened species. The physical habitat template, created by the drivers of climate, unique and complex geomorphology and a variable hydrological regime supports large expanses of lignum shrublands which in turn support significant waterbird breeding. The site is relatively intact although recent water resource development is having an impact on the hydrology of the site. It is representative of a terminal wetland system, with a relatively good condition channelised floodplain which is highly complex and dynamic in nature. The threatened species supported at the site include Australasian bittern, Murray cod, winged peppercress and several state listed species.

The relationship between components, processes and services and how they relate to the Ramsar listing criteria are shown conceptually in Figure E2.

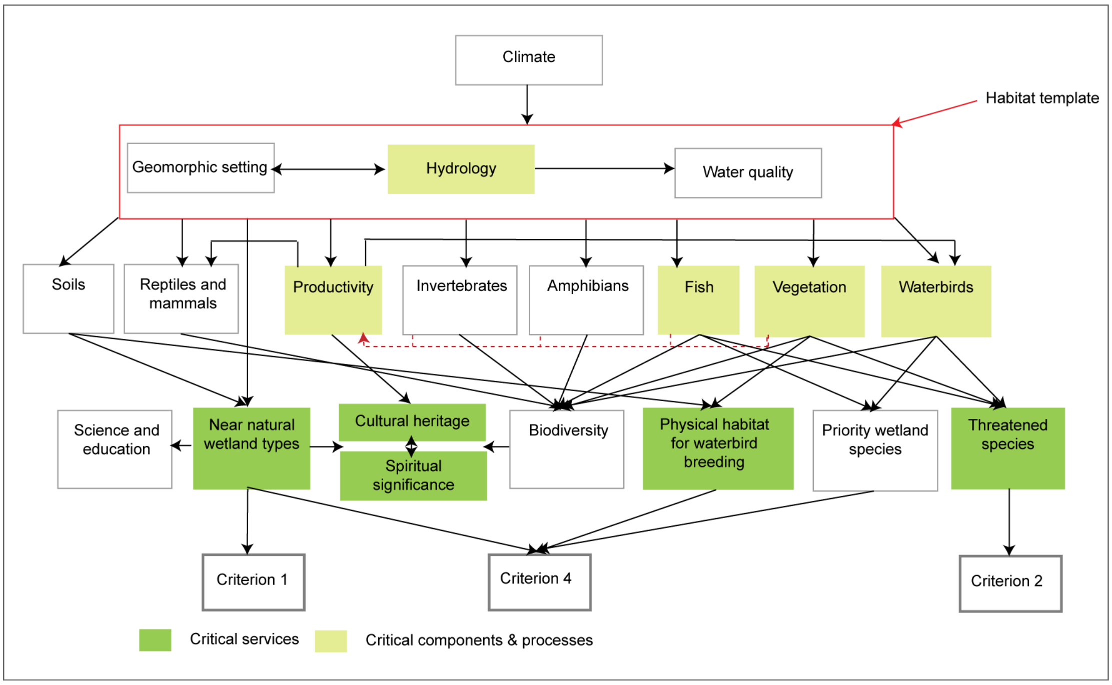


Figure E2: Relationships between components, processes and services and the Ramsar listing criteria.

“Limits of acceptable change” (LAC) are used to describe the range of variation which key aspects of the ecology of the site can vary without representing a change in the ecological character. 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.

If a LAC is breeched this represents the point at which a potential change in the ecological character of a site has occurred. Limits of acceptable change for Narran Lake Nature Reserve Ramsar site have been proposed for critical components, processes and services based on existing data and are summarised in Table E1. Fundamental to the character of the site is the hydrological regime. In many cases the LAC set for hydrology are used as indirect measures of other critical components, processes and services. This has been done mainly for situations where there is insufficient data or knowledge gaps relating to baselines for the critical components, processes and services. The assumption being made is that if the hydrology is right, then the ecological responses of biota and associated services will also be maintained.

Table E1: Proposed LAC for Narran Lake Nature Reserve Ramsar site.

Critical Components, Processes and Services	Limit of Acceptable Change
Hydrology	• In any 10 year period no less than 8 separate flow events each characterised by 25 gigalitres calculated as total volume in any 60 day period in the Narran River at Wilby Wilby. Maximum dry (inter-pulse) period between events of 2 years; and • In any 10 year period no less than 4 separate flow events characterised as 50 gigalitres calculated as total flow in any 90 day period in the Narran River at Wilby Wilby; and • In any 20 year period no less than 7 separate flow events characterised as a total of 100 gigalitres calculated as total flow in any 360 day period in the Narran River at Wilby Wilby; and • In any 20 year period at least 3 separate flow events characterised as a total of 200 gigalitres calculated as total flow in any 180 day period in the Narran River at Wilby Wilby.
Lignum shrublands – extent.	Data insufficient – No direct LAC has been developed and instead the critical component will be assessed indirectly through changes in hydrology see LAC above.
Riparian forest and woodland – condition.	No further decline in condition from baseline of 2004 set by Thoms et al. (2007), measured as percentage of dead trees surveyed (baseline 54 percent of river red gum, 45 percent of river coobas, and 38 percent of coolabahs classed as dead).
Riparian forest and woodland – extent.	Data insufficient – No LAC set.
Ephemeral herbfields – extent.	Data insufficient - No direct LAC has been developed and instead the critical component will be assessed indirectly through changes in hydrology see LAC above.
Productivity	Data insufficient - No direct LAC has been developed and instead the critical process will be assessed indirectly through changes in hydrology, see LAC above.
Fish	All species of native fish recorded over any three sampling events. Native species account for at least 75 percent of the catch in two

Critical Components, Processes and Services	Limit of Acceptable Change
	thirds of sampling events.
Waterbirds – colonial breeding events	Large colonial waterbird breeding event of 50 000 nests occur no less than 1 in 8 years based on frequency of large flood events (>100 000 megalitres total annual flow at Wilby Wilby).
Waterbirds –number of species breeding	In any 20 year period at least 35 of the 44 species of waterbird breeding are recorded breeding at the site.
Near natural wetland type	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology, see LAC above.
Physical habitat which supports waterbird breeding.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and waterbird breeding success see LAC above.
Threatened species – Murray cod	Data deficient – No LAC set.
Threatened species – Australasian bittern	Data deficient – No LAC set.
Threatened species – Winged peppercress	Presence of winged peppercress within the site when conditions are suitable.
Cultural heritage and spiritual significance.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and biota. See all LAC above.

There are a number of potential and actual threats that may impact on the ecological character of Narran Lake Nature Reserve Ramsar site. The main threat to the site is increased upstream water extraction. This will lead to reduced vegetation health and loss of habitat for waterbird breeding, as well as reduced value as drought refuge and support of critical life stages of biota (fish and waterbirds). Exacerbating this threat is climate change. Increased temperature and evaporation will lead to reduced duration of inundation, reduced vegetation health and waterbird breeding opportunities. It's possible that water dependent vegetation will contract to a narrow strip along rivers and channels (DECCW 2010b). Increased extreme local rainfall events may cause changes in patterns of inundation and lead to the potential disruption of breeding triggers for some biota. Invasive species are a relatively minor threat at the site with many of the pest animal species subject to control programs. Pigs, foxes and feral cats all pose a threat to waterbirds via increased predation particularly during breeding events. At the time of listing, and currently, there is a relatively low proportion of introduced fish species, with the site being recognised as having high proportion of native species representing a near intact fish community. Changed hydrological regimes may alter this balance and increase invasive fish populations at the site.

There is evidence that the hydrological regime has changed due to upstream water extraction, however due in part to local rainfall events the site still supports all the critical components, processes and services central to the sites ecological character. At this point in time it is considered that the Narran Lake Nature Reserve Ramsar site still retains its essential ecological character as per when it was listed in 1999, but the site may be on the brink of persistent change.

Knowledge gaps have been identified relating to geomorphic setting, productivity, hydrology (groundwater), vegetation, waterbirds, and threatened species, and cultural heritage. Information required includes setting baselines against which to measure change in ecological character as well as providing a better understanding of wetland functioning. Elements recommended for monitoring have been identified which will address knowledge gaps and assess against LAC.

1. Introduction

1.1 Site details

Narran Lake Nature Reserve Ramsar site was listed as a Wetland of International Importance in 1999. At the time of listing the site was said to cover an area of 5531 hectares (RIS 1999) which incorporated the Narran Lake Nature Reserve (4527 hectares) and a portion of the adjoining Lumeah property owned by NPWS (1004 hectares). In 2010 the area of the site was recalculated using improved mapping techniques which indicated the original site was actually 5343 hectares. A proposed extension of the boundary in 2011 by 3104 hectares will expand the site to a total area of 8447 hectares. This Ecological Character Description (ECD) incorporates the original area and the proposed extension. Further site details for this Ramsar wetland are provided in Table 1.

Table 1: Site details for Narran Lake Nature Reserve Ramsar site.

Site Name	Narran Lake Nature Reserve.
Location in coordinates	Latitude: 29˚ 43' S; Longitude: 147˚ 26' E
General location of the site	Approximately 75 kilometres north-west of Walgett and 50 kilometres north-east of Brewarrina in northern New South Wales, Australia.
Area	8447 hectares.
Date of Ramsar site designation	1999.
Ramsar/DIWA Criteria met by wetland	1, 2, 4.
Management authority for the site	NSW National Parks and Wildlife Service, Northern Plains Region, Narrabri Area.
Date the ECD applies	1999 for original area and 2011 for proposed expanded site boundary.
Status of Description	This represents the first ECD for the site.
Date of Compilation	May 2011.
Name(s) of compiler(s)	Rhonda Butcher and Jennifer Hale on behalf of the Australian Government Department of Sustainability, Water, Population and Communities.
References to the Ramsar Information Sheet (RIS)	Narran Lake Nature Reserve Ramsar Site RIS compiled by New South Wales National Parks and Wildlife Service (NSW NPWS) in 1999. Updated by Rhonda Butcher on behalf of the Australian Government Department of Sustainability, Environment, Water, Population and Communities 2011.
References to Management Plan(s)	New South Wales National Parks and Wildlife Service, (2000), Narran Lake Nature Reserve plan of management. NSW NPWS,

	May 2000.

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 the conservation of Ramsar wetlands 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 Act. The Act also provides 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 Ecological Character Description (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 which is prepared at the time of designation. It conforms with a *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 Australian and state/territory governments.

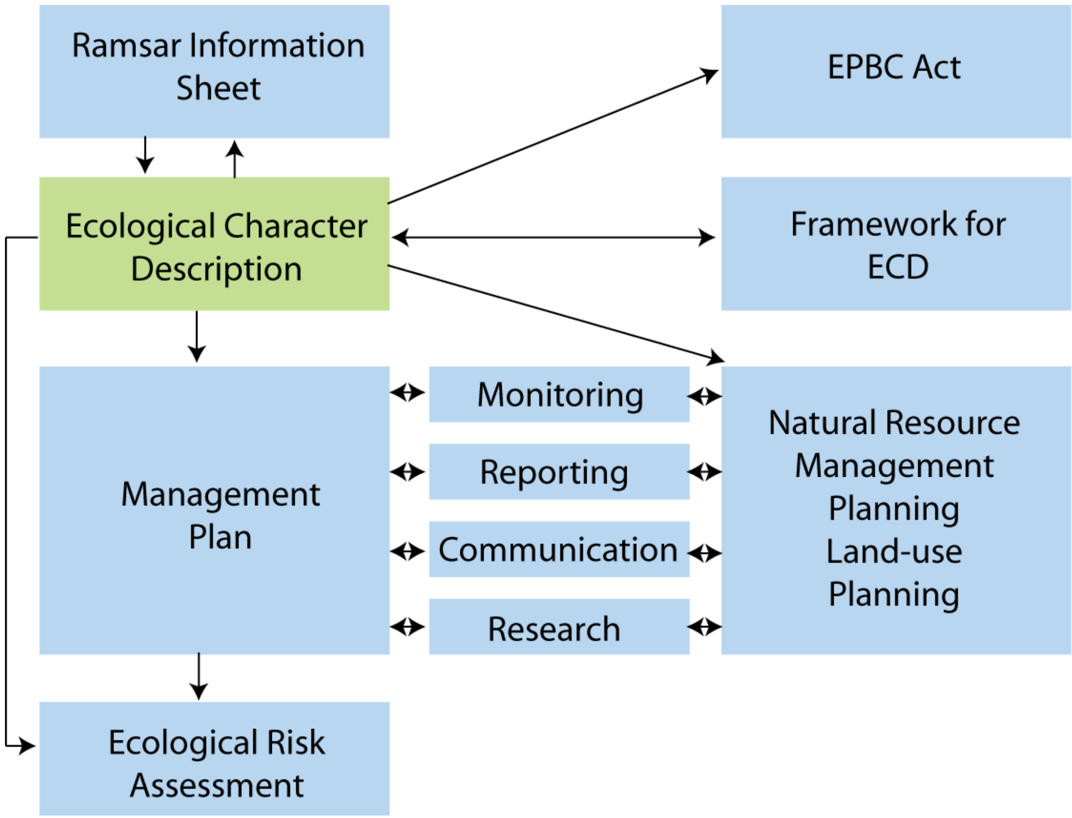


Figure 1: The ecological character description in the context of other requirements for the management of Ramsar sites (adapted from DEWHA 2008).

<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 Ramsar Information Sheet submitted under the Ramsar Convention for each listed wetland and, collectively, 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

The Narran Lake Nature Reserve Ramsar site falls within the jurisdiction of Walgett and Brewarrina Shire Councils and is affected by a number of conventions and legislation. The following provides a brief listing of the legislation and policy that is relevant to the description of the ecological character of the Ramsar site.

International

Ramsar Convention

The Convention on Wetlands of International Importance especially as Waterfowl Habitat, 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 the promotion and 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 Narran Lake Nature Reserve Ramsar site as various migratory bird species covered in these agreements utilise the site. The bilateral agreements are:

- *JAMBA (Japan Australia Migratory Bird Agreement)* – 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;
- *CAMBA (China Australia Migratory Bird Agreement)* - 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;
- *ROKAMBA (Republic of Korea Australia Migratory Bird Agreement)* - 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 (BONN)* - 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

- *Environment Protection and Biodiversity Act 1999:* 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 1999 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 1999 s335), which are set out in Schedule 6 of the *Environment Protection and Biodiversity Conservation Act Regulations*

2000 (the 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. Some matters protected under the EPBC Act are not protected under local or state/territory legislation, and as such, many migratory birds are not specifically protected under some State legislation. Species listed under international treaties (JAMBA, CAMBA and CMS) have been included in the List of Migratory species under the Act. Threatened species and communities listed under the EPBC Act may also occur, or have habitat in the Ramsar site; some species listed under State legislation as threatened are not listed under the EPBC Act as threatened, usually because they are not threatened at the national (often equivalent to whole-of-population) level. The Regulations also cover matters relevant to the preparation of management plans, environmental assessment of actions that may affect the site, and the community consultation process.

- *Native Title Act 1993* 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, invalidated because of the existence of native title.

- *Water Act 2007* 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, NSW, Victorian, South Australian and ACT governments.

- *The Basin Plan*
  The Basin Plan, when finalised, will be a strategic plan for the integrated and sustainable management of water resources in the Murray–Darling Basin. It will provide 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 will identify, and seek 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 will also take into account the impact of this protection and restoration on individual communities, industries, regions and the wider economy (http://www.mdba.gov.au/basin_plan).

Other legislation and policy
The following state and multi jurisdictional based legislation and policy is relevant to the Ramsar site:

- NSW *Western Lands Act 1901* is one of the oldest pieces of legislation in NSW. The objects of the Act are to establish a system of land tenure for the Western Division of NSW, and to facilitate new land uses and development opportunities. It establishes the rights and responsibilities of lessees and other persons with respect to landuse and ensures that land is used sustainably. The Act also makes provision for the effective integration of land administration and natural resource management within the Western Division.

- NSW *Water Act 1912* is being progressively phased out and replaced by the Water Management Act 2000 (see below), however some provisions still apply. Generally, new or expanding businesses requiring groundwater in inland NSW now need to obtain it from an existing license holder. Trading is permitted only where transfers are consistent with the Policy for groundwater transfers in inland NSW outside water sharing plan areas.

- NSW *National Parks and Wildlife Act 1974*: provides for the management of all national parks, nature reserves, Aboriginal areas and state game reserves. In addition the Act allows for the management of all State conservation areas, karst conservation reserves and regional parks. Under Part 5 section 72 of the Act the Director-General will cause a plan of management to be prepared for any nature reserve, such as the Narran Lake Nature Reserve, as soon as practicable after the reservation occurs. The plan of management of the site is the blue print for describing the values of the site, conservation requirements of species, habitat, ecosystems and populations, and the protection of items of cultural significance, landscape values, geomorphic features and wilderness values. Importantly the plan of management takes into consideration the maintenance of natural processes and rehabilitation of processes and landscapes where needed. A plan of management details the means by which the responsible authorities, in this case DECCW, will achieve the objectives and performance measures. Combined with this Ecological Character Description it provides the basic requirements for the wise use and management of the Ramsar site.

- NSW *Heritage Act 1977* to promote the understanding and conservation of NSW heritage, including the identification and registration of items of State's heritage significance. The Act provides for the protection and adaptive reuse of items of significance, as well as to assist owners with the conservation of items. It also constitutes the heritage Council of NSW and confers on it functions relating to the State's heritage.

- NSW *Noxious Weeds Act 1993* provides for the identification, classification and control of weed species that have been declared 'noxious' in NSW. It aims to reduce the negative impact of weeds on the economy, community and environment of NSW by establishing control mechanisms to prevent the establishment of significant new weeds, and restricting the spread of and reducing the area of existing significant weeds. It also provides for the monitoring of and reporting on the effectiveness weed management measures.

- NSW *Threatened Species Conservation Act 1995* (TSCA): provides for protecting threatened species, communities and critical habitat in NSW.

- NSW *Rural Fires Act 1997* establishes the NSW Rural Fire Service. In addition to its other purposes, it defines functions of the NSW Rural Fire Service to make provision for the prevention, mitigation and suppression of rural fires; it repeals the Bush Fires Act 1949; and amends certain other Acts.

- NSW *Water Management Act 2000* provides for the integrated and sustainable management of the State's waters. The Act is based on the concept of ecologically sustainable development, similar to the Ramsar concept of wise use, such that development will not threaten future generation's needs. The Act acknowledges that the basic health of rivers, groundwater, wetlands, floodplains and estuaries has to be protected. Management of water is to be coordinated with the management of other natural resources, and responsibility for water management must be a shared responsibility between the government and community. Any water management decisions must involve consideration of all environmental, social, economic, cultural and heritage aspects.

  The Draft Water Sharing Plan for the Intersecting Streams Unregulated and Alluvial Water Sources (made under section 50 of the *Water Management Act 2000*) includes the Narran River and is currently out for public exhibition. The provisions in this plan provide water to support the ecological processes and environmental needs of high priority groundwater dependent ecosystems (GDEs) and rivers, and direct how the water available for extraction is to be shared.

- NSW *Catchment Management Authorities Act 2003* established authorities to develop operational, investment and decision-making natural resource functions to catchment levels. The Act provides for proper natural resource management at the catchment level. It requires decisions taken at the catchment scale take into consideration State-wide standards and to involve the Natural Resources Commission in catchment planning processes where appropriate.

- NSW *Native Vegetation Act 2003* provides for the management of native vegetation on a regional scale to prevent broadscale clearing and to protect high conservation value native vegetation with regards to such matters as water quality, biodiversity or the prevention of salinity or land degradation. The Act allows for improving condition of existing native vegetation and the revegetation and rehabilitation of land with appropriate native vegetation in accordance with the principles of ecologically sustainable development.

- QLD *Water Act 2000* covers water rights, water planning, and implementation of water resource plans, interim allocation and management arrangements, water licenses and permits in QLD. It also defines catchment areas, allows for riverine protection, deals with quarrying of materials from watercourses, water bore licensing, and operations licenses.

- QLD *Water Resource (Condamine and Balonne) Plan 2004* is subordinate legislation under the Water Act 2000. The plan defines the availability of water in the area, provides a framework for sustainably managing and taking of water. It identifies priorities and mechanisms for dealing with future water requirements and establishes a framework for the allocation of water. The plan also provides a framework for reversing degradation in natural ecosystems, including stressed rivers, and it regulates the taking of overland flow water.

  In relation to the Ramsar site, the plan specifies that the purpose of the rules for managing Narran Lakes filling flow events is to improve waterbird breeding events. Specifically the rules ensure that if a flow event of a volume sufficient to fill the Narran Lakes Ramsar site under the pre-development flow pattern occurs during the winter bird breeding months, water harvesting must be reduced to 90% for the period of the flow event up to a maximum period of 10 days. The rule also ensure that if the site filled during the winter bird breeding months and if within four months of the site filling, a flow event that would refill the site under pre-development flow pattern occurs, then water harvesting must be reduced to 90% for up to a maximum of 10 days.

1.4 Preparing the ECD

The method used to develop the ecological character description for Narran Lake Nature Reserve 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 stakeholder advisory group was formed to provide input and comment on the ECD. Details of members of this group and more details of the method are provided in Appendix A.

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 Narran Lake Nature Reserve Ramsar Site

2.1 Location and regional context

Narran Lake Nature Reserve Ramsar site is located in the central north of New South Wales approximately 70 kilometres south west of Lightning Ridge, 75 kilometres north west of Walgett and 50 kilometres east of Brewarrina. The site is located on the terminal wetland system of the Narran River, in the Condamine-Balonne catchment of the Murray Darling Drainage Division more commonly known as the Murray Darling Basin (Figure 3).

The Condamine-Balonne River drains 143 000 square kilometres of the highlands of eastern Australia in southern Queensland and like many Australian inland rivers the Condamine-Balonne originates in a well-watered area but flows for most of its length across a dry landscape (Thoms and Sheldon 2000). Rainfall within the catchment is variable and droughts and floods occur periodically throughout the region. The long-term median annual rainfall (n = 73 years) decreases from east (1105 millimetres at Toowoomba) to west (517 millimetres at St George) across the catchment. Most rainfall occurs in the summer months (November to April) and is associated with tropical monsoonal activity. Mean annual evaporation ranges from 230 millimetres in the headwaters to 1890 millimetres in the lower catchment. Flows in the Condamine-Balonne are also highly variable, with annual flows at St George, in the lower catchment, ranging between 23 960 megalitres and 7 385 000 megalitres with an annual median of 728 175 megalitres. Flood events generally occur between November and April; hence the annual flow pattern is summer-dominated.

Downstream of St George, the Condamine-Balonne River divides into five separate channels (Figure 3). The Culgoa and Narran Rivers are the main channels, conveying 35 percent and 28 percent respectively, of the long-term mean annual flow at St George. The Ballandool River, Bokhara River and Briarie Creek only flow during higher discharge periods. All five waterways have low channel gradients (0.0002 to 0.0003), are tortuous in planform (sinuosities exceed 2.2, cf. Schumm, 1977) and transport predominantly fine sediments. Bankfull cross-sectional areas of most of the channels (the Briarie is the exception) decrease with distance downstream, so there are regular overbank flows.

The first acquisition of lands that were subsequently gazetted as the Narran Lake Nature Reserve was completed in 1988, with the Ramsar site being declared over an area of 5531 hectares in 1999 (including an additional acquisition). The Nature Reserve now covers an area of 28 323 hectares as further neighbouring properties have been acquired over the past 10 years. Approximately 10 000 hectares of the Narran Lakes terminal wetland system is listed on the Directory of Important Wetlands in Australia (Environment Australia 2001). Terewah, or Narran Lake, is not included in the Ramsar site. The main wetland basins within the Narran Lake Nature Reserve Ramsar site are Clear Lake, Back Lake and Long Arm. The Narran River floodplain extends to the west of Clear Lake and south-west to Narran Lake (Figure 4). The floodplain is an extensive channelised wetland and is vegetated predominantly by lignum shrubland (*Muehlenbeckia florulenta*) (Thoms et al. 2002). The proposed extension to the boundary of the Ramsar site will expand the site to 8447 hectares capturing additional waterbird breeding and feeding habitat (Figure 5) and covering approximately half of the terminal wetland system.

The proposed boundary extension in 2011 will not add any additional critical components, processes or services; it only captures more of the wetland habitat of the terminal wetland system.

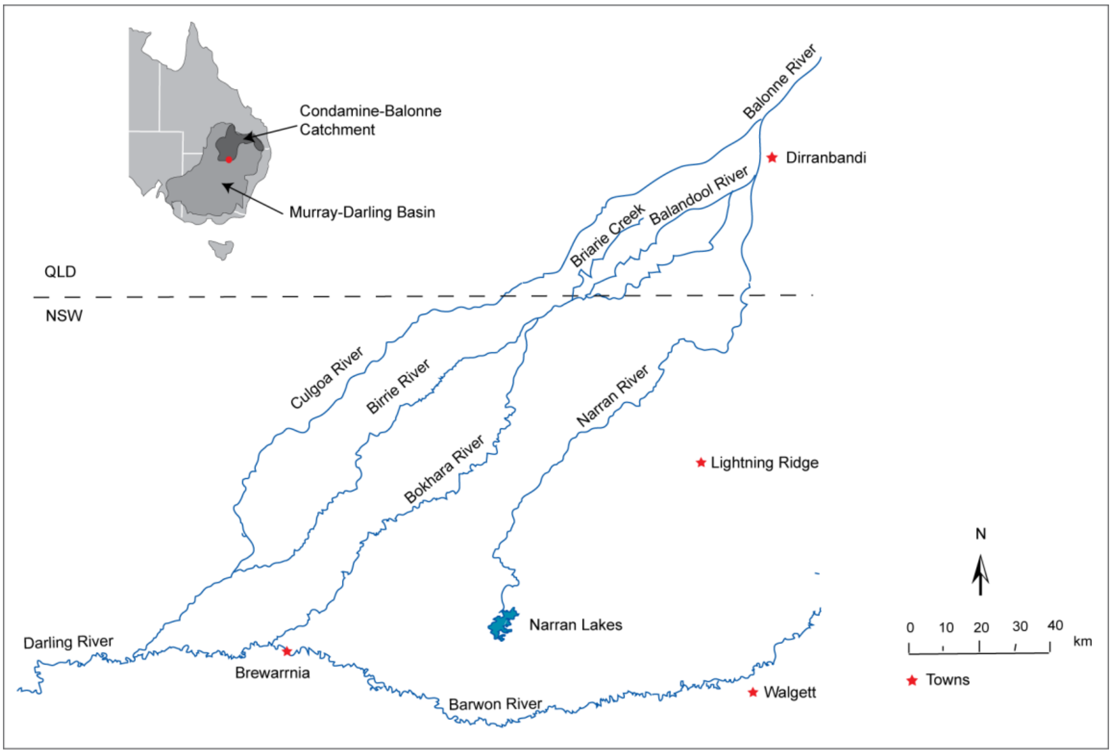


Figure 3: Location of the Narran Lakes terminal ecosystem within Murray-Darling Basin.

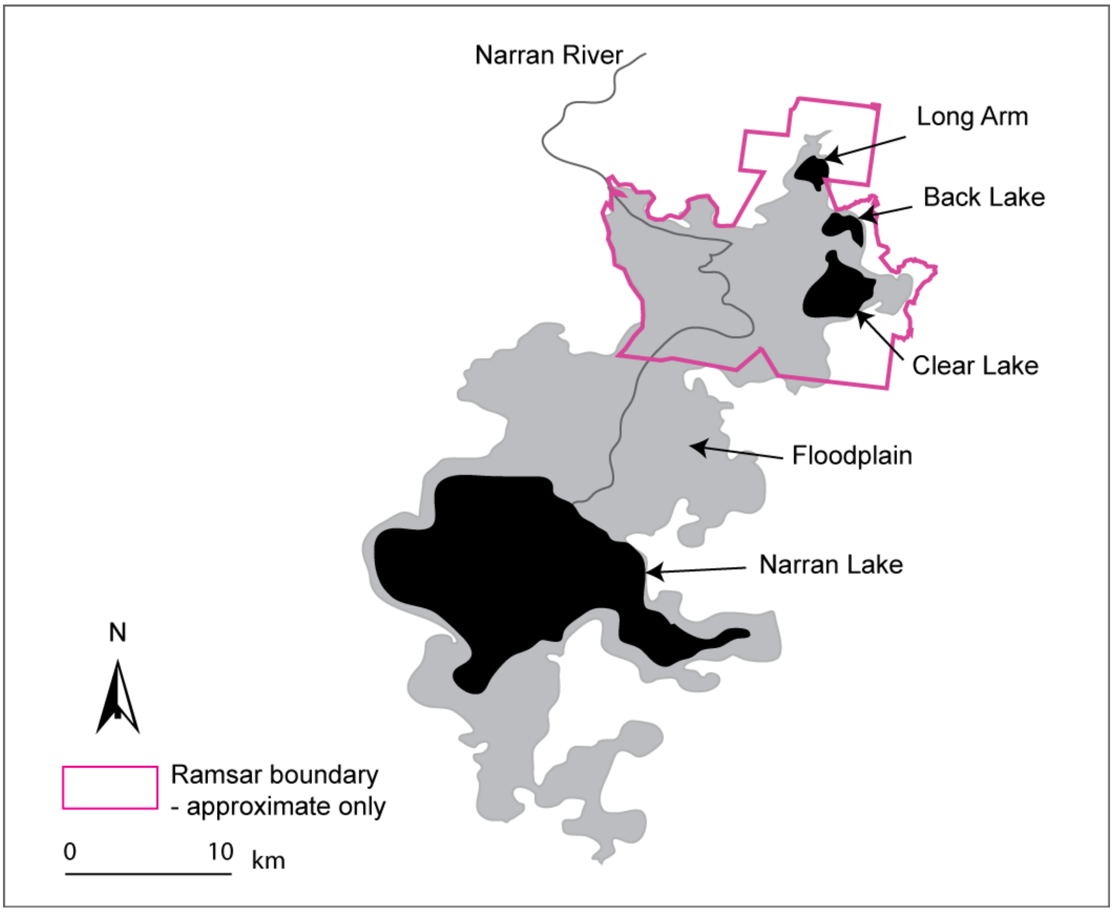


Figure 4: Key features of Narran Lakes terminal ecosystem with approximate location of Ramsar site boundary (modified from Thoms et al. 2007).

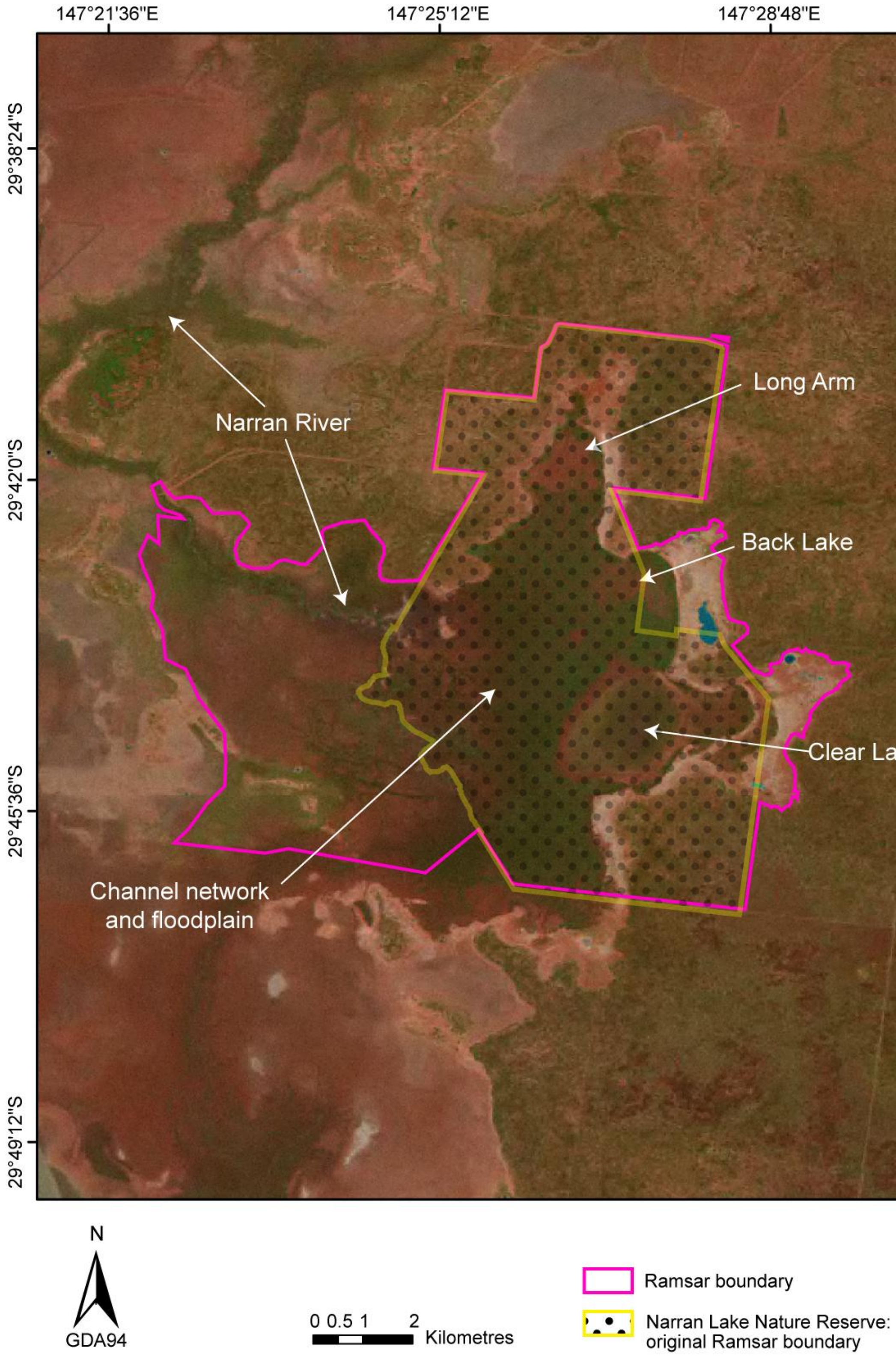


Figure 5: Narran Lake Nature Reserve Ramsar site (data supplied by SEWPaC and DECCW 2010).

2.2 Overview of the site

The Ramsar site forms part of the terminal wetland system on the Narran River. The physical character and behaviour of floodplain wetland ecosystems are governed by the climate, geology, topography, soils, vegetation and land-use of its regional and local catchment. These independent variables determine the discharge of water and sediment from the catchment, thus the local scale morphology and hydrology of the floodplain wetland. The Ramsar site includes a significant area of channelised floodplain as well as three distinct wetlands: Clear Lake, Back Lake and Long Arm (Figure 5). At the time of listing the Narran Lake Nature Reserve component of the Ramsar site was considered to be in relatively good condition despite the hydrology of the ecosystem being altered through upstream extraction and being historically subject to considerable grazing pressure (NSW NPWS 2000; Thoms et al. 2002).

The wetland types found within the Ramsar site include substantial areas of shrub dominated wetlands vegetated with lignum (*Muehlenbeckia florulenta*), open water wetlands including Clear Lake and to a lesser degree Back Lake, substantial areas of floodplain which supports intermittent marsh and meadow habitat, as well as tree dominated areas with river red gum (*Eucalyptus camaldulensis*), coolibah (*Eucalyptus coolabahs*), black box (*Eucalyptus largiflorens*), and river cooba (*Acacia stenophylla*). The open water habitat at Back Lake has reduced since listing due to the expansion of lignum. Lignum wetland shrubland has been cleared in many areas of the Murray Darling Basin, and the lignum wetlands at Narran Lake Nature Reserve Ramsar site are some of the largest in New South Wales (NSW NPWS 2000).

Flooding typically occurs in summer and autumn after heavy rains in the upper catchment, however flooding can also occur in winter and spring. Prior to listing the wetland system had approximately a one in two year flooding pattern over the period 1915 to 1978 (McGrath 1991). This frequent inundation provides breeding habitat on a more regular basis than many other semi-arid zone wetlands in New South Wales (McGrath 1991). In addition variation in duration of inundation creates a mosaic of habitat at different stages of flood recession, providing, on a regional basis, extended habitat availability (Aldis 1987 cited McGrath).

At the catchment scale the Condamine-Balonne has an annual rainfall of 514 millimetres with the majority falling in the summer half of the year and exhibits considerable inter annual variation (CSIRO 2008). Summers are long and hot followed by short cold winters (see section 3.1) with average summer maximum temperatures between 32 and 34 degrees Celsius and average monthly minimum temperatures between 18 and 20 degrees Celsius. During winter average maximum temperatures are cooler (17 to 20 degrees Celsius) and minimum temperatures are cold (4 to 5 degrees Celsius).

The site was listed for the role it plays in providing a refuge in a semi-arid landscape and in supporting significant waterbird breeding. In addition to being listed as a Wetland of International Importance, the Narran system is also listed as an Important Bird Area by Birds Australia (http://www.birdata.com.au/iba.vm) and is on the Register of the National Estate (NSW NPWS 2000). The Narran terminal wetland system as a whole is particularly important for colonial waterbird nesting species, the most notable of which is the straw-necked ibis (*Threskiornis spinicollis*) which has had colonies with up to 200 000 breeding pairs (Birds Australia; http://www.birdata.com.au/iba.vm). Whilst the main ibis breeding colonies are within the bounds of the Ramsar site; Narran Lake is believed to play an important role in providing food resources and also supports breeding colonies. Australian pelican (*Pelecanus conspicillatus*), Australian white ibis (*Threskiornis molucca*), glossy ibis (*Plegadis* falcinellus), and royal spoonbill (*Platalea regia*) all breed in significant numbers within the greater Narran terminal wetland system.

A study in 1999 put the number of plants within the Nature Reserve at 325 species with 11 percent being introduced species, with the flora of the Ramsar site being characterised by arid and semi-arid zone species. Vegetation associations within the Ramsar site are spatially and temporally heterogeneous and reflect historical inundation patterns and dryland topography and geology. The floristic composition is different to that found in the surrounding upland ecosystems (Thoms et al. 2007). The seed bank in the wetland sediments is diverse and significant, with over 70 groundcover species including at least 23 monocot and 54 dicot species having been identified (Thoms et al. 2007). The lignum shrublands support some of the most abundant and diverse seed banks (Thoms et al. 2007) with flooding regime determining the quality and quantity of the seed bank within the Ramsar site. The lignum shrublands, in particular, provide critical habitat for the colonial waterbirds, with the boundary extension in 2011 capturing more breeding habitat as well as key feeding areas. The patches of trees within the Ramsar site also provide habitat for breeding waterbirds.

As with all floodplain ecosystems the pattern of wetting and drying drives the ecological response, and this is most obvious in the diversity, distribution and condition of water dependent vegetation. For example the condition and characteristics of the lignum shrubland is driven by flood inundation history and depth. Frequently flooded areas on the periphery of distributary channels are typically dominated by dense large interconnected clumps. Infrequently flooded areas in the shallower parts of the lake beds support many small lignum clumps, whilst the most frequently flooded habitats in the deeper channels lack lignum in the main. Areas of tree dominated floodplain occur throughout the site with several key species: river red gum (*Eucalyptus camaldulensis*), coolibah (*E. coolabahs*), black box (*E. largiflorens*), river cooba *(Acacia stenophylla)* and bignonia emu-bush (*Eremophila bignoniiflora*). Thoms et al. (2007) found little evidence of recent recruitment and high mortality in all commonly occurring tree species during the Narran Ecosystem Project. In 2004 seedlings and saplings of river red gum, river coolibah and river cooba were all exhibiting very high levels of mortality and stress (Thoms et al. 2007).

Overall, 44 species of waterbirds have been recorded breeding at the Ramsar site, the colonial breeding species mentioned above form the most spectacular breeding colonies. Data on breeding events from 1971 to 1991 indicate that both Clear and Back Lake are important areas for waterbird breeding (Thoms et al. 2002). Narran Lake to the south of the Ramsar site is also important as a waterbird breeding site and also in providing resources for nesting species within the Ramsar site. Waterbirds which occur within the site and are listed at the state level include freckled duck (*Stictonetta naevosa)*, blue-billed duck (*Oxyura australis*), brolga (*Grus rubicunda*), Australasian bittern (*Botaurus poiciloptilus*), magpie goose (*Anseranas semipalmata*), black-necked stork (*Ephippiorhynchus asiaticus*), and black-tailed godwit (*Limosa limosa*) (Appendix E).

Fish surveys have collected 11 native species, including the Murray cod (*Maccullochella peelii peelii*) which is listed under the EPBC Act, and four introduced species. Records for Murray cod are not common, and it may be that the species was only ever rarely found within the Narran River. Patterns of dominant species (in terms of abundance) varies with different surveys but common species of fish encountered include bony herring (*Nematalosa erebi*), spangled perch (*Leiopotherapon unicolour*), golden perch (*Macquaria ambigua*), carp gudgeons (*Hypseleotris* species.), Australian smelt (*Retropinna semoni*), and Murray-Darling rainbowfish (*Melanotaenia fluviatilis*). Supporting the fish population is a diverse and abundant zooplankton and macroinvertebrate fauna (Thoms et al. 2007).

2.3 Land tenure and land use

The immediate area surrounding the Ramsar site is part of the semi-arid pastoral zone and is used primarily for sheep and cattle grazing (NSW NPWS 2000). Grazing has occurred on the Lower Balonne-Culgoa floodplain since the 1840s (Thoms et al. 2002). Introduction of irrigation to the region led to the establishment of irrigated agriculture with the main crop being cotton. By the time of listing the cotton crop on the Balonne-Culgoa floodplain, which is part of the Lower Balonne floodplain, was 38 000 hectares (Thoms et al. 2002). Between 1988 and 1999 water storage on this part of the floodplain expanded from 54 750 megalitres to more than 592 500 megalitres (Thoms et al. 2002). Total storage on the Lower Balonne floodplain is estimated at 1 500 000 megalitres in 2010 (Lower Balonne Floodplain Association, unpublished).

The Ramsar site includes the Narran Lake Nature Reserve (Figure 6) which is managed by New South Wales National Parks and Wildlife Service (NSW NPWS) for conservation purposes, it was declared as a nature reserve in 1988. In addition the NSW NPWS also owns the majority of lands surrounding the Ramsar site as a result of acquisitions over the past ten years. These lands have been gazetted as Nature Reserve and are managed for their conservation values. However the majority of land surrounding the reserve is held under Western Lands Leases granted under the *Western Lands Act 1901*, one of the oldest natural resource management legislation.

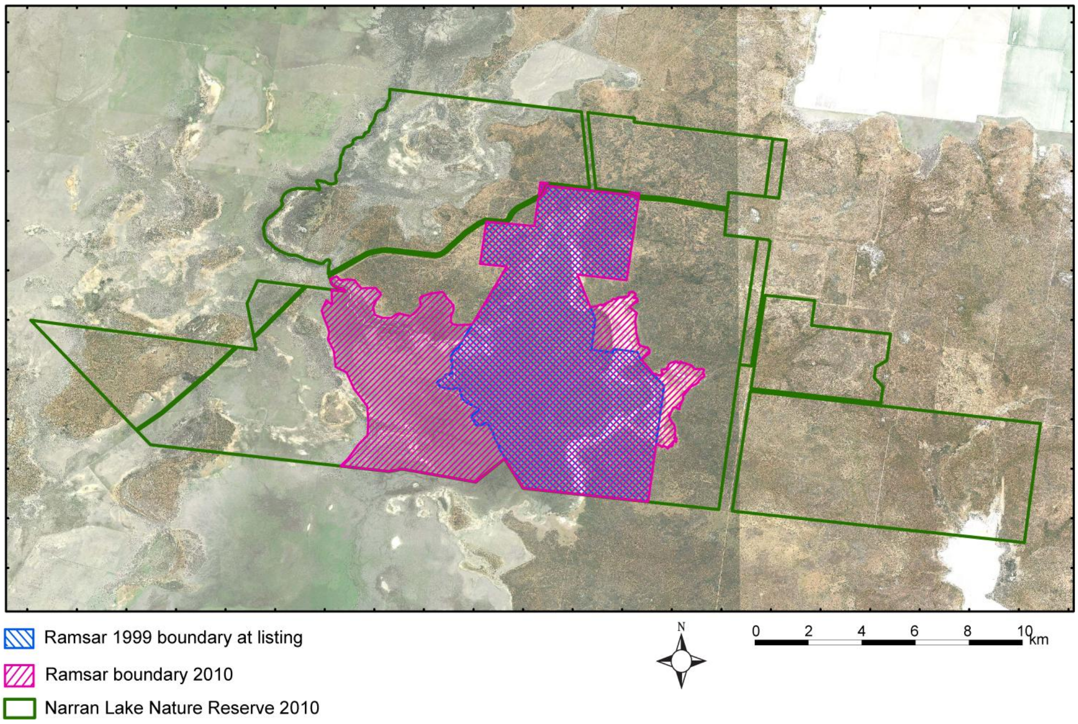


Figure 6: Narran Lake Nature Reserve and Ramsar site (data supplied by DECCW 2010).

2.4 Wetland types

Classification of wetlands into discrete types is a difficult exercise and an inexact science. Clear boundaries are difficult to define or delineate and multiple wetland types could be considered to apply to the same wetland. Wetland mapping of New South Wales wetlands was undertaken by Kingsford et al. (2003) using Landsat satellite imagery to map greatest extent of wetlands in the period 1984-1994. Six broad wetland types were classified in the mapping project, with finer resolution of floodplain areas not undertaken due to a lack of data. In the Narran Lake Nature Reserve Ramsar site there are two main groups of wetlands mapped according to the Kingford et al. (2003) assessment, freshwater lakes represented by Clear Lake, Back Lake and Long Arm, with the majority of the remaining area of the site classified as floodplain wetland (Figure 7). The freshwater lake area is representative of the extent of open water in the late 1980s; however since then there has been an expansion of lignum and a reduction in open water habitat. Kingsford et al. (2003) defined the two wetlands types as follows:

> *Freshwater lake*: Naturally occurring drainage basins of open water and not estuarine or coastal lagoons and lakes or saline on a 1:250,000 map and where surface aquatic vegetation did not dominate spectral reflectance.
>
> *Floodplain wetland*: River and creek channels and adjacent inundated vegetation, including swamps, waterholes and shallow depressions.

Detailed mapping of the Ramsar wetland types at the site is not available. There are approximately 4586 hectares of floodplain wetland and 1186 hectares of freshwater lakes within the boundary of the Ramsar site. An approximation of the distribution of Ramsar wetland types within the site is presented in Figure 8; however these are based on a rough interpretation of aerial imagery, and maps presented in Thoms et al. (2007) and Hunter (1999). It is a composite map and is an estimate only. It is not possible to determine extent for each of the wetland types from the available data, and this remains a knowledge gap for the site.

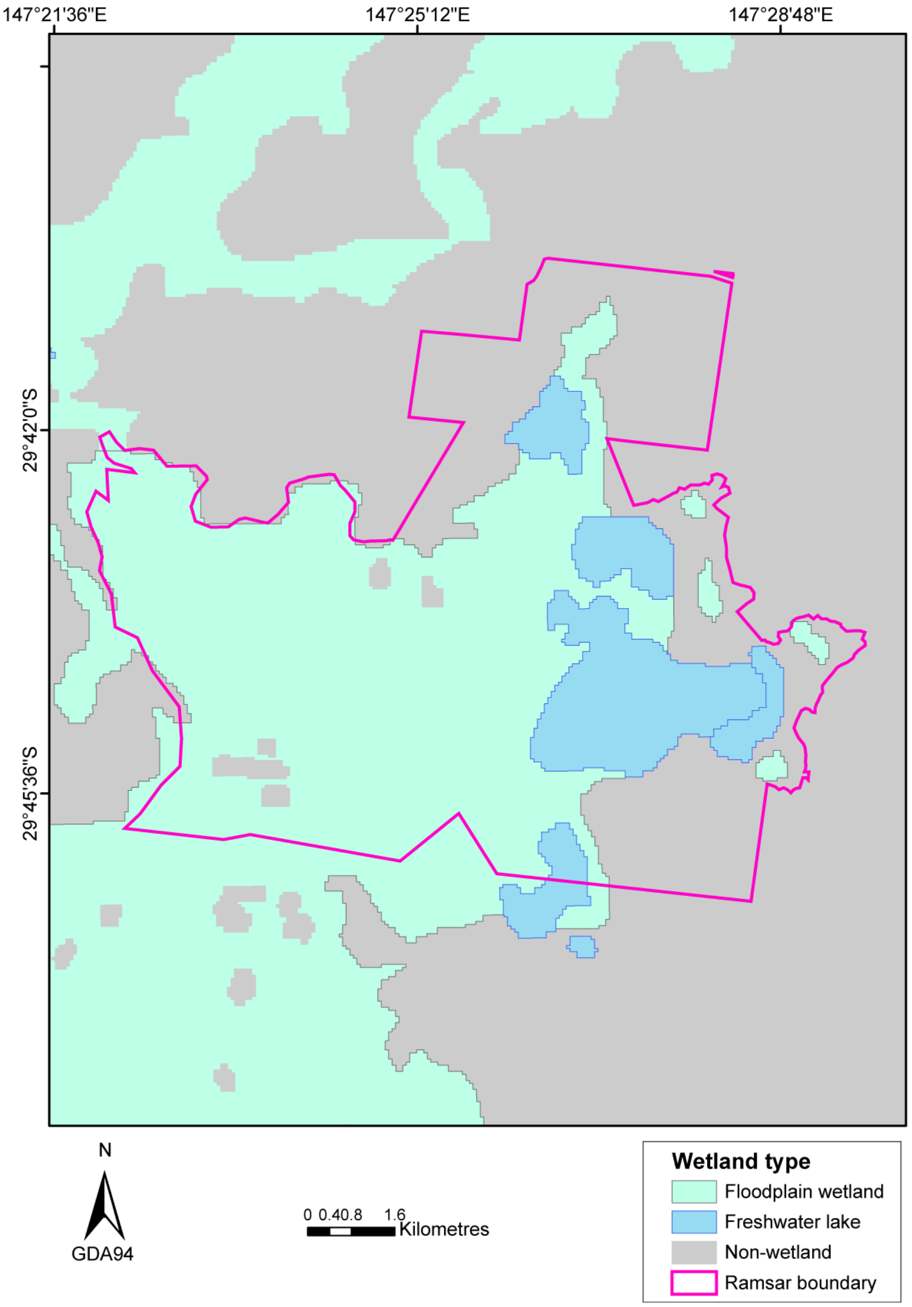


Figure 7: Wetland types (Kingsford et al. 2003 – see text above) within Narran Lake Nature Reserve Ramsar site (data supplied DECCW 2010).

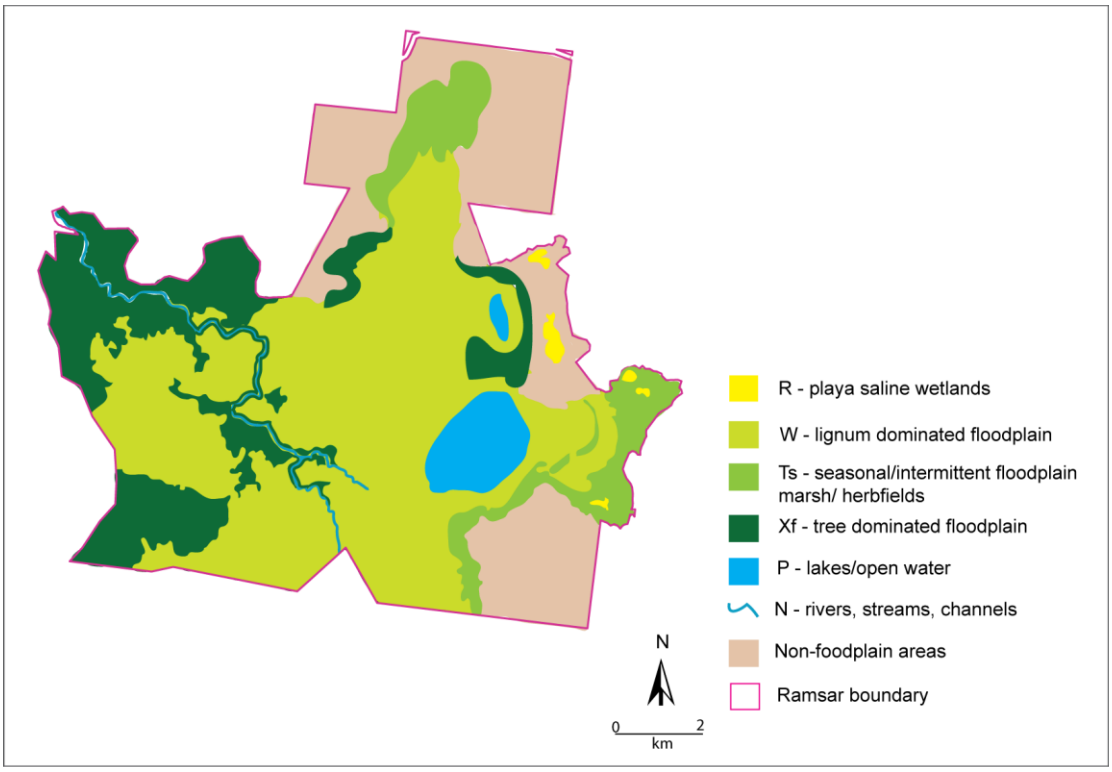


Figure 8: Approximate area of Ramsar wetland types. Note this figure is a composite map created for this ECD; it is not based on a formal assessment of wetland type.

River and floodplain channels (Ramsar type N – Seasonal/ intermittent/ irregular rivers/streams/creeks).
Narran River extends 201 kilometres from the Balonne River to the terminal Narran Lake, carrying 28 percent of the Balonne River annual flow at St George. In addition to the main channel there is a complex series of channels within the bounds of the Ramsar site (Figure 9 and Figure 10), with over 8000 individual channel sections with a combined length of 804.5 kilometres within the Narran Lakes ecosystem. This provides an additional degree of physical diversity to the floodplain–wetland system (Thoms et al. 2007) (see section 3.2).

Figure 9: Main area of Narran Lake Nature Reserve looking south west towards Narran Lake (adapted from photo by Dragi Markovic, Australian Government).

Figure 10: Floodplain channel surrounded by river cooba 2006 (Narran Ecosystem Project 2004, photo supplied by S. Capon).

Playa (Ramsar type R -- Seasonal/intermittent saline/brackish/alkaline lakes and flats).
To the east of Clear Lake there is an area of low gently undulating sandy and rocky ridge country that supports a number of semi-saline playa lakes (Figure 9 above).These are predominantly rainfall and groundwater fed (NSW NPWS 2000) and are covered by a shallow sheet of water for a short period of time. Playa are shallow, nearly level basins with internal drainage, and are referred to as playa lakes when water is present. The area of these wetlands is not known, but overall they are a small component of the aquatic habitat present within the Ramsar site.

Lakes (Ramsar type P – Seasonal/intermittent freshwater lakes over 8 hectares, includes floodplain lakes).
This wetland type is represented by Clear Lake (Figure 11), which one of the main areas of open water within the Ramsar site. Clear Lake can retain water for between four to twelve months after filling, typically holding water longer than Back Lake. On flooding Clear Lake fills first, then overflows to Back Lake and ultimately the Long Arm. Clear Lake is approximately 540 hectares, Back Lake 130 hectares and Long Arm 150 hectares (Thoms et al. 2007). Clear Lake has a storage capacity of 4476 megalitres, Back Lake 861 megalitres and Long Arm 0.6 megalitres (Thoms et al. 2007).

Figure 11: Clear Lake and flooded surrounds 2008 (Duncan Vennell, DECCW).

Floodplain marsh areas (Ramsar type Ts – Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows and sedge marshes).
This wetland type includes the ephemeral herb vegetation associations described in section 3.6. Spatially these wetlands occur on the eastern side of Clear and Back Lakes, and to the north and west of Long Arm. These lakes have variable inundation patterns with depth and duration of inundation determining the vegetation associations. These wetland areas expand as floodwaters recede.

Floodplain swamp areas (Ramsar type Xf - Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.).
Areas of river red gum (*Eucalyptus camaldulensis*) – coolibah (*Eucalyptus coolabah*) – black box (*Eucalyptus largiflorens*) – river cooba (*Acacia stnophylla*) fringe the channel network on

several areas of the floodplain as well as the Narran River (Figure 12). A large area of river red gum occurs to the north east of Clear Lake.

Figure 12: Floodplain channel with river red gum and coolibah (Duncan Vennell, DECCW).

Floodplain lignum areas (Ramsar type W – Shrub-dominated wetlands; scrub swamps, shrub dominated freshwater marshes, shrub carr, alder thicket on inorganic soils).
Lignum (*Muehlenbeckia florulenta*) covers extensive areas forming dense shrublands (Figure 13) surrounding Clear and Back Lakes. Back Lake is also lignum shrub dominated (Figure 14). Lignum shrubland, including water requirements are detailed in section 3.6. Data on extent of lignum shrubland is not available however this is the dominant vegetation cover on the floodplain and the Ramsar site is considered to be one of the largest intact lignum shrublands in New South Wales.

Figure 13: Flooded lignum shrub dominated wetlands (Duncan Vennell, DECCW).

Figure 14: Back Lake (Duncan Vennell, DECCW).

2.5 Ramsar criteria

2.5.1 Criteria under which the site was designated

At the time that the Narran Lake Nature Reserve site was first designated as a Wetland of International Importance (1999), the criteria for identifying wetlands of international importance were those adopted at the fourth conference of contracting parties in Montreaux in 1990. The original nomination documentation for the Ramsar site considered that the site met three of these criteria as shown in (Table 2).

Table 2: Criteria originally used to identify the Narran Lake Nature Reserve Ramsar site as a Wetland of International Importance as documented in the RIS (1999). Criteria met at this time are shaded.

Basis	Number	Criterion	Criterion met
Criteria for representative or unique wetlands	1a	it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region	Met
	1b	it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region	Not met
	1c	it is a particularly good representative example of a wetland, which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position	Not met
	1d	it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.	Not met
General Criteria based on plants and animals	2a	it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species	Not met
	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	Not met
	2c	it is of special value as the habitat of plants or animals at a critical stage of their biological cycle	Met
	2d	it is of special value for one or more endemic plant or animal species or communities.	Not met
Specific criteria based on waterfowl	3a	it regularly supports 20,000 waterfowl	Not met
	3b	it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity	Not met
	3c	where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl	Met

The original justification for the site meeting each of three criteria is provided in Table 3 against the current criteria met by Narran Lake Nature Reserve Ramsar site.

Table 3: Current (2005) Ramsar listing criteria showing justification for listing as per RIS (1999) and current assessment.

Number	Criterion	Justification RIS (1999)	Current assessment
Group A. Sites containing representative, rare or unique wetland types			
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.	Justification against former **Criterion 1(a) -** Narran Lakes contain a considerable diversity of habitats including some of the largest expanses of Lignum (*Muehlenbeckia florulenta*) in NSW which are wetlands are geomorphologically significant as an excellent example of a relatively undisturbed terminal lake system in NSW.	Met
Group B. Sites of international importance for conserving biological diversity			
2	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	Not met	Met
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.	Not met	Not met
4	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.	Justification against former **Criterion 2(c)**: Waterfowl which have been recorded breeding in Narran Lake Nature Reserve and which are considered to have a restricted breeding distribution in Western NSW include: Australian pelican *Pelecanus conspicillatus,* great cormorant *Phalacrocorax carbo,* pied cormorant *Phalacrocorax varius,* darter *Anhinga melanogaster,* rufous night heron *Nycticorax caledonicus* ,*large egret *Ardea alba,* little egret *Ardea gazetta,* intermediate egret *Ardea intermedia,* *glossy ibis *Plegadis falcinellus,* *Australian white (sacred) ibis *Threskiornis molucca* ,*straw-necked ibis *Threskiornis spinicollis,* great crested grebe *Podiceps cristatus,* *royal spoonbill *Platalea regia,* and gull-billed tern *Sterna nilotica* (***** = Significant breeding populations).	Met

Number	Criterion	Justification RIS (1999)	Current assessment
		Narran Lakes are considered to be nationally and internationally significant as they are the major breeding site for the above species of waterbirds and many other species. During the 1994-96 Murray-Darling Basin Water Monitoring Project run by Birds Australia, the Narran wetlands were among the highest ranked sites for species richness, number of breeding species and total number of birds. Narran Lake Nature Reserve also supports a number of internationally important migratory bird species. The Narran Lakes are listed on the Australian Register of National Estate.	
5	A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.	Not met	Not met
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.	Justification against former **Criterion 3(c):** The large numbers of black-winged stilts (*Himantopus himantopus*), red-necked avocets (*Recurvirostra novaehollandiae*), marsh sandpiper (*Tringa staganatilis*), Straw-necked Ibis (*Threskiornis spinicollis*) and red-kneed dotterel (*Erythrogonys cinctus*) recorded in Narran Lake wetlands suggests that these wetlands may be of international importance for these species (Ley, 1998).	Not met
7	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.	Not met	Not met
8	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.	Not met	Not met

Number	Criterion	Justification RIS (1999)	Current assessment
9	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.	Not met	Not met

2.5.2 Assessment based on current information and Ramsar criteria

There have been a few developments since the site was listed in 1999 that influence the application of the Ramsar criteria to wetland sites this includes:

- Refinements and revisions of the Ramsar criteria: a ninth criterion was added at the ninth Conference of the Contracting Parties to the 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 are now based on drainage divisions and for marine systems the interim marine classification and regionalisation for Australia (IMCRA). This affects the application of criteria one and three.
- Updating of threatened species listings, which affects criterion two.

An assessment against each of the criteria for Narran Lake Nature Reserve Ramsar site is provided below:

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 application of this criterion must be considered in the context of the Bioregion within which the site is located. Narran Lake Nature Reserve Ramsar site is located within the Murray Darling Drainage Division.

In the original listing of the site appears to have been assessed at the NSW scale rather than the bioregion. Despite this, the justification for meeting this criterion presented at the time of listing (see Table 3 above) still holds using the current bioregional scale of assessment. The site is unique within the bioregion for its juxtaposition of highly channelised floodplain with open water wetland habitat. As a terminal wetland system it plays an important hydrological role in the natural functioning of the Narran River. In addition the vast lignum (*Muehlenbeckia florulenta*) (Ramsar wetland type W) dominated floodplain represents one of the largest expanses of relatively intact lignum in NSW (Aldis 1987). The site is part of a largely intact, unmodified terminal wetland ecosystem in good condition.

This criterion was judged to be met at designation in 1999 and is still considered met.

Criterion 2: ***A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.***

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 1999 or the International Union for Conservation of Nature (IUCN) red list.

A case was not made against this criterion at the time of listing.

Central to the application of this criterion are the words “a wetland” and “supports”. Guidance from Ramsar (Ramsar 2005) in applying the criteria indicates that the wetland must provide habitat for the species concerned. For this reason, vagrant species have not been considered to contribute to the meeting of this criterion; nor are non wetland dependent species.

Murray cod (*Maccullochella peelii peelii*) has been recorded in the Ramsar site in the Narran River (Thoms et al. 2007) and lower the reaches of the Condamine system (Davies et al.

2008). Large bodied adults have not been caught in recent years, with most specimens caught being juveniles (G. Wilson, University of New England, pers. comm.). Murray cod is listed as vulnerable under the EPBC Act and critically endangered on the IUCN Red List (IUCN 2010).

The Australasian bittern, *Botaurus poiciloptilus*, has been recorded at the site (DECCW 2010a) in the vicinity of Clear Lake in 2008 and upstream of the Ramsar site in 1994. This species is cryptic and difficult to find using targeted ground surveys; however the majority of the surveys of waterbirds at Narran Lake Nature Reserve have been aerial and are not suited to sighting this species. It is considered possible that the species is a resident at the site but the migratory/movement of this species is poorly understood. Birds Australia list this species as being present, but uncommon, within the Narran Wetlands Important Bird Area (Birds Australia http://www.birdata.com.au/iba.vm accessed July 2010), but this data is based on the one record from 2008.

A third wetland dependent species, winged peppercress, *Lepidium monoplocoides*, is also found within the site. Whilst not a true aquatic species, its essential habitat is waterlogged soils associated with a range of wetland plant communities. In Narran Nature Reserve the species was found as isolated individuals but was not considered to be rare (Hunter 1999 cited in Thoms et al. 2002).

This criterion was not considered to be met at listing but is considered to be met currently.

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.***

Like criterion one, application of this criterion must be taken in the context of the appropriate bioregion, in this instance the Murray Darling Drainage Division. Guidance from the Convention indicates that this criteria should be applied to "hotspots" of biological diversity, centres of endemism, sites that contain the range of biological diversity (including habitat types) occurring in a region; and/or support particular elements of biological diversity that are rare or particularly characteristic of the biogeographic region.

The site is not considered a hotspot of biological diversity, or a centre of endemism. It is characterised by a number of regionally significant species and communities but these are not exceptional in a bioregional context.

This criterion is not considered to be met either at listing or currently.

Criterion 4: ***A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.***

The long term intention of this criterion is to ensure wetlands within the Ramsar estate include those which are vital for providing habitat during critical life stages and or in period of adverse conditions (Ramsar 2009).

Despite the justification for this criterion in 1999 (see Table 3 above) being applied at the wrong bioregional scale and only including a limited number of species, it was based on the premise that the site supports two critical life stages for waterbirds – breeding and migration.

The current assessment indicates that Narran Lake Nature Reserve supports a significant number of migratory bird species including 14 species listed under international migratory species treaties and a further 26 species which are migratory within Australia (Appendix B).

The site supports substantial breeding of waterbirds with 44 species having been recorded breeding at the site since listing (Appendix B). Significant breeding populations of colonial breeding species including great eastern egret (*Ardea modesta*), glossy ibis (*Plegadis falcinellus*), Australian white ibis (*Threskiornis molucca*) straw-necked ibis (*Threskiornis* *spinicollis*), and royal spoonbill (*Platalea regia*) are supported at the site. In 2008 the flooding of the Ramsar site from local rainfall resulted in large breeding event of colonial waterbird species which was believed to be the last opportunity for many of the adults in the population with no breeding events having occurred in the previous eight years. The 2008 breeding event occurred on a smaller flood than in all previous records.

Narran Lake terminal wetland ecosystem has been identified as one of a handful of wetlands in the Murray Darling Basin which retain water for a period of time after flooding, thereby providing drought refuge (Scott 1997).

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

Criterion 5: *A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.*

Comprehensive waterbird count data are relatively rare for the site and this may be due to the temporary nature of the wetland and the difficulties of access during inundation. This means assessing the requirement of 'regularly supports' for this criterion (see Text box 1) is more difficult. Temporary wetlands in semi-arid regions may have counts which exceed 20 000 on a less frequent basis and therefore can be considered critical at certain times. The importance of the site for supporting waterbird breeding in a semi-arid environment is covered by the site meeting criterion 4.

A case was not made for the site meeting this criterion as part of the original listing, possibly due to a lack of data. Prior to listing the most complete data set is from aerial counts from 1977 to 1981 (Brooker et al. 1993) (see section 3.10), and this data does not indicate the site regularly supported 20 000 waterbirds as defined by Ramsar (Ramsar 2009). Consideration of data over a longer timeframe, including post listing, also suggests the site does not meet this criterion.

The observed large counts of waterbirds at the Ramsar site corresponds to the times at which there are large colonial waterbird breeding events, which are in turn linked to high flow events. Colonial waterbird breeding events are known to have occurred in 21 years with nest count data for 16 of these years. However records indicate that 20 000 or more birds were recorded in only seven years (Figure 15), which is less than the two thirds required to meet this criterion (K. Brandis unpublished data; P. Terrill unpublished data). Over a 45 year period, 1965-2010, there have been 20 large flow events, those which have annual flow magnitudes of 100 000 gigalitres, at which breeding occurred however as stated above only seven of these had large breeding events/numbers of birds (Rayburg and Thoms 2008; K. Brandis unpublished data; P. Terrill unpublished data).

Examples of very large numbers of birds are records for greater than 200 000 birds in 1983 and again in 1996 (Ley 1998), 28 000 in October 1998 (Birds Australia unpublished), over 100 000 in 2008 (Kingsford et al. 2008) and over 100 000 in early 2011 (P. Terrill unpublished).

This criterion is not considered to be met either at listing or currently.

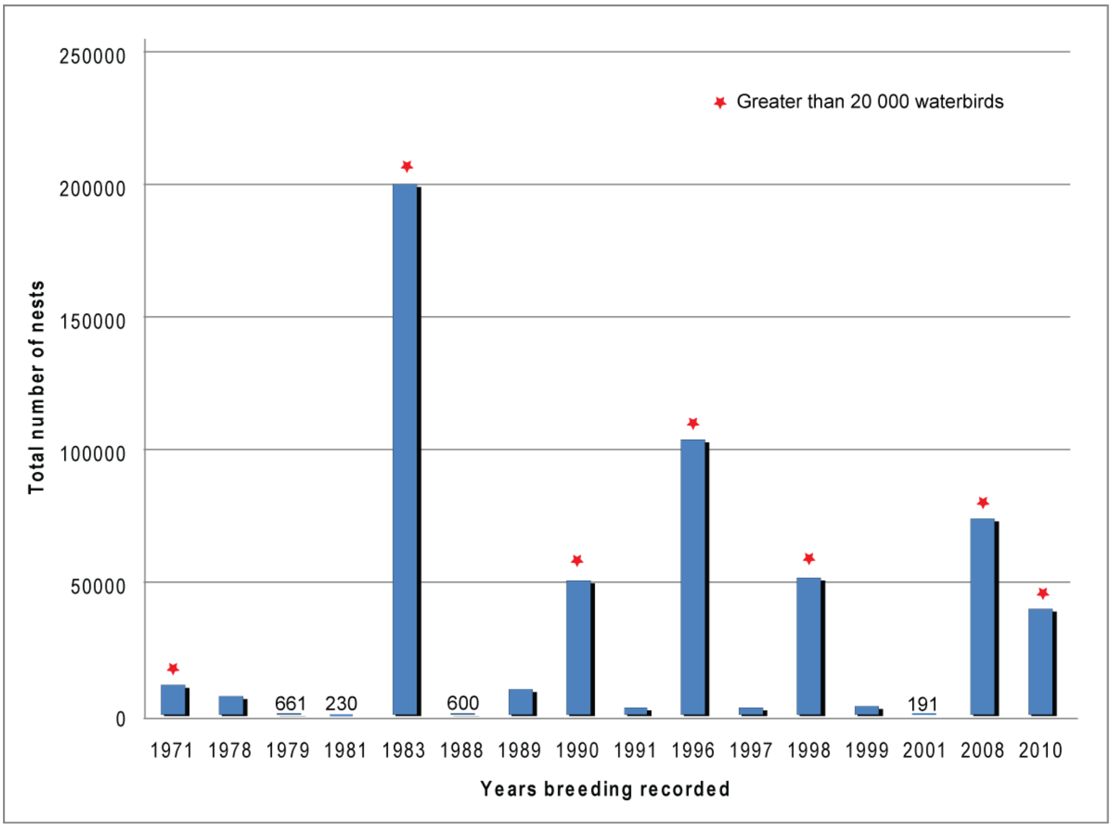


Figure 15: Total number of nests from the Narran Lake ecosystem (data from K. Brandis unpublished; P. Terrill unpublished). Note breeding occurred in an additional five years but nest counts are not recorded.

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.***

Narran Lake Nature Reserve Ramsar site supports significant numbers of individual species of waterbirds. For the time of listing the RIS (1999) lists five species as exceeding the one percent population estimate including black-winged stilts (*Himantopus himantopus*), red-necked avocet (*Recurvirostra novaehollandiae*), marsh sandpiper (*Tringa staganatilis*), straw-necked ibis (*Threskiornis spinicollis*), and red-kneed dotterel (*Erythrogonys cinctus*). The available data does not support this claim for other than the straw-necked ibis. However, the data sourced indicated that only on occasion, not regularly, did the site support more than one percent of the population of the following species (population estimates from Wetlands International 2006):

- Australasian shoveler (*Anas rhynchotis*) (1% = Australia 1000)
- Royal spoonbill (*Platalea regia*) (1% = Australia 1000)
- Australian white ibis (*Threskiornis molucca*) (1% = Australia 10 000)
- Straw-necked ibis (*Threskiornis spinicollis*) (1% = Australia 10 000)
- Australian pelican (*Pelecanus conspicillatus*) (1% = Australia 10 000)
- Sharp-tailed sandpiper (*Calidris acuminata*) (1% = East Asia Australian Flyway 1600)

It should be noted that the assessment for this criterion at the time of listing was compiled from limited data and that for a number of occasions when large numbers of birds were present in the Ramsar site (for example 1983, 1996) data on individual species numbers was not available. The paucity of data on individual bird species does not allow for the application of the concept of ‘regularly supports’ to this site at the time of listing.

Looking at data pre and post listing, large numbers of birds were recorded in years which the annual discharge in the Narran River exceeded 100 000 megalitres (Thoms et al. 2007; Rayburg and Thoms 2008), except in 2008 when total inflows were 35 937 megalitres (P. Terrill, pers. comm.). Over a 45 year period data exists for 20 years in which there were breeding events, with only seven considered large (K. Brandis, unpublished; P. Terrill unpublished). For the most part count data for individual species in these breeding events is not available and as such it is not possible to attribute numbers to species for these events. However if the straw-necked ibis did account for the majority of the nests counted, which is likely, then this still doesn't meet the requirement of 'regularly supports'.

Whilst this criterion was considered to be met at listing, the data sourced do not support this claim. It is considered that the site does not meet the criteria either at listing or currently.

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.

The International Waterbird Census data collated by Wetlands International is the key reference source.

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

Criteria 7: ***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.***

Guidance from the Ramsar Convention (Ramsar Convention 2009) on the application of this criterion indicates that in order to meet this criterion, a site should have a high degree of endemism or biodisparity in fish communities. A site can potentially qualify based on the proportion of fish species present that are endemic to the site (must be greater than 10 per cent) or by having a high degree of biodisparity in the fish community.

This criterion is not considered to be met either at listing or currently.

Criteria 8: ***A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.***

This criterion relates to the importance of wetlands for providing food sources, spawning grounds, nursery grounds and or migratory routes for fish, thus supporting fish stocks. Whilst the site does support some spawning of a few species on the floodplain, the Ramsar site is not considered critical to sustaining fish stocks.

This criterion is not considered to be met either at listing or currently.

Criteria 9: ***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.***

The application of this criterion relies on estimates of the total population of non-avian wetland dependent species.

This criterion is not considered to be met either at listing or currently.

3. Ecosystem components and processes

The attributes and characteristics of each of the components and processes of Narran Lake Nature Reserve Ramsar site are described below (section 3.1 -3.12) with critical components and processes summarised in section 3.13. Ecosystem services are described in section 4.

It is difficult to separate components (physical, chemical and biological parts) and processes (reactions and changes). For example, aspects of hydrology such as rainfall and water regime may be considered as components, while other aspects of hydrology such as groundwater flow and connectivity could be considered processes. Similarly the species composition of waterbirds at a site may be considered a component, but breeding and migration are processes. In the context of this ECD a separation of the ecology of wetlands into nouns (components) and verbs (processes) is an artificial boundary and does not add clarity to the description. As such components and processes are considered together.

First the abiotic environment is described including the main drivers of wetland ecology, climate, geomorphology and hydrology. Combined with the physico-chemical environment they provide the physical habitat template on which the biotic components and processes interact. Where possible, quantitative information is included in the description of each component or process. However, as with many ecological character descriptions, there are significant knowledge gaps relating to the key characteristics of this site (see section 8). A summary of these components and processes within Narran Lake Nature Reserve Ramsar site is provided in Table 4.

Table 4: Summary of components and processes within Narran Lake Nature Reserve Ramsar site.

Component / process	Description
Climate	Semi-arid climate with peak rainfall in the summer months.
Geomorphic setting	The Ramsar site is part of a terminal wetland system of the Narran River a distributary of the Balonne River in the Condamine catchment. A key characteristic of the site is the complex channelised floodplain which is vegetated with lignum in vast expanses. Three distinct wetland basins are present within the site: Clear Lake, Back Lake and the Long Arm.
Hydrology	Highly variable flows driven by summer rainfall in the upper catchment. The Narran River is a loosing system due to high evaporation. Flows of 100 000 megalitres have been identified as a threshold for most large waterbird breeding events, the exception being the 2008 flood. Annual return rates for floods greater than 50 000 and 100 000 megalitres are 1.85 and 2.6 years respectively. Considered an intermittent river, the historical records indicate flow in 90% of years, however since 1992 there has been a significant reduction in frequency and magnitude of floods reaching the Ramsar site. The current decade is likely to be the driest on record.
Water quality	Predominantly freshwater with high turbidity and nutrients in inflowing waters.
Vegetation	Three main associations characterise the Ramsar site: lignum shrublands, riparian open forest and ephemeral herbfields. Lignum condition at the time of listing and in 2004 was considered good. Tree health in 2004 was poor with a high mortality and low recruitment. Seed banks remain viable and diverse especially on the edges of areas of inundation.
Invertebrates	Invertebrates are important in the food chain providing food for both fish and waterbirds. Zooplankton is diverse with a high floodplain specific component.
Amphibians	Nine species of frog are found within the site, several are burrowing

Component / process	Description
	species emerging only after heavy rains.
Fish	Eleven native, including Murray cod, and four introduced species have been recorded at the site. The lowland reaches of the Condamine valley has a high degree of nativeness which is unusual within the Murray Darling Basin: native species dominate in terms of species richness and abundance. Thoms et al. (2007) reported that in 2004 more than 90 percent of the fish caught in per unit effort were native.
Waterbirds	The site supports a total of 68 species, 14 international migrants and 26 species that migrate within Australia. The site is considered critical as a drought refuge within the Murray Darling Basin for waterbirds and supports 44 breeding species including large colonial waterbird breeding events of ibis, spoonbills and cormorants.
Reptiles and mammals	The site supports 24 reptiles including the long-necked tortoise (*Chelodina longicollis*), 27 native mammals and seven introduced species. The only wetland dependent mammal present is the water rat (*Hydromys chrysogaster*). All of the bats surveyed by Smith (1993) were shown to be reliant on the riparian trees for foraging, nesting and roosting.
Productivity	Whilst no site specific data exists, the wetland has a boom and bust ecology which is supported by high primary productivity. Loss of reactive floodplain upstream of the Ramsar site may influence productivity in the Ramsar site.

3.1 Climate

Narran Lake is located in the hot, persistently dry grassland climate (Koppen classes) of northern New South Wales. The climate is semi-arid with hot dry summers and cold winters. The aspects of climate that most directly affect wetland ecology are rainfall (both local and in the catchment), temperature and evaporation as these all fundamentally affect wetland hydrology and the water budget. The nearest weather station is at Walgett approximately 45 kilometres south east of the Ramsar site.

At the catchment scale the Condamine-Balonne has an annual rainfall of 514 millimetres with the majority falling in the summer half of the year and exhibits considerable inter annual variation (CSIRO 2008). In the period 1997 to 2006 the average rainfall was two percent lower than the long term average, which is not considered significant (CSIRO 2008). Runoff occurs principally from summer through to autumn (CSIRO 2008). Locally, rainfall is highest during summer months with average monthly rainfall of approximately 60 millimetres during January and February. Lowest average rainfall is during late winter (August and September) at approximately 28 millimetres. However, there is considerable variability in rainfall as evidenced by the 10^{th} and 90^{th} percentiles (Figure 16). Rainfall extremes range from no rainfall within a month (recorded at least once in every month for records 1978 to 2010) to over 345 millimetres recorded in January 1974.

Annual average rainfall at Walgett is in the order of 480 millimetres per year. However, there is a moderate amount of inter-annual variation with annual rainfalls ranging from less than 200 millimetres to more than 740 millimetres in the past 40 years (Figure 17).

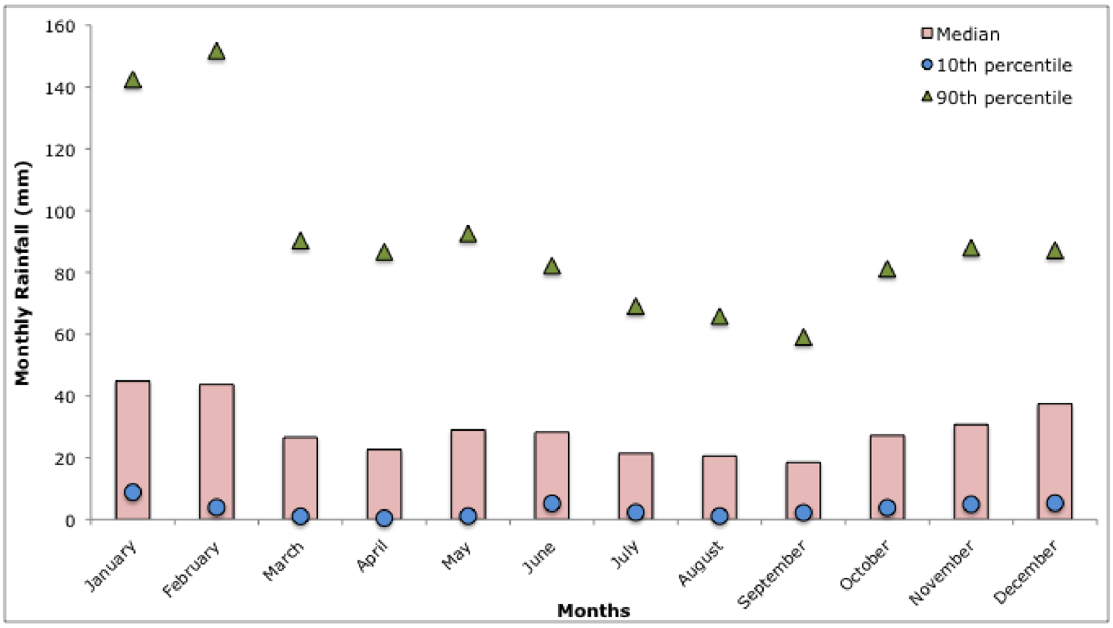


Figure 16: Median (10th and 90th percentile) monthly rainfall at Walgett, 1878 to 2010 (data from Bureau of Meteorology 2010).

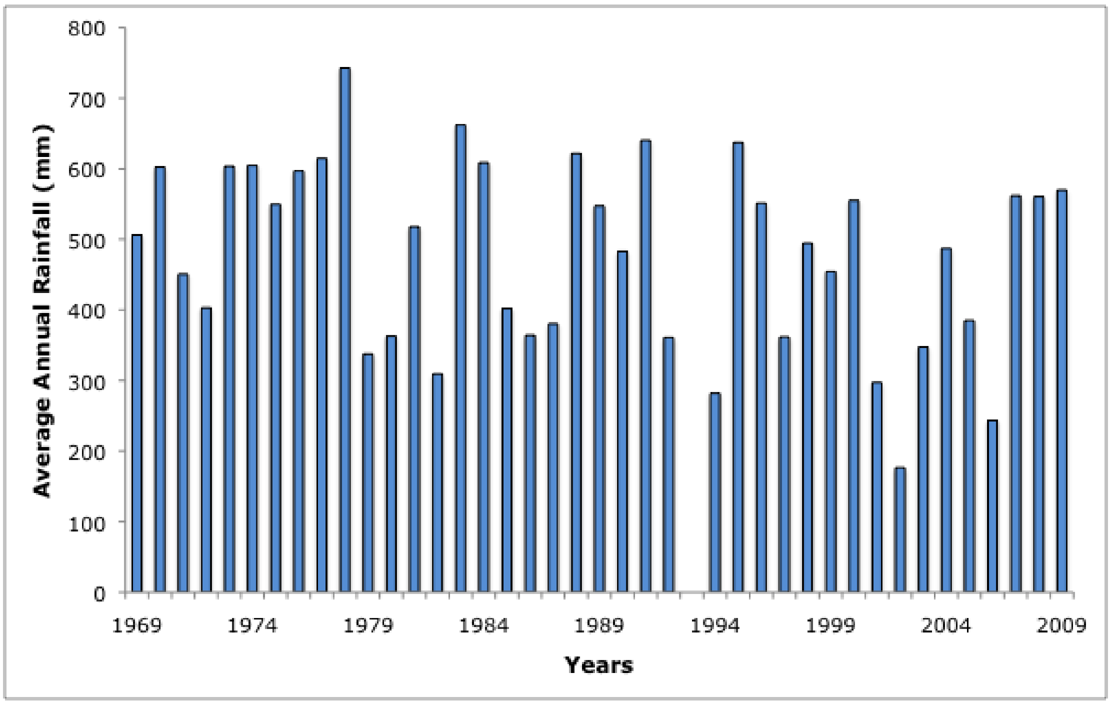


Figure 17: Average annual rainfall at Walgett, 1969 to 2010 (data from Bureau of Meteorology 2010).

Temperatures are hot during summer and cold during winter (Figure 18), with average summer maximum temperatures between 32 and 34 degrees Celsius and average monthly minimum temperatures between 18 and 20 degrees Celsius. During winter average maximum temperatures are cooler (17 to 20 degrees Celsius) and minimum temperatures are cold (4 to 5 degrees Celsius).

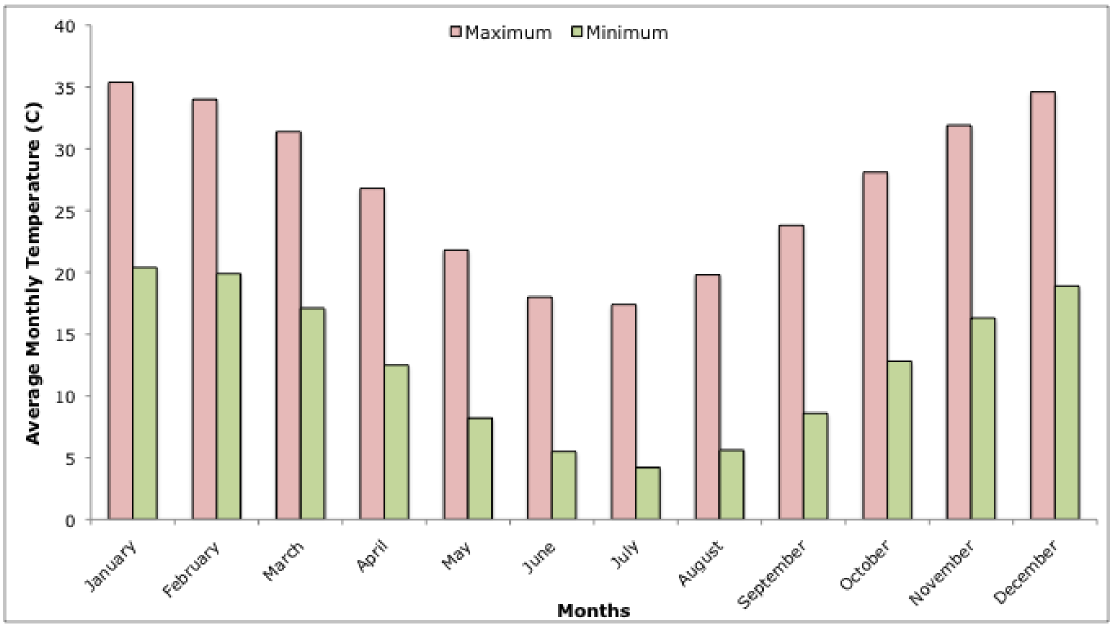


Figure 18: Average monthly maximum and minimum temperatures at Walgett, 1878 to 2010 (data from Bureau of Meteorology 2010).

Relative humidity ranges from 50 percent in summer to 70 percent in the winter months. This, combined with the high temperatures produces evaporation that, on average greatly exceeds rainfall year round (Figure 19).

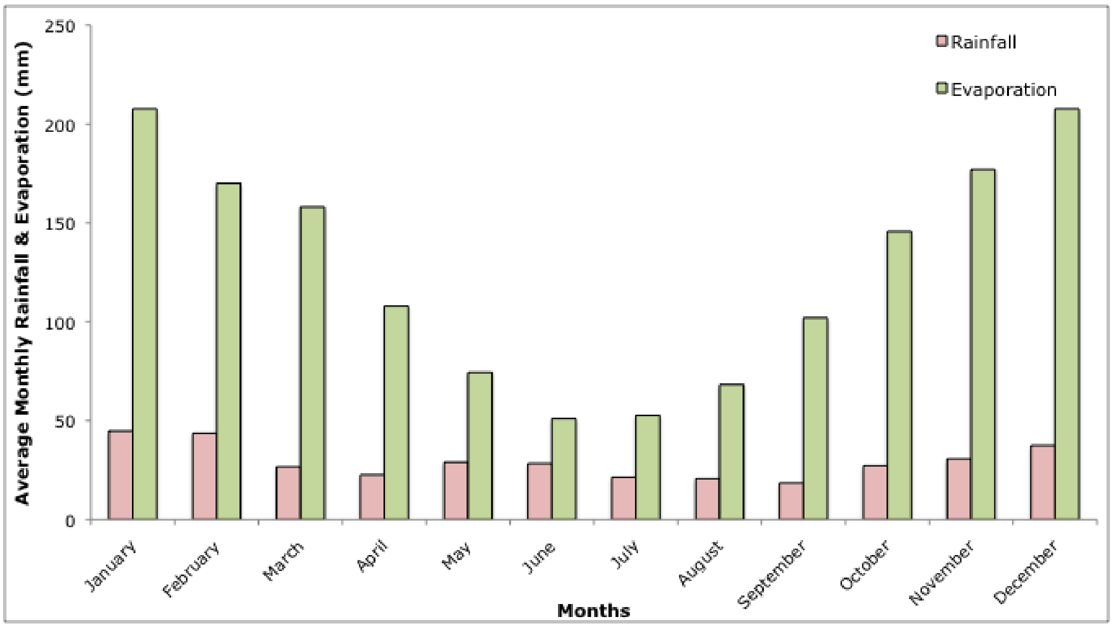


Figure 19: Average monthly rainfall and evaporation at Moomba, 1973 to 2005 (data from Bureau of Meteorology 2010).

3.2 Geomorphological setting

The Narran Lakes terminal ecosystem is approximately 278 square kilometres in area and is composed of two morphologically distinct lake systems, Narran Lake in the south, Clear Lake, Back Lake and Long Arm in the north, and an extensive network of channels and floodplains. The lakes of the Ramsar site and Narran Lake cover approximately 142 square kilometres with the floodplain extending over 136 square kilometres (MDBA 2010). It is this extensive channelised floodplain juxtaposed against the floodplain lakes which contribute significantly to the value of the site.

Narran Lake is very flat, uniform in configuration and devoid of perennial vegetation, where as the Ramsar site is relatively complex with several areas of open water interspersed with stands of trees and shrubs, and a series of interconnecting floodplain channels. There is a gradient of geomorphic complexity from the Ramsar site south to Narran Lake (Rayburg et al. 2009) (Figure 20).

The channel network of the Narran Lake terminal ecosystem is very complex comprising more than 8000 channels. Thoms et al. (2007) stated that the channel network maintained its extent between 1969 and 1992 but underwent a contraction between 1992 and 2003 which was attributed to a reduction in inflows to the ecosystem. In addition to this contraction, the channel network has also lost complexity since 1969 (Thoms et al. 2007). The channel network is very dynamic with over 80 percent of the system changing over the period 1969 to 2003 (Thoms et al. 2007). The 2003 channel network represents the baseline for this aspect of ecological character of the site.

On the eastern side of the Narran Lake Nature Reserve is an area of low, gently undulating sandy and rocky ridge country which contains semi-saline playa lakes and drainage depressions (see section 2.2). Discontinuous aeolian lunettes and sandy levees occur between Clear Lake and the ridge country, having been formed by deflation of the lake (NSW NPWS 2000).

The geomorphic setting provides a diverse range of wetland areas which, according to their degree of connectivity and topography, hold water for varying periods following inundation. The hydrological connectivity, via the floodplain channels supports the significant stands of lignum and other wetland vegetation which in turn provides critical habitat for breeding waterbirds.

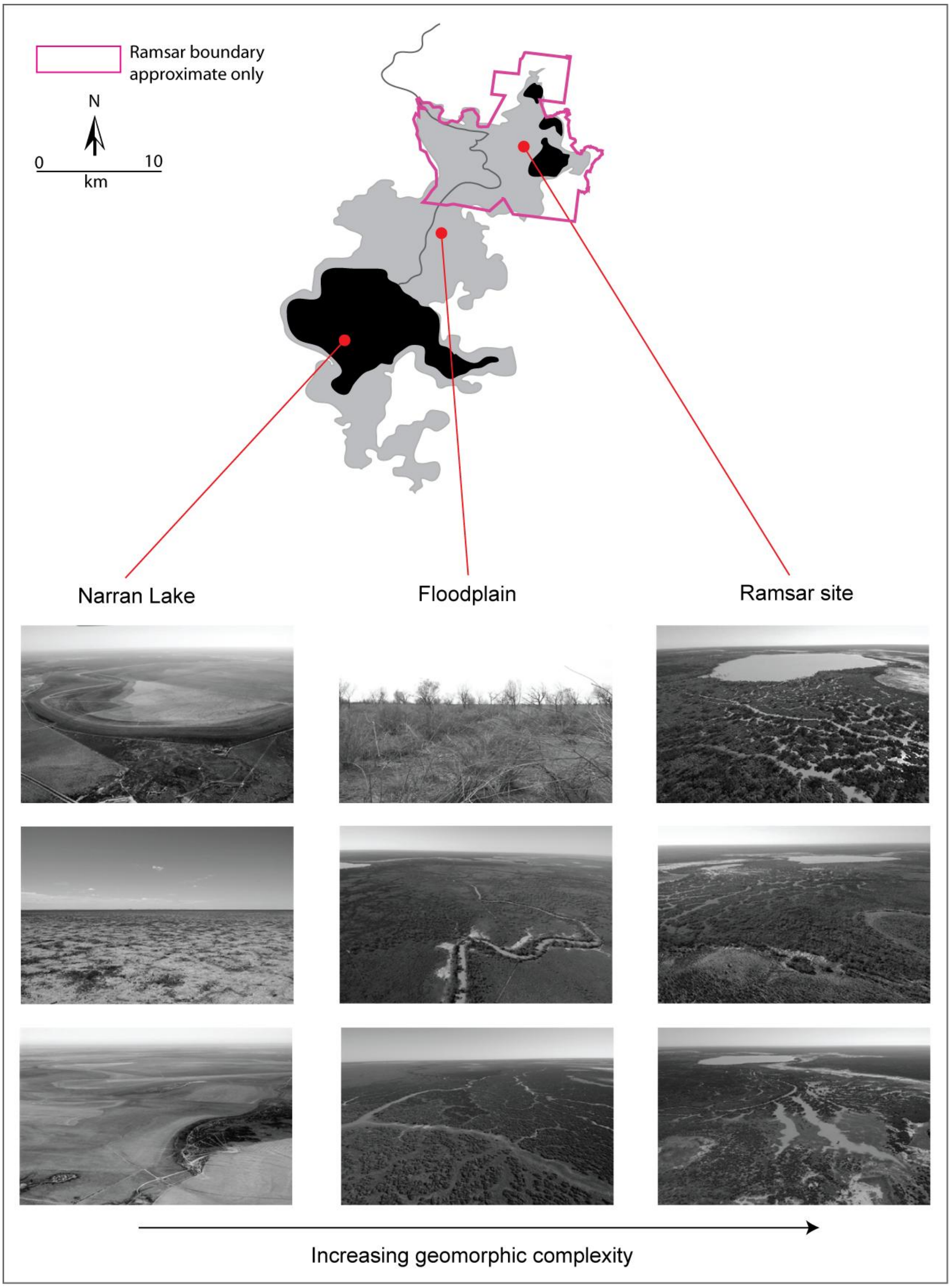


Figure 20: Morphologic complexity within the major structural elements of the Narran Lakes Ecosystem (modified from Rayburg et al. 2009).

3.3 Soils

The soils of the Ramsar site are generally very fine in texture, with on average over 65 percent silts and clays and are classified as being clayey mud soils according to the standard soil nomenclature (Thoms et al. 2007). Investigations as part of the Narran Ecosystem Project have shown there are distinct patterns in the physical and chemical character of the soils within the Ramsar site (Thoms et al. 2007).

Rayburg et al. (2006) identified eight geomorphic units in the Narran Lakes terminal ecosystem, five of which occur within the bounds of the Ramsar site: northern Lakes, red soil, north eastern floodplain, north western floodplain and a small area of central western floodplain (Figure 21).

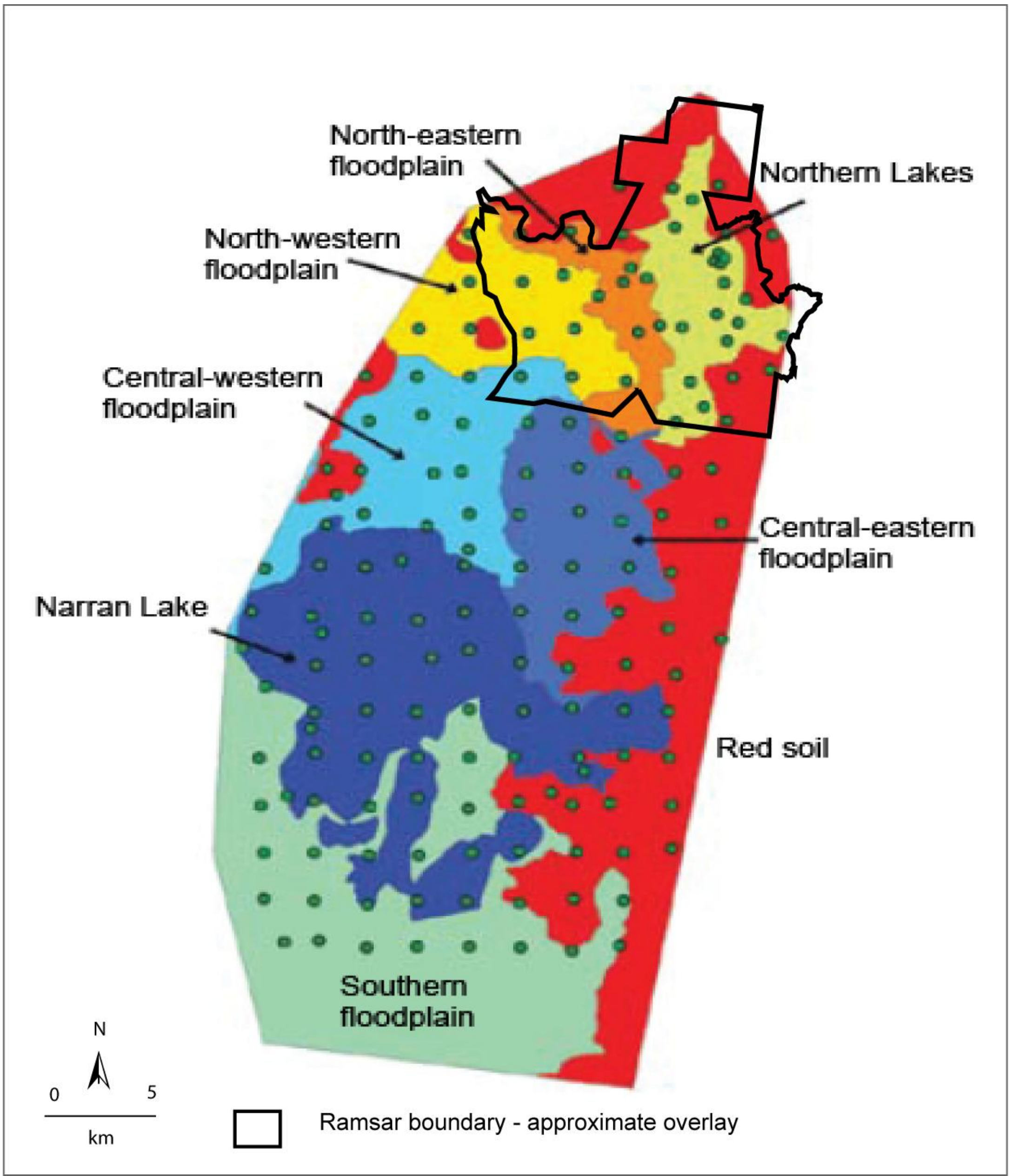


Figure 21: The eight geomorphic units used to analyse the soils in the Narran Ecosystem. Dots represent soil sample points (modified from Thoms et al. 2007).

On the eastern edges of the Ramsar site, within the red soil unit, Cretaceous sandstone and quartzite sediments of the Rolling Downs Group are exposed on the ridge country. The ridges are capped in places by Cainozoic silcrete and the slopes have scattered silcretized sandstone cobbles. Soils in this area of the Ramsar site are typically red sandy loams with the higher areas being gravelly. The red soils are soft and erode easily, with minor areas of gullying evident where tracks from stock occurred (NSW NPWS 2000). The red soils are characterised by low pH, organic matter, liquid and plastic limits and clay content while it has the highest sand content. The grey clays of Clear and Back Lakes have high pH, organic matter, liquid and plastic limits and clay content while they have very low sand content (Rayburg et al. 2006; Thoms et al. 2007).

The Rolling Downs sediments are overlain by Quaternary sediments on the wetland and floodplain areas (NSW NPWS 2000). The clays have high shrink-swell potential and when dry, the surfaces of the wetlands are dissected by a large number of medium-to-large cracks ranging from several centimetres to several metres in width and depth (Thoms et al. 2007). The floodplain soils are more similar to the lakes than the red soils, with more intermediate values for each soil variable, although locally high or low values do occur in some locations (Rayburg and Thoms 2006; Thoms et al. 2007). The soil character of the Northern Lakes samples is clearly separated from both the north-eastern and north-western floodplains whilst the southern-floodplain is clearly separated from the north-eastern floodplain (Rayburg et al. 2006; Thoms et al. 2007).

3.4 Hydrology

Setting and flood history

Surface water inflows are the dominant source of water in the Narran Lake Nature Reserve Ramsar site. Groundwater-surface water interactions are believed to be negligible at the Ramsar site. Groundwater discharge is often a feature of ephemeral arid-zone wetlands in western NSW; however the lake bed at Narran is often dry with no evidence of waterlogging or any salt accumulation typical of discharge wetlands (Mount 1992). The ratio of calcium carbonate and sodium chloride to precipitation (see Gibbs 1970) can be used to determine relative contribution of surface and groundwater at a site. Based on this ratio there appears to be very little groundwater influence (M. Thoms pers. comm.). Mount (1992) recommended establishment of a series of piezometers to establish aquifer responses to flooding and regional groundwater movement. This remains a knowledge gap for the site.

The local catchment area of the Ramsar site is relatively small (approximately 46 square kilometres), with the wetlands rarely filling from local rainfall events, the most recent exception being the flood of 2008 (see section 4.3.2). Typically floods are generated in the upper catchment areas of the Condamine (Thoms 2003). It should be noted, however, that flooding in 2008 was due to local rainfall not rain in the upper catchment. Flooding in 2010 included an initial inflow from local rain followed by a large flood from the mid and upper catchment, including substantial inflows from the Maranoa River. Cease to flow conditions occur approximately 60 percent of the time in the Narran River immediately upstream of the Ramsar site. Mean annual flow in the Narran River is about 141 000 megalitres with a standard deviation of greater than 150 000 megalitres and a maximum recorded annual flow of 567100 megalitres. The high inter-annual variability of flows in the Narran River insures that the Narran Lake Nature Reserve Ramsar site has a complex flood history with periodic wet/dry cycles (Thoms 2003).

The distributaries of the Lower Balonne, including Narran River, have high variability in flows with coefficients of variation (CVs) for annual flows ranging from 103 to 200, and median annual flows can be less than 30% of mean annual flow (Thoms 2003). A large proportion of average flows occur in very wet years and during major floods, with both annual and flood peak flows generally decreasing downstream towards the end of the system (Thoms 2003).

Three primary gauging stations on the Narran River provide data used to describe the hydrological regime of the Ramsar site; New Angledool, Wilby Wilby and Narran Park (Figure 22). The flows in these gauges indicate a close correlation with the highest flows upstream and lower flows downstream indicating that, in most cases, flows are generated in the headwaters, transported downstream, and the Narran River is generally a losing stream (Thoms et al. 2007). Data from Wilby Wilby is used to set the Annual Return Intervals (see below) and for setting Limits of Acceptable Change (see section 6). The New Angledool gauging station, located approximately 110 kilometres upstream of the Ramsar site has a very long flow record and provides a useful window into historical flow patterns in the Narran River (Figure 23). The driest period on record occurred between 2000 and 2008 (Figure 23 for up til 2006) and in part is attributed to drought/climate change impacts with significant declines in inflows to the system. Combined with water extraction activities this has had a considerable impact on flooding within the Ramsar site within this timeframe. However, the reduction in flooding can not be attributed to climate change alone (M. Thoms, University of New England, pers. comm.).

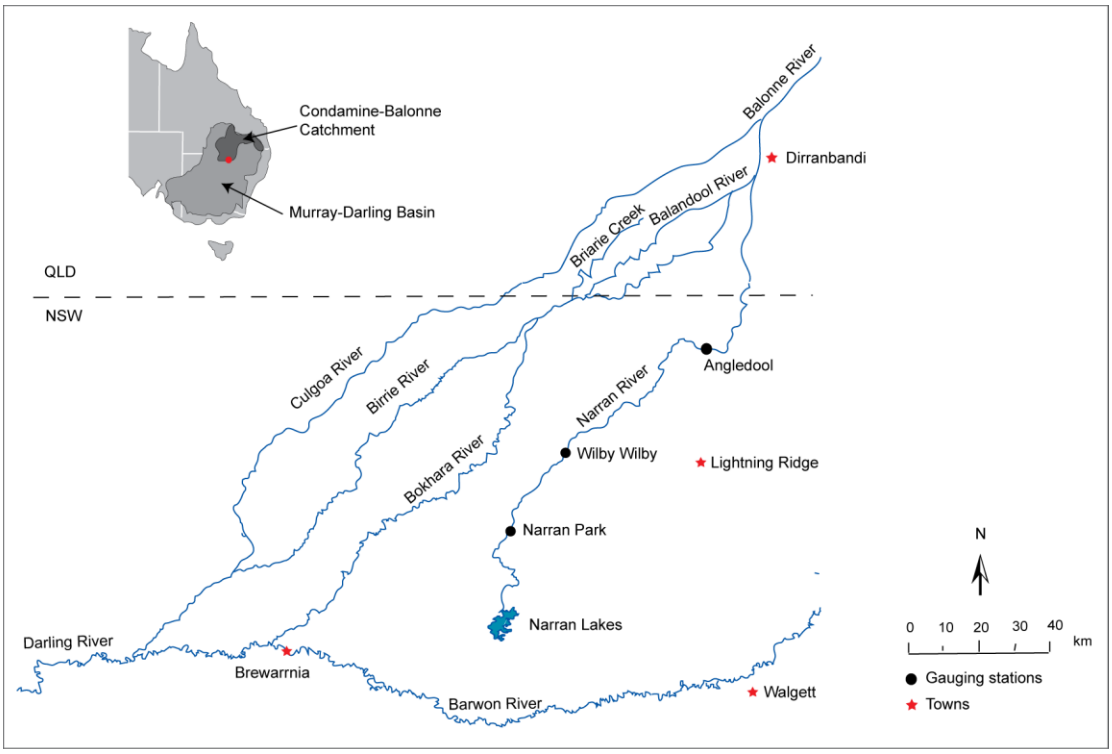


Figure 22: Location of gauging stations on Narran River.

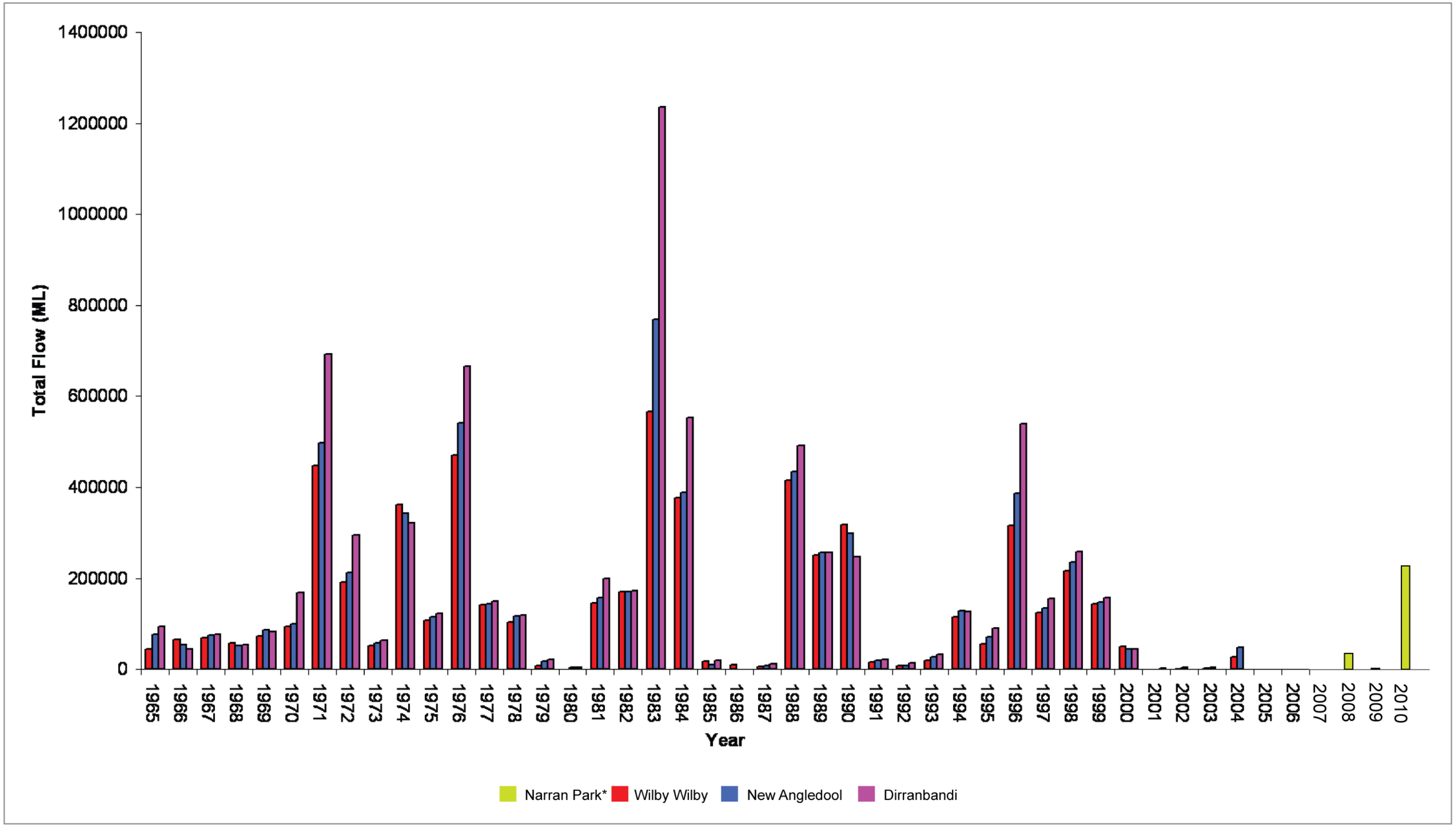


Figure 23: Comparisons between annual flow levels at the principal gauges on the Narran River (data for 1985-2006 from Thoms et al. 2007; Narran Park data, P. Terrill pers. comm.).

Flows per decade provide an indication of how wet or dry particular periods have been in the past (Table 5). The period 2000 to 2010 is the driest on record. Flows in the Narran River occur in nearly 90 percent of all years on record (Table 6) with medium to large floods being quite common historically with more than two thirds of all years recording 50 000 megalitres or more of discharge.

Table 5: Decadal flows for the New Angledool gauge (Thoms et al. 2007 and Office of Water 2010).

Decade	Total flow (megalitres)
1930	629 701
1940	1 012 949
1950	2 841 997
1960	1 012 224
1970	2 143 551
1980	2 195 617
1990	1 454 258
2000	403 530

Table 6: Number of years with threshold flow levels and the likelihood of occurrence for these flow levels at the New Angledool gauge (1929-2004) (from Thoms et al. 2007).

	Years	% Chance
Total	75	
No flow	8	10.5
1-50 000	17	22.4
50 000-100 000	17	22.4
100 000-200 000	15	19.7
200 000-500 000	15	19.7
500 000-750 000	2	2.6
750 000-1 000 000	1	1.3
greater than 1 000 000	1	1.3

The flows at the Wilby Wilby gauge show a systematic removal of medium sized floods since 1992 and an overall decrease in discharge when compared to the earlier part of the record (Thoms et al. 2007). A more detailed comparison of pre- and post 1992 flows shows that the recurrence intervals for floods of all magnitudes has increased (meaning floods have become more rare) since 1992 (Table 7). The annual recurrence interval (ARI) set for the period 1992 to 2003 was determined using partial series analysis, and represents the benchmark for flood frequency at the time of listing. A partial series analysis was necessary as data was limited. The time interval was selected because the level of water resource development had tapered and the possibility of enhanced climate variability was reduced.

Table 7: Changes in the number of floods and flood recurrence intervals pre- and post-large scale development upstream of the Narran system (from Thoms et al. 2007).

Size of flood (megalitres)	Number of floods		Recurrence interval	
	1969 to 1991	1992 to 2003	1969 to 1991	1992 to 2003
Larger than 50 000	17	7	1.30 years	1.85 years
Larger than 100 000	14	5	1.50 years	2.63 years
Larger than 200 000	8	2	2.78 years	6.67 years

Size of flood (megalitres)	Number of floods		Recurrence interval	
	1969 to 1991	1992 to 2003	1969 to 1991	1992 to 2003
Larger than 300 000	7	1	3.13 years	12.50 years
Larger than 400 000	4	0	5.56 years	less than 25 years
Larger than 500 000	1	0	20.00 years	less than 100 years

Wetting and drying

Thoms et al. (2007) undertook a patch analysis of wet and dry patches in the Ramsar site to determine the inundation character the system based on Landsat images from the period 1974 to 2004. These images captured each major flood event in the ecosystem since the mid 1970s and then a series covering two flooding and drawdown sequences that took place from December 1995 to February 1997 and from February to December 2004 (Thoms et al. 2007). The results indicated that Narran Lakes ecosystem has a high degree of spatial variability in the frequency of inundation. The main wetlands of the Ramsar site and Narran Lake are inundated in most years (27 out of 32 years) while floodplains areas are inundated with much less regularity (Figure 24). Water is much more persistent in the larger Narran Lake, but has fewer occasions when it is uniquely inundated (Figure 25). In floodplain areas, the number of times uniquely inundated equate to the total number of years inundated which highlights the rapid drying rates in floodplain areas. In Narran Lake, the average time to dry, in the absence of top up events, is about 15 months although this depends on the season in which inundation occurs. In the Ramsar site, the average time to dry is about 10 months, although the shallower parts of the Ramsar site may dry much more quickly (for example Long Arm dries in about 2 months while Back Lake dries in about 3 months on average).

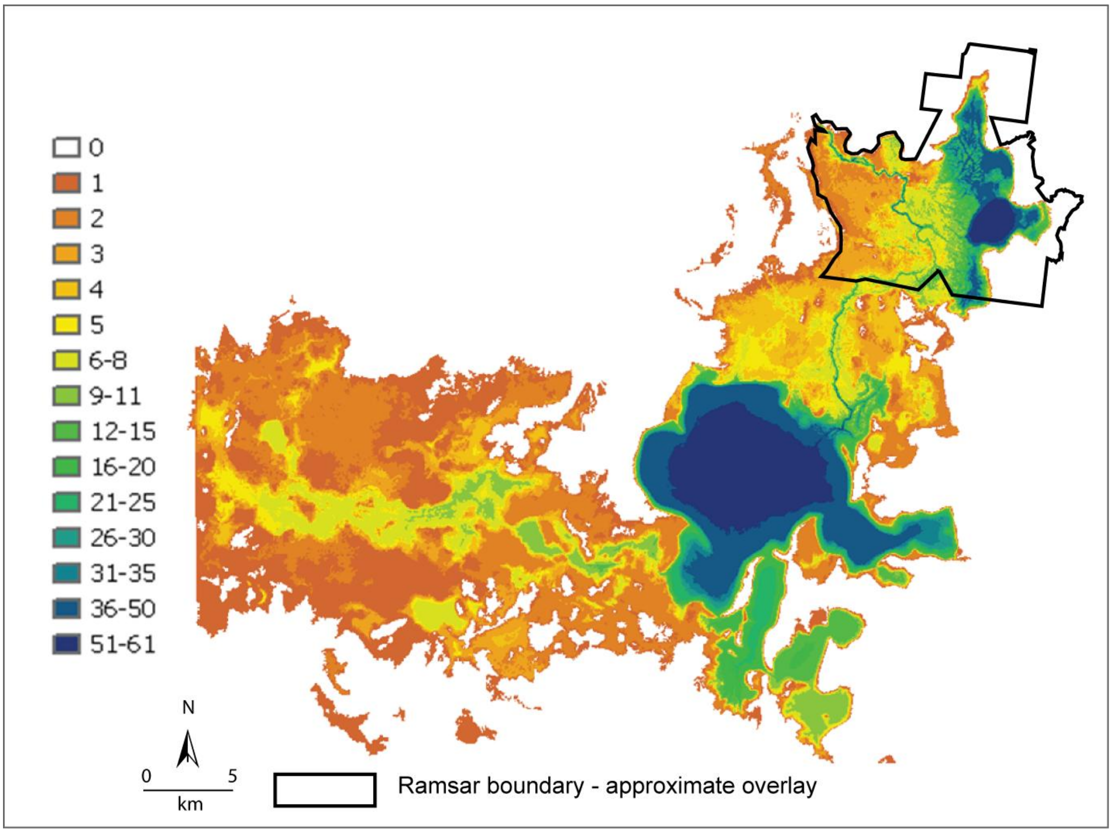


Figure 24: The number of satellite images on which water occurred in a particular location (1974-2004). Note: this data set includes 72 images which means that no water was present in a total of 11 images (modified from Thoms et al. 2007).

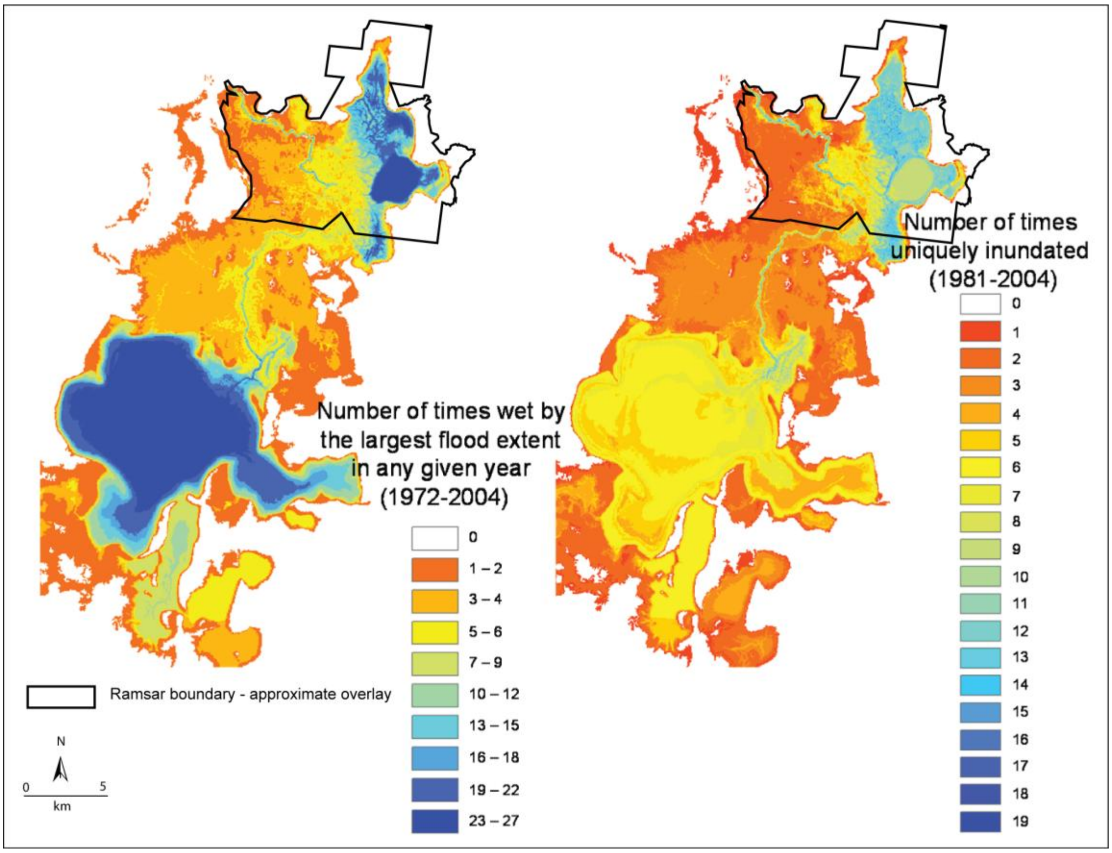


Figure 25: Flood frequency for the Narran system as determined by satellite imagery. (left) Records a value of one for every year that a location within the Narran system was wet by the largest recorded flood during that year; (right) records a value of one for every instance in which a location within the Narran system was wetted after having been previously dry (modified from Thoms et al. 2007). Ramsar boundary is an approximate overlay.

As stated above the average inundation frequency is one in two years, therefore providing more reliable waterbird breeding habitat than in many other wetlands in semi-arid areas in NSW (Magrath 1991). Duration of inundation and rates of drying are critical factors in supporting waterbird breeding. Floods need to inundate habitat for long enough for colonial waterbirds to complete their breeding cycles. If water levels drop too fast then nests are abandoned. Data from the 2008 breeding event suggest a conservative figure of 28 centimetres water height in Back Lake as the point at which breeding of colonial species, in particular straw-necked ibis, will commence, and that a reduction in this level may lead to desertion of nests (Terrill 2008a). Over any single inundation event Clear Lake, Back Lake and Long Arm can undergo several wet-dry cycles (Thoms et al. 2007). Flooding in Narran River is flashy with relatively high magnitudes and short durations separated by periods of low to no flow. However the system often has multiple flood events of a similar magnitude in close succession which effectively extend the duration of inundation (MDBA 2010).

Pattern of inundation

During floods approximately 58 percent of flows enter the Ramsar site, with the remaining 42 percent flows south to Narran Lake. During filling events in the Ramsar site the floodplain lakes fill sequentially with Clear Lake filling first, then Back Lake and Long Arm. In very large events water will then spill into Narran Lake (MDBA 2010, Thoms et al. 2007) (Figure 26). The surface area and capacity of the wetlands of the Ramsar site and larger terminal ecosystem are shown in Table 8. The floodplain areas fill less often than do the wetland areas. Over a 32 year period Clear Lake and Back Lake filled 23 and 16 times respectively, whilst the intervening floodplain only flooded six times (Thoms et al. 2007, MDBA 2010). Clear Lake reaches approximately one and a half metres depth when full.

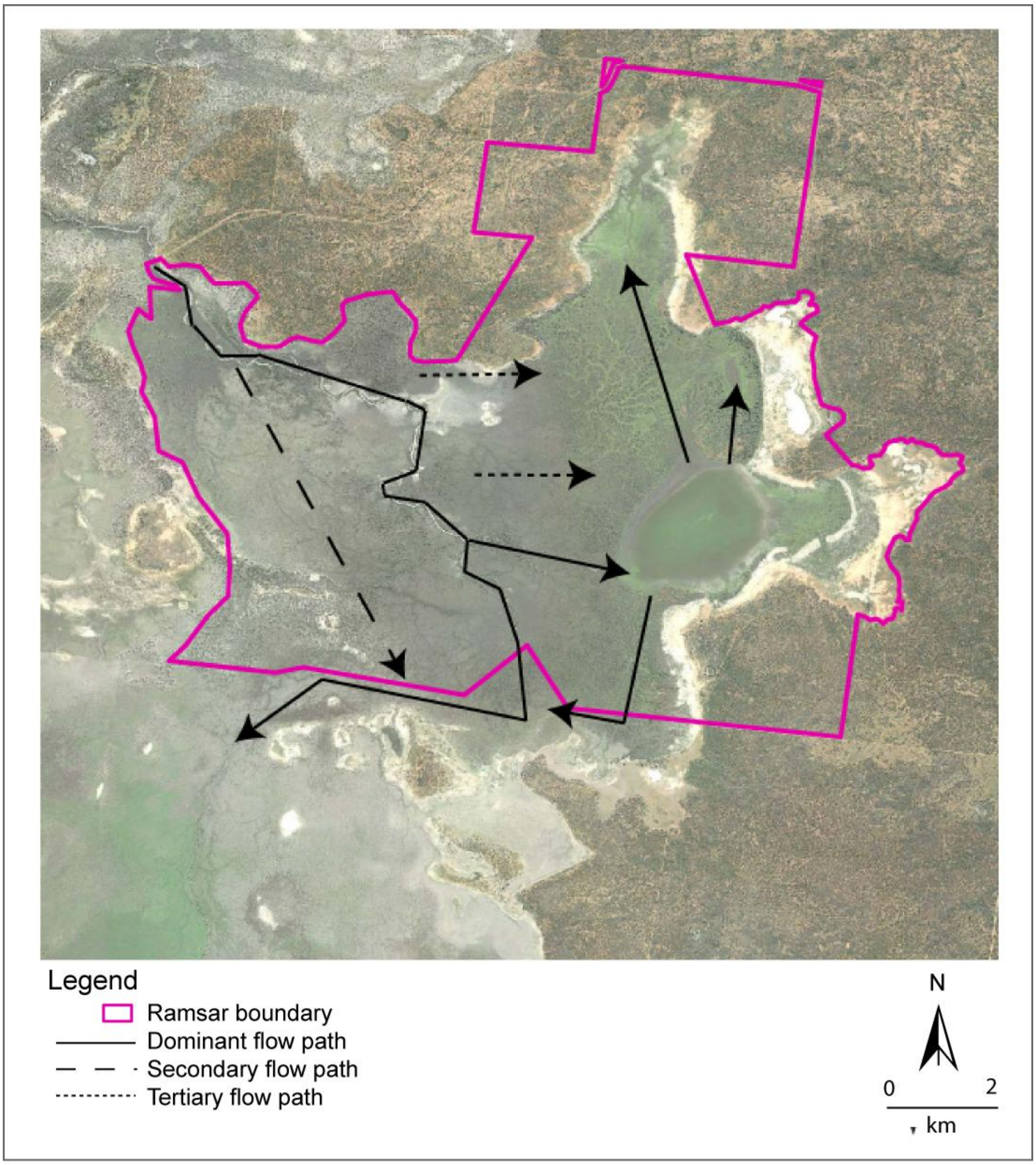


Figure 26: Flow paths within Narran Lake Nature Reserve Ramsar site (modified from Thoms et al. 2007).

Table 8: Surface areas and volumes (modified from MDBA 2010).

Wetland	Surface area (square kilometres)	Storage volume (megalitres)
Clear Lake	5.4	4476
Back Lake	1.3	861
Long Arm	1.5	0.6
Narran floodplains	135.7	13 573
Intervening storages	11.3	4035
Narran Lake	122.9	122 876
All Narran Lakes ecosystem	278.10	145 821

3.5 Water Quality

Water quality data are scarce for the Narran Lakes Ramsar site. The only information that could be sourced for within the site is from the 2004 Narran ecosystem project where water was sampled six times between February and November 2004 as the system dried post flood (Thoms et al. 2007). This is presented here as potentially indicative of conditions at the time of listing in 1990 (Figure 27).

The system remained fresh with electrical conductivity less than 0.5 milliSiemens per centimetre throughout the sampling. The exception to this was the final sample in Clear Lake (November 2004) when concentration effects resulted in higher salinity (conductivity of 1.36 milliSiemens per centimetre). Temperature followed a seasonal pattern with a decline into the colder winter months. Dissolved oxygen and pH varied considerably both spatially and temporally. Increases in dissolved oxygen as temperature decreases are to be expected as cooler water can hold greater amounts of dissolved oxygen than warmer waters. However, concentrations of dissolved oxygen in the Long Arm site decreased from March to August, perhaps reflecting consumption of oxygen by aquatic organisms over this time. Turbidity was highly variable between sites, with low turbidity throughout sampling at Back Lake, but high turbidity (greater than 500 nephelometric turbidity units) in the Narran River and Clear Lakes sites from July to November (Thoms et al. 2007). Turbidity is naturally high and variable in the region and the variation seen within Narran is not considered unusual.

Nutrient concentrations were generally high and increased as water levels decreased. Total nitrogen concentrations ranged from 550 micrograms per litre in the Narran River to over 5000 micrograms per litre in Clear Lake. Total phosphorus concentrations ranged from 140 micrograms per litre in the Narran River to over 2000 micrograms per litre in Clear Lake (Thoms et al. 2007).

A more comprehensive data set is available for the source water for the site, in the Narran River at Angledool. Data around the time of listing in 1999 and ten years post listing provides an indication of the quality of the water entering the site. During this period river water remained fresh and ranged between 60 and 280 microSiemens per centimetre (Figure 28). Turbidity was variable ranging from 25 to 1500 nephelometric turbidity units, but was often high with an average of over 500 nephelometric turbidity units (Figure 29). Highest turbidities were recorded during summer months and are likely to reflect increased phytoplankton numbers as well as suspended sediments.

Nutrient concentrations in the Narran River were also high with total nitrogen ranging from 500 to 1400 micrograms per litre and total phosphorus generally greater than 200 micrograms per litre (Figure 30). Similar to condition within the Ramsar site during 2004, the ratio of nitrogen to phosphorus is low (consistently less than 5:1) which indicates that nitrogen is likely to be the nutrient limiting phytoplankton growth. Water quality directly influences biotic responses and ecological processes. For example salinity levels affect species richness of community structure of obligate aquatic species, whilst turbidity and nutrients influence primary productivity and growth of macrophytes.

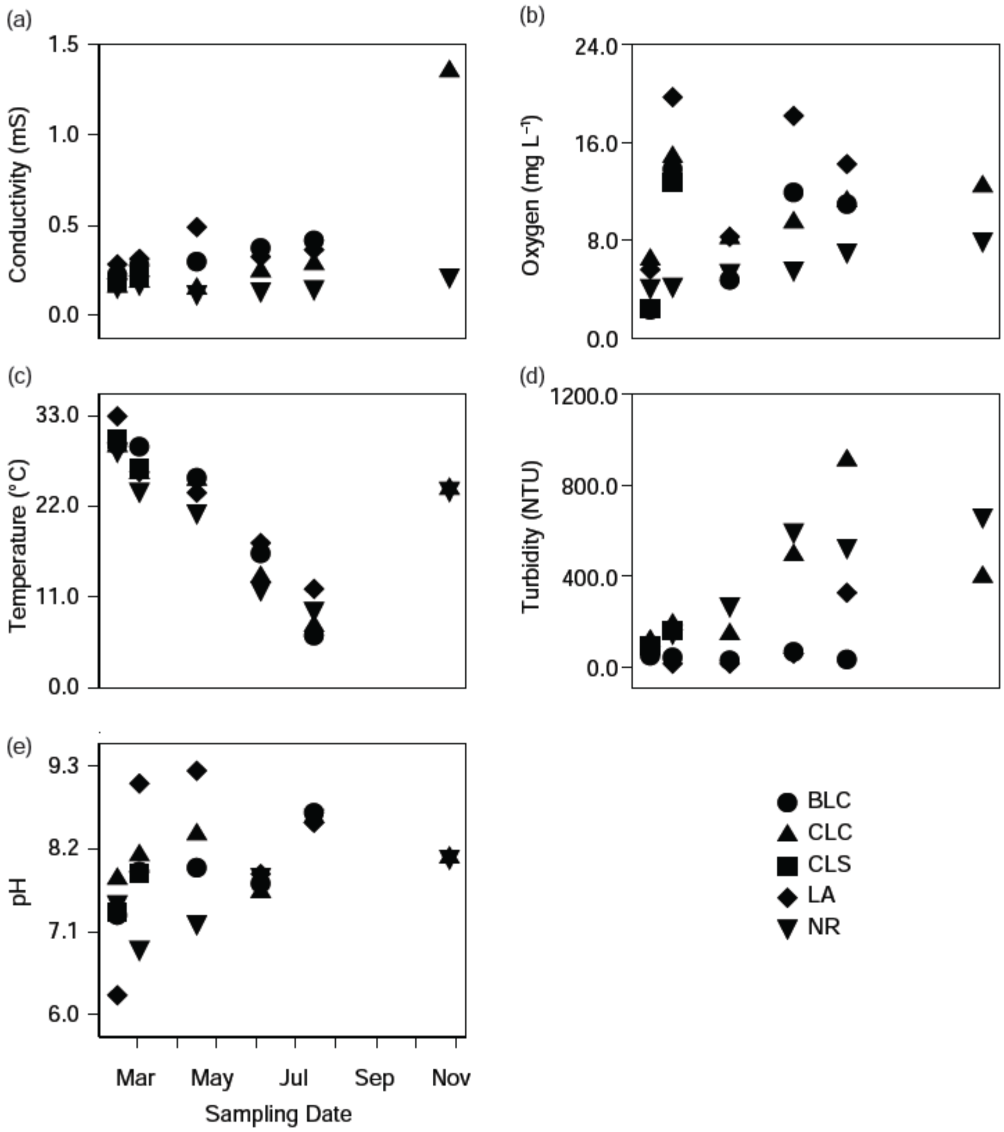


Figure 27: Water quality results for sampling between February and November 2004 in the Narran Lakes Ramsar site (Thoms et al. 2007). Site codes: BLC: Back Lake centre; CLC: Clear Lake centre; CLS: Clear Lake shore; LA: Long Arm; NR: Narran River.

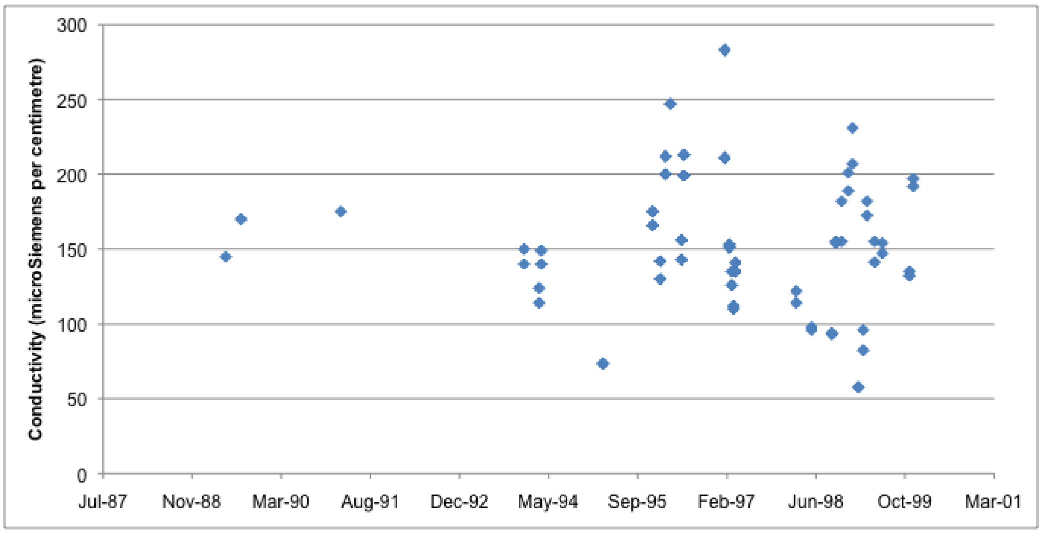


Figure 28: Salinity (as indicated by conductivity) in the Narran River at Angledool 1989 to 1999 (data provided by the Office of Water).

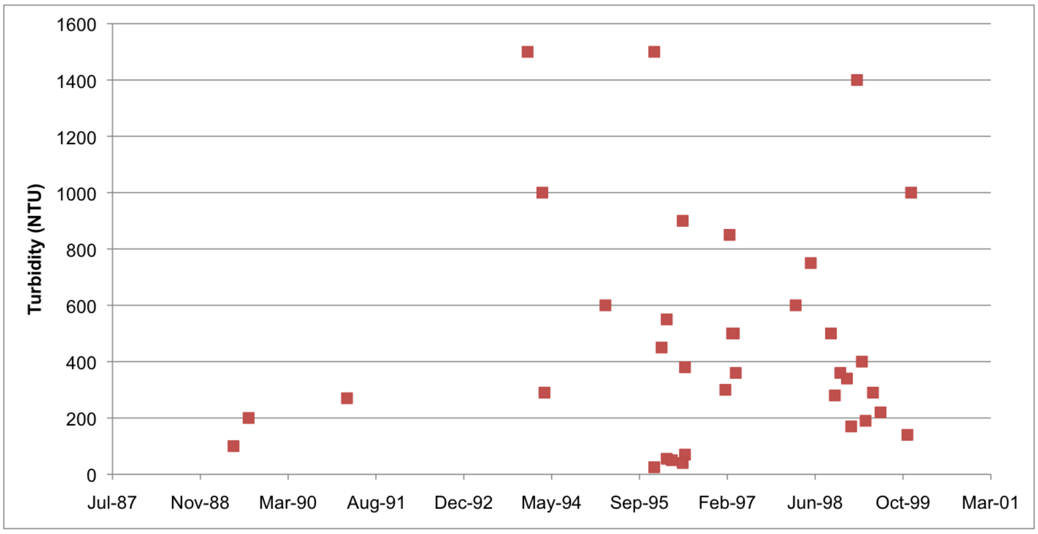


Figure 29: Turbidity in the Narran River at Angledool 1989 to 1999 (data provided by the Office of Water).

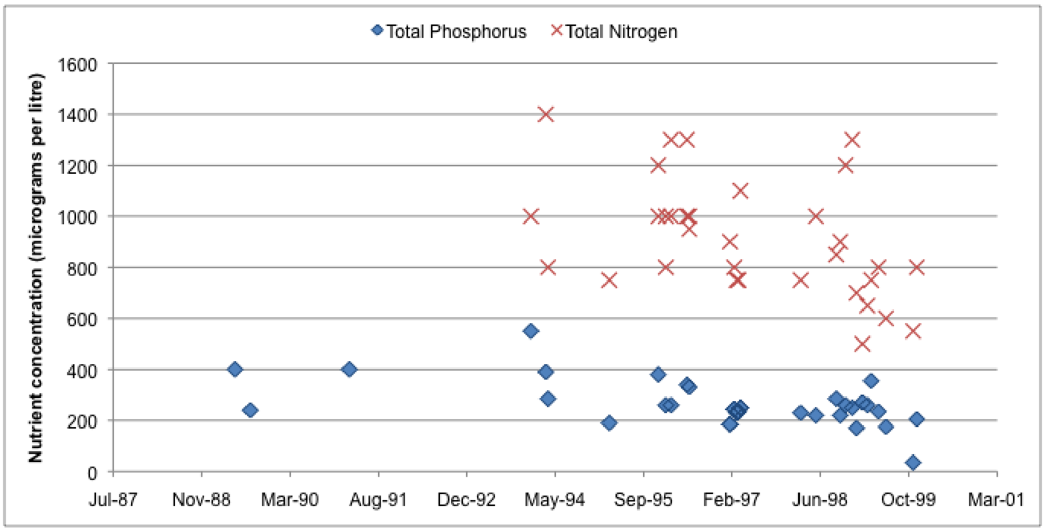


Figure 30: Total nitrogen and total phosphorus in the Narran River at Angledool 1989 to 1999 (data provided by the Office of Water).

3.6 Vegetation

Wetland vegetation in the Ramsar site is characterised by three main community types: i) riparian open forest and woodland, ii) lignum shrubland and iii) ephemeral herbfields. In their description of vegetation in the Narran Lake Nature Reserve, McGann et al. (2001) classify the first and second of these communities as “wetland” vegetation and distinguish this from “fringing herb and shrublands” which, under their classification, comprises both ephemeral herb field and chenopod low open shrubland communities. The spatial extent of these latter communities, however, are not separated and it is likely that fringing wetland areas fluctuate between ephemeral herbfields and chenopod open shrublands over time depending on conditions, i.e. with chenopod shrublands appearing during dry periods (Capon 2010). Consequently, ephemeral herbfields and chenopod low open shrublands are considered here as a single community type. All of these communities occur within the extent of the largest mapped inundation event (Thoms et al. 2007). A summary of ecological attributes of these key communities is provided in Table 9.

Adjacent terrestrial vegetation within the Ramsar site boundary includes: mixed low woodlands dominated by *Callitris glaucophylla* (white cypress pine), *Eucalyptus populnea* (poplar box) and *Geijera parviflora* (wilga); *Acacia aneura* (mulga) low woodlands; and *Triodia* (spinifex) hummock grasslands and low woodlands (McGann et al. 2001).

Table 9: Summary of ecological attributes of critical vegetation communities in the Narran Lake Nature Reserve Ramsar site.

Community	Description	
Riparian open forests and woodlands	Trees	*E. camaldulensis, E. coolabah, A. stenophylla, E. largiflorens, G. parviflora* and other acacias.
	Shrubs	Tall mid-storey of *A. stenophylla* and *Eremophila bignoniiflora* +/- lignum understorey and chenopod shrubs.
	Understorey	Ephemeral grasses and forbs including *Alternanthera denticulata, Crinum flaccidum, Stellaria angustifolia, Ixiolaena brevicompta, Euchiton sphaeircus, Eleocharis plana, Marsilea costulifera, Haloragis glauca, Centipeda cunninghamii, Wahlenbergia fluminalis, Pratia concolor, Portulaca oleracea, Pluchea dentex, Plantago varia* and *Oxalis chnoodes*
	Temporal variability	Groundcover highly variable depending on rainfall and flooding.
	Spatial variability	High spatial variability in composition and structure of canopy and recruitment patterns. Lignum shrub layer present in more frequently inundated areas. Chenopod shrub layer dominates in drier areas.
Lignum shrublands	Trees	Scattered *E. camaldulensis* and *A. stenophylla*.
	Shrubs	*Muehlenbeckia florulenta* +/- *Calotis scapigera, Atriplex versicaria, Sclerolaena convexula* and *Abutilon leucopetalum*.
	Understorey	+/- *Phragmites australis*. Ephemeral grasses and forbs including *Azolla filiculoides* var. *rubra*, *Stellaria angustifolia, Lemna disperma, Haloragis glauca, Cyperus gymnocaulos, Myriophyllum verrucosum, Goodenia glauca, Rorippa eustylis, Cynodon dactylon, Alternanthera angustifolia* and *Limosella australis*
	Temporal variability	Condition of lignum shrubs temporally variable with rapid growth response to flooding and rainfall. Groundcover highly variable depending on rainfall and flooding. Greatest diversity and productivity following floodwater recession.
	Spatial variability	High spatial variability in structure and condition of lignum shrub layer. Few large and dense shrubs in frequently flooded areas. Many scattered and small shrubs in drier areas of distribution.
Ephemeral herbfields	Trees	Very sparse Acacias and Eucalypts
	Shrubs	+/- chenopod shrubs and sub-shrubs including *Sclerolaena decurrens, Atriplex nummularia, Halosarcia pergranulata* and *Maireana apressa*.
	Understorey	Aquatic macrophytes including *Myriophyllum* species, *Vallisneria* sp., *Marsilea drummondii*, *Chara* species and *Nitella* species. Ephemeral grasses and forbs including *Centipeda cunninghamii, Ammania multiflora, Polygonum plebeium* and *Cyperus pygmaeus, Sporobolus mitchellii, Haloragis glauca*, *Cullen cinerea* and *Malva pressiana*.
	Temporal	Groundcover highly variable depending on rainfall and flooding. Greatest diversity and productivity following

Community	Description	
	variability	floodwater recession. Chenopods increase in abundance during periods of drying and composition approaches that of neighbouring terrestrial systems.
	Spatial variability	High spatial variability primarily reflecting flood history.

Riparian open forest and woodlands

Forest and woodland communities are sparsely distributed across the floodplain and wetlands of the Narran Lake Nature Reserve Ramsar site. Mature tree communities are mostly restricted to narrow riparian bands lining the river and major distributary channels in addition to several reasonably well-defined patches on the floodplain and fringing some of the major waterbodies such as Clear and Back Lakes. A total of twelve floodplain tree patches were mapped within the Ramsar site boundary using LiDAR and Landsat imagery as part of the Narran Lakes Ecosystem Project (Figure 31). These were defined as areas within the boundary of the greatest known flood extent of more than 50 000 square metres with more than 50 percent canopy cover of vegetation over three metres in height (Thoms et al. 2007).

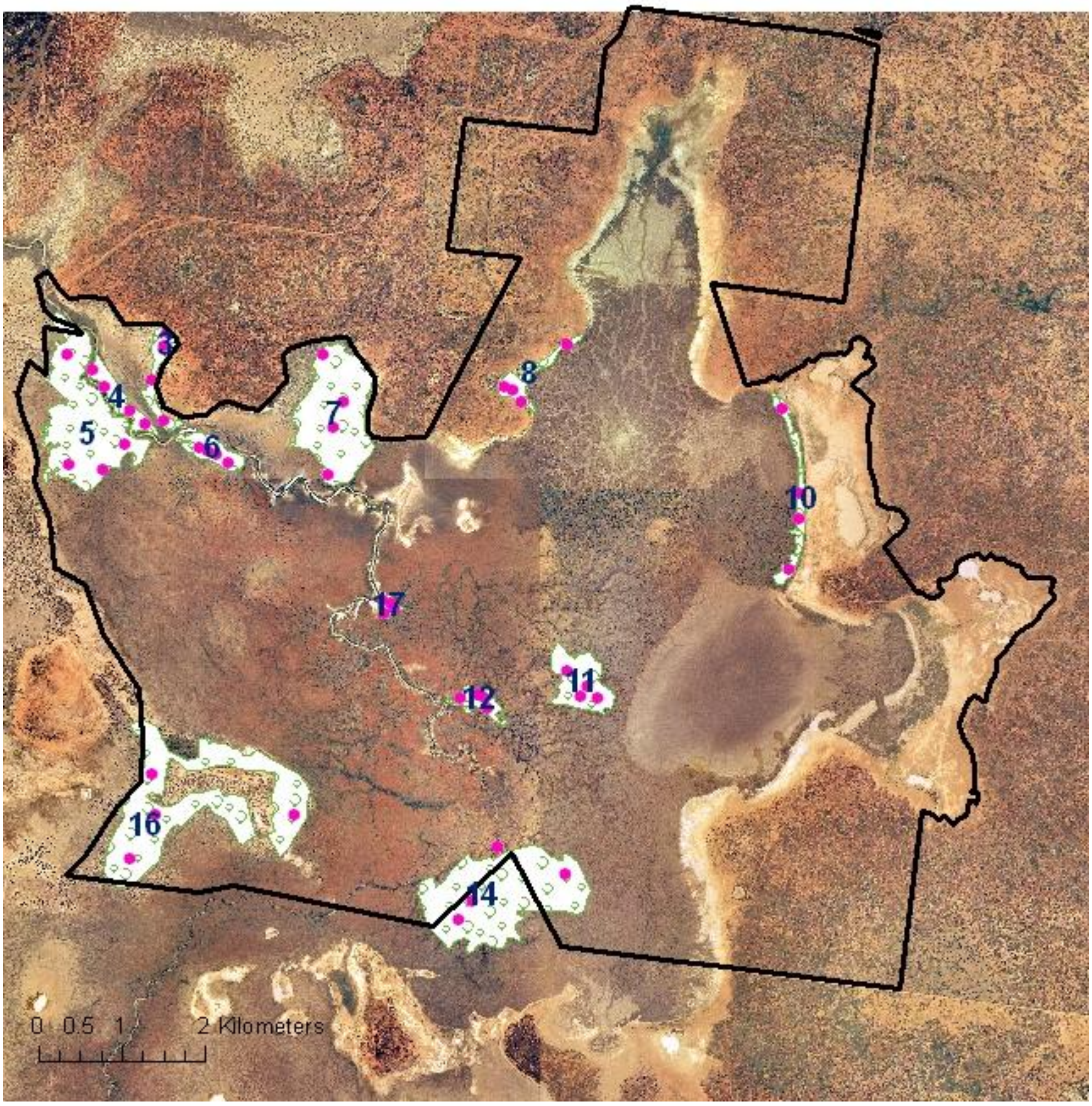


Figure 31: Location of mature tree patches identified using LiDAR and Landsat imagery during the Narran Lakes Ecosystem Project. Numbers show patch labels. Low flood frequency patches (recurrence intervals ranging from ~five to 16 years): 3 and 16; Medium flood frequency patches (recurrence intervals from three to five years): 4, 5, 6, 7 and 17; High flood frequency patches (recurrence intervals less than three years): 8, 10, 11, 12 and 14.

Riparian open forest and woodland canopies within the Ramsar site are dominated by *Eucalyptus camaldulensis* (river red gum) and, in less frequently flooded areas along less major channels, *E. coolabah* (coolibah) (Figure 32). *Acacia stenophylla* (river cooba) and *Eremophila bignoniiflora* (creek wilga) commonly form a tall mid-storey in riparian areas (McGann et al. 2001) and several of the floodplain tree patches, particularly those west of

Clear Lake (for example patch 11, Figure 31) are also dominated by river cooba. Of more than 4000 trees surveyed in tree patches between 2005 and 2006 as part of the Narran Lakes Ecosystem Project, these four species accounted for over 90 percent. Other tree species recorded in riparian communities by Hunter (1999) include *A. brachystachya* (umbrella mulga), *A. pendula* (weeping myall) and *Eucalyptus largiflorens* (black box), with the latter typically occurring further away from the channel at slightly higher elevations, though not as frequently as in riparian and floodplain woodlands further south (McGann et al. 2001). A shrub layer comprising *Muehlenbeckia florulenta* (lignum) and various chenopods, for example *Sclerolaena* species, may also be present (Hunter 1999). In terms of structure, the riparian open forests mapped by Hunter (1999) have canopies ranging in height from eight to 20 metres with 20 to 40 percent canopy cover and mid-storeys between three and eight metres tall with 10 to 30 percent cover (McGann et al. 2001).

Riparian open forest and woodland communities support diverse and highly variable understorey herb layers of up to one to two metres in height, ranging from 10 to 70 percent cover and comprising ephemeral grasses and forbs, many of which are only likely to appear in response to flooding or rainfall (McGann et al. 2001). Common understorey species recorded by Hunter (1999) include, in order of declining importance; *Alternanthera denticulata*, *Crinum flaccidum*, *Stellaria angustifolia*, *Ixiolaena brevicompta*, *Euchiton sphaeircus*, *Eleocharis plana*, *Marsilea costulifera*, *Haloragis glauca*, *Centipeda cunninghamii*, *Wahlenbergia fluminalis*, *Pratia concolor*, *Portulaca oleracea*, *Pluchea dentex*, *Plantago varia* and *Oxalis chnoodes*. Exotic species recorded in this community include *Phyla nodiflora* (lippia), *Verbena officinalis*, *Cyperus eragrostis* and *Aira cupaniana*. Persistent soil seed banks dominated by annual forb and monocot species are present in riparian forest and woodland communities of the Ramsar site and these appear to be somewhat distinctive in terms of composition from those of other hydrogeomorphic units examined at the site, for example Clear Lake and Back Lake (James et al. 2007).

Figure 32: Examples of riparian open forest and woodlands with medium flood frequency (left – tree patch 4 – coolibah and *Eremophila bignoniiflora* with lignum understorey) and low flood frequency (right – tree patch 16 – coolibah) (Images supplied by S. Capon © Narran Ecosystem Project).

Lignum shrublands

Lignum shrublands, or “lignum shrubby thickets” (McGann et al. 2001), cover almost 3 000 hectares of the Narran Lake Nature Reserve (Hunter 1999) and occur throughout the floodplain of the Ramsar site, particularly between Clear Lake and the Narran River channel, as well as across most of Back Lake and Long Arm (Figure 33). Lignum also lines the majority of major and minor channels within the Ramsar site, often as an understorey to riparian open forest and woodland communities. However it is typically absent from the rarely flooded fringing floodplain areas and from the most frequently and deeply flooded parts of the wetlands such as the bed of Clear Lake and the centre of distributary channels (for example Webb et al. 2006). The extent of lignum shrublands across the entire Narran Lakes Ecosystem is likely to be one of the largest remaining in New South Wales (see Aldis 1987 in NSW NPWS 2000).

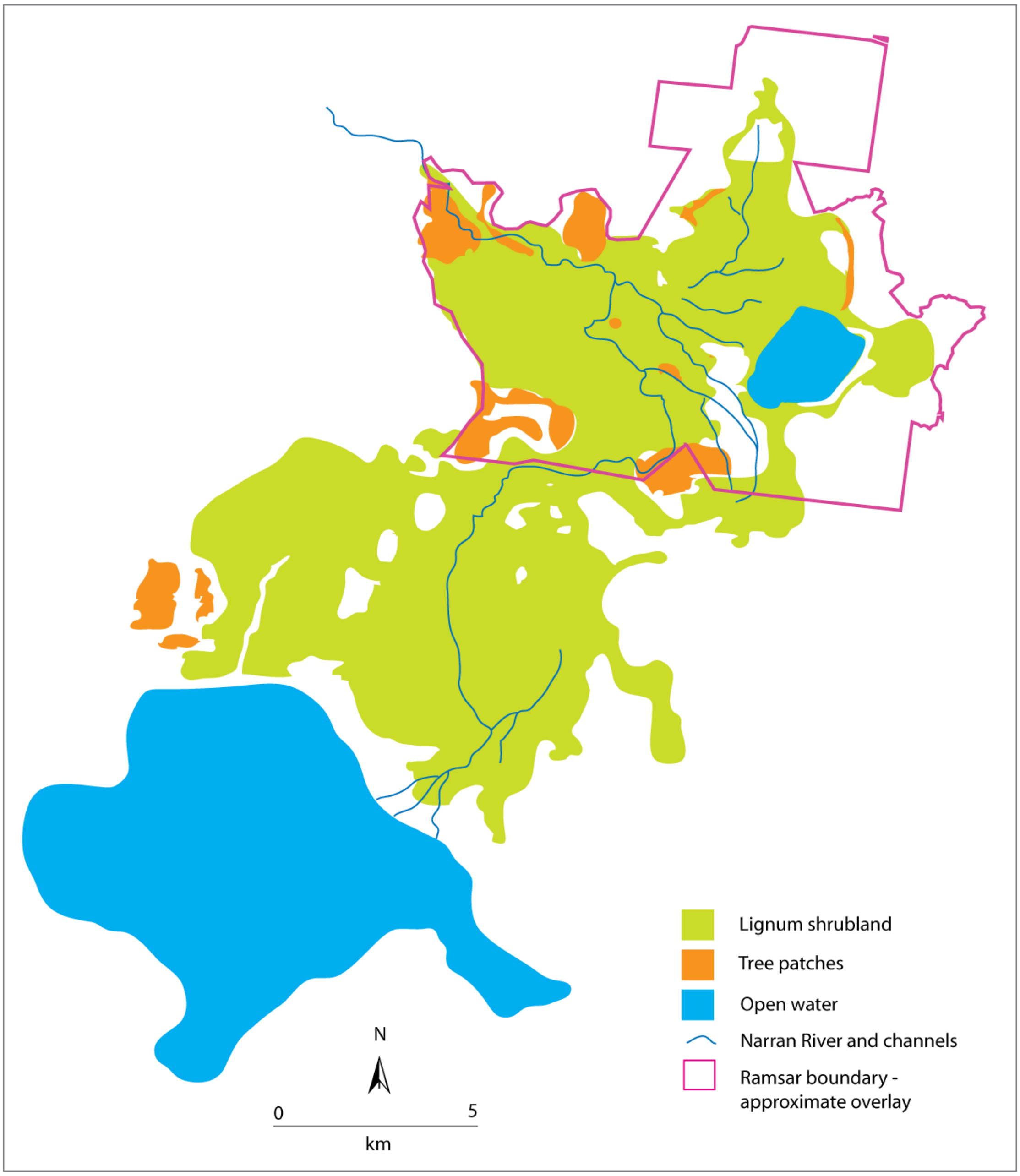


Figure 33: Map of lignum shrublands (green) over entire Narran Lakes ecosystem created using LiDAR, Landsat imagery and air photos during the Narran Lakes Ecosystem Project (Modified from graphic supplied by S. Capon).

Lignum shrublands are dominated by the shrub *Muehlenbeckia florulenta* (tangled lignum) but may also support scattered trees in varying abundance. *Acacia stenophylla* is particularly abundant in areas fringing Clear Lake and on the floodplain west of Clear Lake while *Eucalyptus camaldulensis* is relatively frequent in shrublands on the eastern edge of Clear and Back lakes, (Hunter 1999; S. Capon, pers. observation). The character of lignum shrubland varies considerably across its range with dense cover (up to 90 percent) of shrubs reaching up to four metres in height in wetter areas, for example Back Lake, while less frequently flooded areas, with higher elevations west of the river channel, may only support sparsely distributed, stunted shrubs (Hunter 1999; S. Capon pers. observation) (Figure 34). Dense reed-beds of *Phragmites australis* (common reed) also occur intermingled with lignum shrublands in several locations fringing Clear Lake and along the Long Arm (Thoms et al. 2002; S. Capon, pers. observation).

Figure 34: Lignum shrubland inundated (left) and in rarely a flooded area of the Ramsar site (right) (Images supplied by S. Capon © Narran Ecosystem Project).

As in the other dryland wetland communities, the composition and structure of groundcover vegetation in lignum shrublands of the Ramsar site is highly variable both spatially and temporally (Capon 2010). Forty-seven taxa, comprising other shrubs and understorey forb and monocot species, were recorded by Hunter (1999) from lignum shrublands within the Nature Reserve. Of these, common shrub and sub-shrub species included *Calotis scapigera, Atriplex versicaria, Sclerolaena convexula* and *Abutilon leucopetalum*. Common groundcover species included *Azolla filiculoides* var. *rubra*, *Stellaria angustifolia*, *Lemna disperma*, *Haloragis glauca*, *Cyperus gymnocaulos*, *Myriophyllum verrucosum*, *Goodenia glauca, Rorippa eustylis, Cynodon dactylon, Alternanthera angustifolia* and *Limosella australis.* The exotic species *Phyla nodiflora* and *Conyza albida* were also recorded from this community type (Hunter 1999).

Research conducted during the Narran Lakes Ecosystem Project indicates that lignum shrublands contain some of the most abundant and diverse soil seed banks within the wetland complex (James et al. 2007).

Ephemeral herbfields

Vegetation communities that can be broadly classified as ephemeral herbfields occur in both the most frequently flooded parts of the Ramsar site such as the bed of Clear Lake, and in the least frequently flooded areas of the floodplain at higher elevations than the extent of lignum shrubland. Hunter (1999) classified 1000 hectares of the Nature Reserve as ephemeral herb fields, excluding low-lying lake beds and depressions that are devoid of lignum (Figure 35). This area is much larger, however, if this vegetation community is taken to incorporate all of the non-wooded vegetation communities within the greatest extent of floodplain inundation as well as these some time open water habitats classified by Hunter (1999) as lignum shrubland.

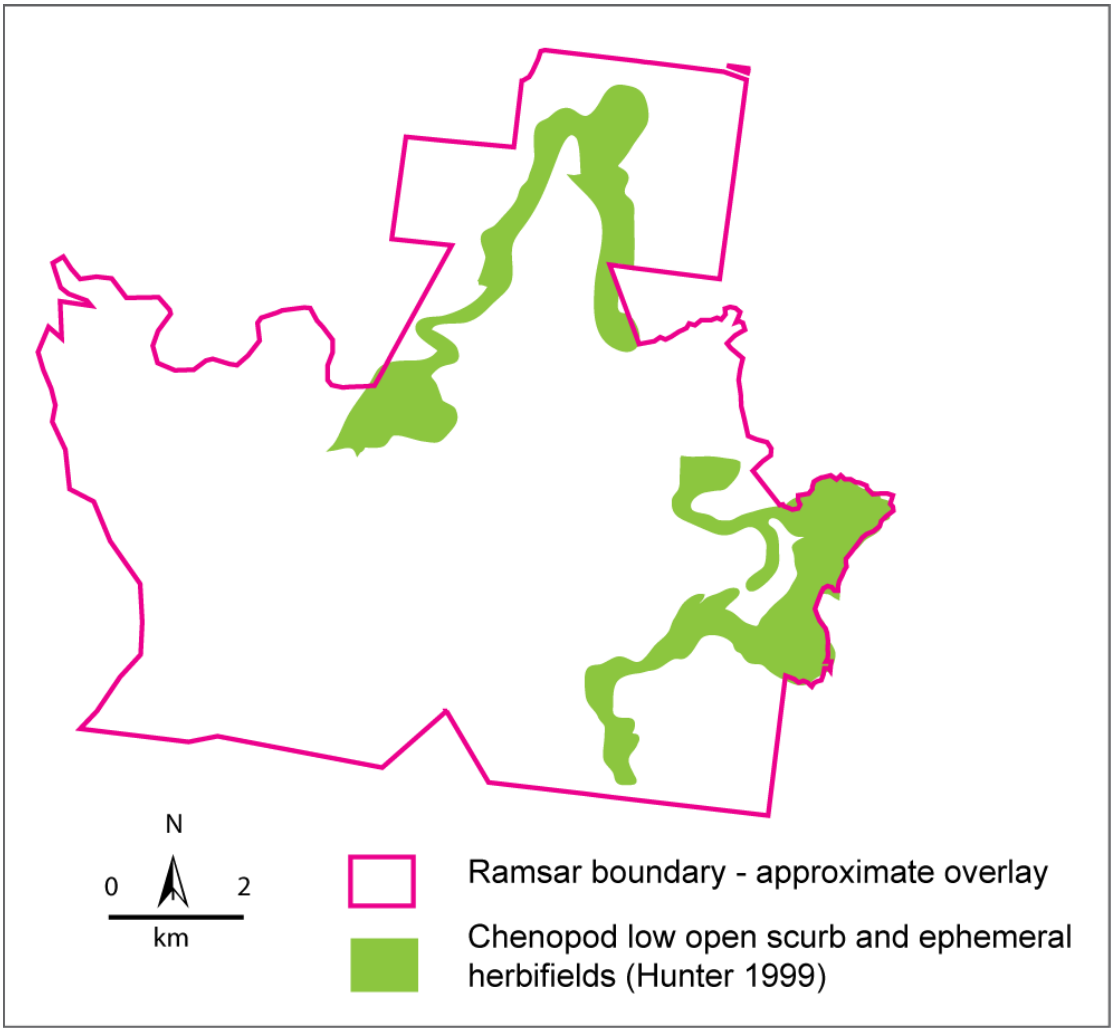


Figure 35: Extent of ephemeral herbfields in the Narran Lake Nature Reserve as mapped by Hunter (1999).

Ephemeral herb fields in the Ramsar site are mostly devoid of trees, although scattered eucalypts and acacias may be present, and, by definition, do not support shrub layers dominated by lignum. Other shrubs and sub-shrubs, however, particularly chenopods such as *Sclerolaena* species, *Maireana apressa* and *Atriplex holocarpa*, may be present and even locally abundant, particularly during dry periods (Hunter 1999; Capon 2010). In some areas, especially on patches of red earths, lunettes and playas to the east of Clear Lake, chenopods including *Sclerolaena decurrens* (green copperburr), *Atriplex nummularia* (old man saltbush) and *Halosarcia pergranulata* (samphire) may dominate most of the time and these communities may therefore be more specifically classified as chenopod low open shrublands (McGann et al. 2001).

Groundcover in ephemeral herbfield communities within the Narran Lakes Ramsar site tends to be dominated by annual forbs in terms of species diversity (Capon 2010). Composition and structure, however, are highly variable in both space and time and are strongly influenced by patterns of both flooding and rainfall (James et al. 2007; Thoms et al. 2007; Capon 2010). According to Hunter (1999), groundcover typically ranges from 30 to 80 percent cover. Vegetation surveys conducted during and since the Narran Lakes Ecosystem Project, however, indicate that cover values both lower and higher than these bounds are possible depending on location and prevailing conditions (Capon 2010).

Overall, plant community composition of herbfields within the extent of historic inundation in the Narran Lakes ecosystem tend to be quite distinct from that of the understoreys of adjacent terrestrial communities (Thoms et al. 2007; Capon 2010). Composition tends to vary along gradients of flood frequency with rarely flooded parts of the floodplain exhibiting the greatest degree of similarity with terrestrial vegetation communities, largely due to the presence of chenopod shrubs (Capon 2010).

During periods of inundation, shallowly flooded low-lying wetland areas such as the Long Arm and Back Lake, support aquatic plants including *Myriophyllum* species (water milfoil), *Vallisneria* species (ribbonweed), *Marsilea drummondii* (nardoo) and charophytes (*Chara* and *Nitella*) (McColl 2006). More deeply flooded areas such as Clear Lake, however, appear to be too turbid to support significant aquatic plant growth although narrow littoral bands of emergent vegetation comprising *Sporobolus mitchellii* (rat's tail couch) and *Haloragis glauca* may be present (S. Capon pers. observation).

Following the recession of floodwaters, ephemeral herbfields are particularly diverse and productive. Areas that have been shallowly flooded for intermediate durations, such as Back Lake and Long Arm, tend to develop the most species rich communities dominated by annual forbs and monocots including *Centipeda cunninghamii, Ammania multiflora, Polygonum plebeium* and *Cyperus pygmaeus* (James et al. 2007; Thoms et al. 2007; Capon 2010). Although generally lacking aquatic vegetation whilst flooded, Clear Lake also supports significant groundcover production following drawdown (Figure 36), dominated by forbs such as *Cullen cinerea* and then *Malva pressiana* (Australian hollyhock) when dry (McColl 2006).

Hunter (1999) recorded 31 taxa in the fringing herbfields community type from the Nature Reserve including the grasses *Eriochlamys* species A (woolly mantle), *Tripogon loliiformis* (five minute grass) and the forbs *Centaurium spicatum* (*Schenkia spicata*), *Lepidium monoplocoides*, *Wahlenbergia fluminalis*, *Pimelea trichostachya*, *Daucus glochidatus*, *Crassula sieberiana*, *Calandrinia pumila* and *Brachyscome ciliaris*. Three exotic taxa were recorded from ephemeral herbfields in the Nature Reserve by Hunter (1999): *Hypochaeris glabra*, *Festuca pratensis* and *Aira cupaniana*. A further 20 exotic species were observed in the vegetation and the soil seed bank during the Narran Lakes Ecosystem Project (McColl, 2006).

Soil seed banks in ephemeral herbfields are likely to be diverse (> 70 species) and spatially heterogeneous, dominated by annual forb and monocot species including *Cyperus pygmaeus, Centipeda cunninghamii, Ammania multiflora* and *Polygonum plebeium* (James et al. 2007).

Figure 36: Ephemeral herbfield on dry lake bed of Clear Lake, November 2004 (Image supplied by S. Capon © Narran Ecosystem Project).

Hydrology vegetation relationships

Surface water hydrology tends to be the primary driver of vegetation dynamics in dryland floodplain and wetland ecosystems (Brock et al. 2006). Species inhabiting these systems typically exhibit morphological and physiological traits as well as life histories which enable plants to persist under unpredictable regimes of flooding and drying, either as adult plants or as dormant propagules that enable escape from these stressors in time and space. Variations in the tolerances and responses of different species to flooding and drought have a major influence on temporal and spatial patterns of vegetation composition and structure. A summary of hydrological drivers relevant to key species of the Narran Lakes is provided in Table 10.

Table 10: Summary of hydrological drivers of key plant species in the Narran Lake Nature Reserve Ramsar site (summarised from Roberts and Marston (2000) except where otherwise stated).

Species	Flood frequency	Flood timing	Flood duration	Flood depth	Rate of rise and drawdown	Duration of inter-flood period
River red gum	One to three years for healthy populations.	Seedling establishment favoured by winter floods with spring – early summer drawdown (Dexter 1967).	Can survive two to four years of flooding. Short floods may also be beneficial for growth.	Not significant for mature trees but seedlings will not survive submergence.	Not significant for mature trees but seedling survival may be favoured by rapid drawdown.	Two years before signs of stress, five years to die in absence of sufficient water, five to 15 months for healthy populations (Johns et al. 2009).
Coolibah	10 to 20 years.	Germination and establishment may be favoured by summer flooding (Doran and Boland 1984).	-	Unknown, probably similar to river red gum.	Unknown, probably similar to river red gum.	Unknown, likely to tolerate longer dry periods than river red gum due to distribution at higher elevations.
River coobah	Flooding is important but knowledge is lacking as to the actual requirements. It is thought that under natural conditions frequency of inundation is about one in three years (J. Roberts, pers. comm.).	-	Unknown but likely to be around three months (J. Roberts, pers. comm.).	-	-	It is likely to be drought tolerant, and therefore intervals of 5-7 (J. Roberts, pers. comm.).
Lignum	Three to ten years for healthy populations (Craig et al. 1991).	Probably not important in Narran.	Two to four months for healthy populations.	Important relative to height of shrubs and seedlings as may not survive submersion (Capon	Slow drawdown may favour seedling establishment (Capon et al.	Likely to be in the order of five to seven years.

Species	Flood frequency	Flood timing	Flood duration	Flood depth	Rate of rise and drawdown	Duration of inter-flood period
				et al. 2009).	2009).	
Water milfoil	-	-	-	Adapted to fluctuating water level.	-	Unknown. Has small persistent soil seed bank.
Ribbonweed	-	May be favoured by inundation in spring and summer (Briggs and Maher, 1985).	-	Important relative to turbidity therefore probably favoured by shallow water in Narran.	-	Unknown. Has small persistent soil seed bank.
Rat's tail couch	-	-	Up to ~ 73 - 75 days (Blanch et al. 1999).	Tolerates 20-60 centimetres (Blanch et al. 1999).	-	-
Common reed	-	-	Long durations will result in mortality.	Growth favoured by shallow flooding.	-	Unknown. May have small persistent soil seed bank. May have rhizome bank for several years.

3.7 Invertebrates

Arid and semi-arid wetlands display a typical ‘boom and bust’ ecology which is driven by the hydrological connectivity and flooding frequencies (Jenkins and Boulton 2003). Inundation triggers different ecological responses according to differing species requirements. The flush of zooplankton growth on the arrival of floodwaters provides the basis of the food chain on which the more iconic wetland fauna, fish and waterbirds, depend.

At the time of listing information on the aquatic invertebrate fauna was limited with sampling effort primarily restricted to the main channel of the Narran River (Thoms et al. 2002). Thoms et al. (2002) suggested that the Narran Lakes ecosystem would support a large invertebrate biomass as evidenced by the wetland supporting significant fish and waterbird populations.

Results from the Sustainable Rivers Audit (MDBC 2008) for the Condamine Valley had the lowland reaches scoring as moderate condition for the macroinvertebrate indicator. Diversity was moderate to low (average 18 families per site). Most sites sampled had impoverished communities, dominated by disturbance tolerant families (MDBC 2008).

As part of the Narran Ecosystem project macroinvertebrates were sampled to describe the composition and structure of assemblages and to examine spatial and temporal patterns in aquatic macroinvertebrate species composition and abundance during a wetting and drying event (Thoms et al. 2007). Sampling was undertaken at seven sites and included the Narran River, Clear Lake, Back Lake and Long Arm. Three sampling events in February, April, and June 2004 covered a range of microhabitats across each wetland area using replicate sweep netting (Thoms et al. 2007).

Zooplankton were also sampled as part of the Narran Ecosystem project revealing a variable community both temporally and spatially (Thoms et al. 2007). Zooplankton species richness on the floodplain was considered high with 24 taxa of the 52 taxa collected restricted to the floodplain zone (Thoms et al. 2007). Overall zooplankton densities ranged from 100 to over 3500 individuals per litre; however densities at sites peaked at different times. The highest densities were recorded in the Narran River in the first month after flooding. This is similar to the findings of Jenkins and Boulton (2003) that early colonising species were shown to arrive on floodwaters, with distinctive communities establishing weeks after inundation as new species emerged from the egg bank of floodplain sediments. Densities in the Long Arm and Back Lake peaked in March, whereas densities of zooplankton peaked at Clear Lake in June (Thoms et al. 2007).

In addition to the field sampling a zooplankton egg bank mesocosm experiment was also undertaken in which sediment from seven sites was used to establish emergence patterns. A low number of taxa, eight genera, emerged from the sediment samples with distinct emergence patterns for different species. Studies in other semi-arid system floodplains, such as Currawinya on the Paroo River (for example Timms 1999) and Darling River floodplain (for example Jenkins and Boulton 2003) also exhibited high spatial and temporal variability in zooplankton assemblages.

3.8 Amphibians

Nine of the 29 species of frog found in the Murray Darling Basin have been recorded from the Narran Lake Nature Reserve and associated floodplains. None of the species are threatened at the national level. Most of the species found at the site are common; several are burrowing species which only emerge from the soils after heavy rainfall (Table 11).

Amphibians, both as tadpoles and as adults, contribute to the diet of waterbirds and fish and are important for their role in the food chain.

Table 11: Amphibians found within Narran Lake Nature Reserve and associated floodplain (DECCW 2010a; Smith 1993; Henderson 1999a; Environment Australia 2001; Frogs Australia 2010).

Common name	Species	Habitat
Green tree frog	*Litoria caerulea*	Variety of habitats.
Peron's tree frog	*Litoria peronii*	Forests, grasslands and open areas near rivers.
Desert tree frog	*Litoria rubella*	Variety of habitats.
Long-thumbed frog/Barking marsh frog	*Limnodynastes fletcheri*	Inundated grassy areas, littoral zone of wetlands
Salmon striped frog	*Limnodynastes salmini*	Burrowing frog, spends majority of time underground, emerges after rains.
Spotted grass frog	*Limnodynastes tasmaniensis*	Very common, early colonisers, range of habitats, prefer marshy country with grass lined streams.
Crucifix frog	*Notaden bennettii*	Burrowing frog on black soils, only found above ground after rains.
Bibron's toadlet	*Pseudophryne bibronii*	Forests, heathlands and grasslands.
Warty water-holding frog/rough collared frog/rough frog	*Cyclorana verrucosa*	Burrowing frog in open grasslands and woodlands.

3.9 Fish

Fish surveys of the Narran system are limited, however surveys were undertaken as part of the Narran Ecosystem project in 2003 and 2004, the Sustainable Rivers Audit (MDBC 2008) and in association with an environmental water allocation in 2008 (Rolls and Wilson 2010).

Results from the Sustainable Rivers Audit for the Condamine Valley scored the lowland area of the catchment, which included sites in the Narran system, as moderate for fish. The fish nativeness indicator was 76 percent, the highest of all valleys in the Murray Darling Basin (MDBC 2008). The nativeness indicator is a measure of the proportions of abundance, biomass and species numbers that are native rather than alien species (MDBC 2008). Common species included bony herring (*Nematalosa erebi*), carp gudgeons *Hypseleotris* species, Australian smelt (*Retropinna semoni*), golden perch (*Macquaria ambigua*), Murray–Darling rainbowfish *Melanotaenia fluviatilis*) and spangled perch (*Leiopotherapon unicolour*) were common. Ten natives and three invasive species were recorded in the lowland reaches.

The Narran Ecosystem project recorded 11 fish species, eight of which were native with spangled perch, bony herring and common carp accounting for 99 percent of the catch per unit effort (Thoms et al. 2007).

Rolls and Wilson (2008a, 2008b, 2010) report on fish response to the extended flooding of the Narran system in 2008 when an environmental water allocation was delivered to prolong a natural flood event. They investigated differences between main stream and floodplain assemblages and the influence of Narran weir on fish movement. Abundances of most species encountered were higher in the main river channel but the results clearly indicated the fish assemblage utilised the floodplain when inundated (Rolls and Wilson 2010). Floodplain habitat was utilised by young of the year golden perch and bony herring, suggesting that the floodplain provides rearing habitat for these species (Rolls and Wilson 2010). The common carp (*Cyprinus carpio*) was also utilising the floodplain (Thoms et al. 2007).

Rolls and Wilson (2010) sampled nine native, three introduced and one hydrid non-native species. Spangled perch, bony herring (*Nematolosa erebi*) and golden perch were the most abundant native species accounting for 81 percent of the individuals sampled in 2008. Species found in all habitats included spangled perch, golden perch, bony herring, gold fish (*Carrasius auratus*), common carp and eastern gambusia (*Gambusia holbrooki*) (Rolls and Wilson 2010). Murray cod (*Maccullochella peelii peelii*) and western carp gudgeon (*Hypseleotris klunzingeri*) were recorded by Thoms et al. (2007) but not by Rolls and Wilson (2010). The carp-goldfish hybrid was only recorded by Rolls and Wilson (2010). The common species (bony herring, golden perch, carp gudgeons, Australian smelt, silver perch and spangled perch) are widespread and abundant in the region and it is likely that most if not all were present in the wetland at the time of listing. Species recorded in surveys for the site are presented in Table 12.

Table 12: Summary of fish species collected in Narran Lake Nature Reserve (Thoms et al. 2007; MDBC 2008; Rolls and Wilson 2010).

Common name	Scientific name
Australian smelt	*Retropinna semoni*
Silver perch	*Bidyanus bidyanus*
Carp gudgeons	*Hypseleotris* species
Western carp gudgeon	*Hypseleotris klunzingeri*
Spangled perch	*Leiopotherapon unicolour*
Bony herring	*Nematolosa erebi*
Murray River rainbowfish	*Melanotaenia fluviatilis*
Hyrtl's tandan	*Neosilurus hyrtlii*
Long-finned eel	*Anguilla reinhardsii*
Murray cod	*Maccullochella peelii peelii*
Golden perch (Callop)	*Macquaria ambigua*
Common carp	*Cyprinus carpio*
Carp-goldfish hybrid	
Eastern gambusia	*Gambusia holbrooki*
Goldfish	*Carrasius auratus*

Native fish exhibit a range of migratory behaviour; however all except one species recorded from the Ramsar site are potamodromous, in that they only migrate within freshwater. The long-finned eel typically migrates to the sea to spawn however the population at Narran is landlocked, with the Condamine Balonne Catchment the only inland catchment from which this coastal species has been recorded. Species characteristics are detailed in Appendix D.

3.10 Waterbirds

Diversity and abundance

A total of 68 species of waterbird have been recorded within the Ramsar site which contributes to the sites listing as a Wetland of International Importance (Table 13, Appendix B). This includes 14 species that are listed under international migratory agreements CAMBA (14), JAMBA (12), BONN (9) and ROKAMBA (9). An additional 26 species are listed as marine or migratory under the EPBC Act. This includes a record for the threatened Australasian bittern (*Botaurus poiciloptilus*) listed as endangered under both the EPBC Act and the IUCN Red List and observed in Clear Lake in 2008 (BirdLife International 2009).

Table 13: Number of wetland birds recorded within the Narran Lake Nature Reserve Ramsar site (Birds Australia unpublished; Brooker 1993; Ley 1998; Kingsford et al. 2008). See Appendix B for full list of species.

Bird Group	Typical feeding habitat	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, and Darters.	Deeper open waters feeding mainly on fish.	6
Heron, Ibis, and Spoonbills.	Shallow water or mudflats. Feeding mainly on animals (fish and invertebrates).	15
Hawks and Eagles.	Shallow or deeper open water on fish and occasionally waterbirds and carrion.	2
Cranes, Crakes, Rails, Water Hens, and 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.	6
Shorebirds.	Shallow water, bare mud and salt marsh. Feeding mainly on animals (invertebrates and some fish).	16
Gulls and Terns.	Terns, over open water feeding on fish and invertebrates; gulls, opportunistic feeders over a wide range of habitats.	5
Other.	Non water birds that are reliant on wetlands for breeding or feeding (Australian reed warbler and sacred kingfisher).	2
Total		**68**

Comprehensive count data are relatively rare for the site and this may be due to the temporary nature of the wetlands and the difficulties of access during inundation. The most complete data set available prior to listing is from aerial counts from 1977 to 1981 for the whole Narran Lakes ecosystem (Brooker 1993). The terminal system periodically supports large numbers of birds, with peaks in abundance corresponding with breeding events following large flow events. Large counts reported for the site prior to listing are greater than 200 000 birds in 1983 and again in 1996 (Ley 1998), and 28 000 in October 1998 (Birds Australia unpublished). Since listing large counts of more than 20 000 birds have been recorded in 2008 (Kingsford et al. 2008), 2010 and 2011 (P Terrill unpublished). Of the 21 years in which breeding is known to have occurred, data on nest counts are available for 16 years (Figure 15). Recent flooding in February 2011 has triggered another large breeding event, with approximately 100 000 waterbirds, mainly straw-necked ibis, being recorded within the Ramsar site.

The Narran Lake Nature Reserve Ramsar site also periodically supports significant numbers of individual waterbird species. Maximum counts for six species exceed the one percent population thresholds (Wetlands International 2006; Table 14). The list comprises predominantly Australian resident species, but includes the international migratory shorebird the sharp-tailed sandpiper (*Calidris acuminata*). It should be noted that this list was compiled from very limited data and that for a number of occasions when large numbers of birds were present in the Ramsar site (for example 1983 and 2008) data on individual species numbers are not available. Current data does not satisfy the definition of “regularly support” as determined using Ramsar guidance, see section 2.5.

Table 14: Waterbird species for which more than one percent of the relevant population has been recorded in the Narran Lake Nature Reserve Ramsar site. * It is unclear if this record is for Clear Lake, Narran Lake or a combined count.

Common name	Species name	Population (one percent)	Maximum count	Reference
Australasian shoveler	*Anas rhynchotis*	Australia 1000	2447, Apr 1978	Brooker 1993
Australian Pelican	*Pelecanus conspicillatus*	Australia 10 000	13 245, Jan 1978	Brooker 1993*
Royal spoonbill	*Platalea regia*	Australia 1000	3000, Aug 1998 7000, Oct 1998 Approximately 5000, 2010	Henderson 1999b; Birds Australia unpublished, Peter Terrill pers. comm.
Australian White Ibis	*Threskiornis molucca*	Australia 10 000	20 000, Oct 1998	Birds Australia unpublished
Straw-necked Ibis	*Threskiornis spinicollis*	Australia 10 000	20 000, 1971 18 000, Sept 1989 100 000, Sept 1990 200 000, Mar 1996 100 000, Aug 1999 140 000, Jan-May 2008 Approximately 42 000 May 2010	Smith 1993; Magrath 1991; Ley 1998; Henderson 1999b; Kingsford et al. 2008; Terrill 2011.
Sharp-tailed Sandpiper	*Calidris acuminata*	EAAF 1600	2000, Oct 1997	Ley 1998

Waterbird breeding

The Narran Lake Nature Reserve Ramsar site is particularly important in terms of breeding of waterbirds. Forty four species of wetland bird have been recorded breeding within the site (Appendix B), which represents 64 percent of the wetland birds recorded at the site. Nesting abundance data is highly variable reflecting a combination of actual variability in breeding events and the poor documentation of breeding events at the site (Ley 1998) (see Figure 15 in section 2.5). Ley (1998) provides a detailed description of breeding species at the site from the 1996 flood. Notable records from this event include (Ley 1998):

- 200 pairs of Australasian darter (*Anhinga novaehollandiae*)
- 750 pairs of pied cormorant (*Phalacrocorax varius*);
- 2500 pairs of little black cormorant (*Phalacrocorax sulcirostris*);
- 400 pairs of great cormorant (*Phalacrocorax carbo*);
- 50 pairs of Eastern great egret (*Ardea modesta*);
- 500 pairs of Australian white ibis (*Threskiornis molucca*);
- 102 00 nests of straw-necked ibis (*Threskiornis spinicollis*); and
- 150 pairs of royal spoonbill (*Platalea regia*).

The site is considered particularly important for colonial breeding species (Figure 37 and Figure 38) with nesting records for 17 years of the period 1971 to 2008 (Appendix C). The longest period without a record of a breeding event at the site is the period 2001 to 2008 and is a reflection of drought conditions in the region.

Figure 37: Straw-necked ibis eggs on lignum (Duncan Vennell, DECCW).

Figure 38: Straw-necked ibis chicks on lignum (Duncan Vennell, DECCW).

Functional feeding groups
Classification of waterbirds based on diet and foraging method was developed for arid Australian wetlands by Reid and Jaensch (2004). The classification divides wetland bird species into the following categories:

- Piscivores – fish eating birds;
- Diving ducks – including coots and swans;
- Dabbling and filter-feeding ducks;

- Grazing ducks and geese;
- Non-diving rails;
- Storks, cranes, ibises and spoonbills;
- Waders (shorebirds) that breed in Australia; and
- Waders (migratory shorebirds) that do not breed in Australia

The abundance of each of these groups was determined in the larger Narran Lake ecosystem for the period July 1977 to July 1978 by applying the function feeding group categories to the abundance data reported in Brooker (1993). Abundance and composition of waterbirds varied considerably in response to hydrology and reflects the "boom and bust" cycle experienced by the wetlands in the Ramsar site and larger ecosystem (i.e. Narran Lake) (Figure 39). The period was characterised by an inundation event in mid 1977, followed by a drawdown to nearly dry by July 1978. The pattern of waterbirds indicates a lag between inundation and the arrival of large numbers of waterbirds.

There is also a temporal pattern of functional feeding groups, with fish eating species dominating in the early to mid flood. During the peak inundation and productivity phases, the waterbird numbers reached their maximum and were comprised of the full component of function groups, but dominated by piscivores, diving and dabbling ducks. As wetlands began to dry, waterbirds from the region become concentrated in the last remaining inundated areas and the number of dabbling ducks and non-diving rails increased. Similarly as the water receded and areas of shallow mud were exposed, the numbers of waders increased. By July 1978 there was little water left in the system and numbers of all functional groups were low as waterbirds supposedly dispersed to other regions.

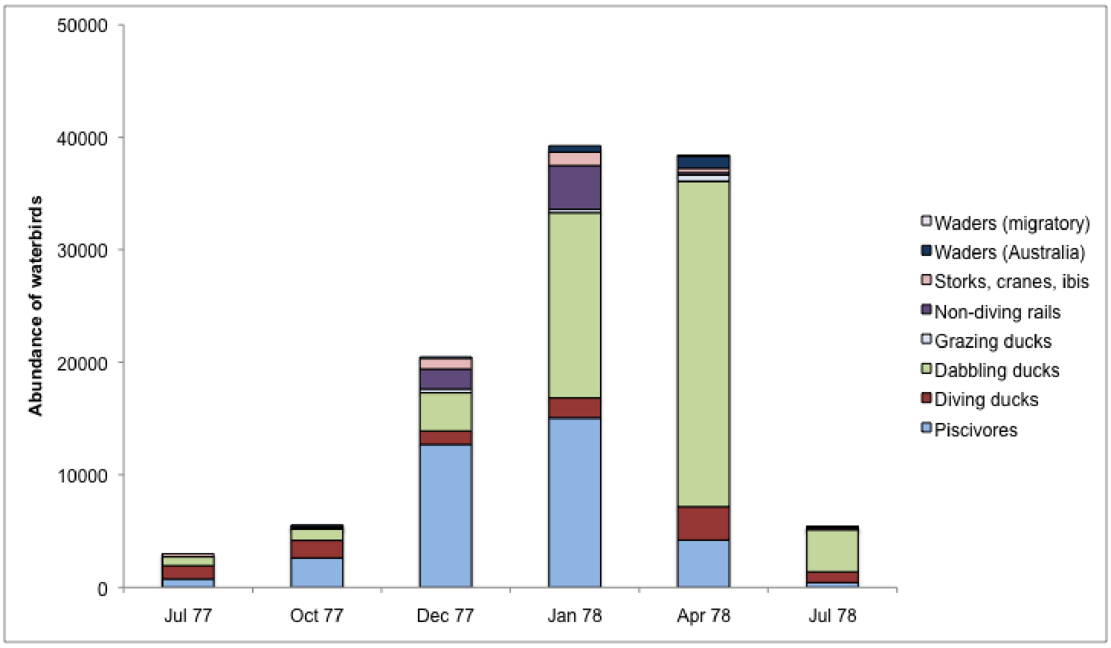


Figure 39: Abundance of waterbird functional feeding groups at Narran Lake Ecosystem from July 1977 to July 1978 (data from Brooker 1993).

3.11 Reptiles and mammals

Twenty four species of reptiles including the long-necked tortoise (*Chelodina longicollis*) have been recorded within the site according to NSW Atlas data (DECCW 2010a). The RIS (1999) lists 27 native mammals and seven introduced species as occurring at the site. Notable species include the koala (*Phascolarctos cinereus*) which is listed in New South Wales (Smith 1993) as vulnerable and at Narran is at its western most limits, and the yellow-bellied sheathtail-bat (*Saccolaimus flaviventris*). The only wetland dependent mammal present is the water rat (*Hydromys chrysogaster*). All of the bats surveyed by Smith (1993) were shown to be reliant on the riparian trees for foraging, nesting and roosting.

3.12 Productivity

Primary productivity is a key ecological function in river and floodplain ecosystems and has a major role in the boom and bust ecology of semi-arid riverine systems. There are a number of conceptual models regarding the relative importance of sources of organic carbon in primary productivity in lowland rivers, several of which have elements relevant to Australian systems (Gawne et al. 2007). These include the Flood Pulse Concept (FPC) (Junk et al. 1989), River Continuum Concept (RCC) (Ward and Stanford 1983) and River Productivity Model (RPM) (Thorp and Delong 1994) (Gawne et al. 2007). Each model assigns varying importance to different sources of carbon. The FPC emphasises the lateral connections between the main channel and floodplain and identified allochthonous carbon from the floodplain as important. The RCC focuses on longitudinal connectivity with dissolved organic carbon being transported from upstream as being the most important. The RPM allows for variation within a river and between rivers. Relative importance of carbon sources can vary depending on level of connectivity with the floodplain, floodplain vegetation type, and channel morphology (Gawne et al. 2007).

Gawne et al. (2007) found that primary productivity in the Murray River is derived from a combination of phytoplankton, riparian vegetation and macrophytes, with the relative contribution of each group varying spatially and temporally. Investigations into primary productivity at Narran Lake Nature Reserve Ramsar site have not been undertaken and this remains a knowledge gap.

The Narran River and terminal wetland system is considered to have a boom and bust ecology characteristic of semi-arid and arid wetland systems. Boom and bust ecologies are based on the high productivity associated with wet periods followed by a crash during dry periods. Whilst primary productivity has not been benchmarked for the site, other measures of productivity have been. Thoms et al. (2007) investigated groundcover productivity finding that high productivity was associated with intermediate durations (one to three months) of inundation followed by long periods of floodwater drawdown (three to six months). Sustained inundation was shown to limit productivity and species richness in groundcover vegetation, the exceptions being the perennial macrophytes (charophytes and perennial species including *Vallisneria* and *Myriophyllum*). Soil seed bank composition and abundance follows a gradient of inundation with the seed bank on the less frequently inundated areas supporting a richer seed bank than areas which are more frequently inundated (Thoms et al. 2007).

3.13 Critical components and processes

Ecological Character Descriptions (ECDs) identify, describe and where possible, quantify the critical components, processes and services of the site which determine the wetland's character and ultimately allow detection and monitoring of change in that character. These are the aspects of the ecology of the wetland, which, if they were to be significantly altered, would 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:

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

The role that components and processes play in the provision of critical ecosystem services should also be considered in the selection of critical components and processes. Each of the identified critical components and processes meet the four criteria provided by DEWHA (2008) in that they are central to the character of the site, are directly linked to the Ramsar criteria for which the site was listed, could potentially change in the next 100 years and for which change would result in negative consequences and a change in the ecological character of the site.

The remaining components and process, although important in supporting the critical components and processes, benefits and services are not considered critical as a change in these components and process, in isolation (that is without a corresponding biological response) would not result in a change in the ecological character of the site.

The critical components and processes for Narran Lake Nature Reserve Ramsar site are:

- Hydrology
- Vegetation: lignum shrublands, riparian woodlands and ephemeral herblands
- Fish
- Waterbirds
- Productivity

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 Narran Lake Nature Reserve Ramsar site are summarised in Table 15 and described below.

Table 15: Ecosystem services and benefits provided by Narran Lake Nature Reserve Ramsar site at the time of listing.

Category	Description
Regulating services	
-	No significant regulating services identified.
Provisioning services	
-	No significant provisioning services identified.
Cultural services	
Cultural heritage and identity.	Significant site for indigenous people, with current use of the site for intergenerational transfer of traditional knowledge, presence of artefacts, middens.
Spiritual and inspirational.	The site is an important spiritually for the local Indigenous people with several Dreamtime Paths converging at Narran Lake.
Science and education.	Science and education– the site is well studied being the focus of some major investigations 2002 to 2008. Note that traditional education practices are captured under cultural heritage and identity.
Supporting services	
Supports near-natural wetland types.	Representative of a terminal wetland system in good condition. Channelised floodplain wetland is highly complex and dynamic in relatively good condition. The combination of the river, channelised floodplain and open water habitat is rare in the Murray Darling Basin.
Provides physical habitat (for breeding waterbirds).	Supports significant lignum wetlands and areas of trees in which colonial nesting birds breed. Forty four waterbirds breed at the site.
Threatened wetland species, habitats and ecosystems.	Supports threatened flora and fauna including Australasian bittern, Murray cod, winged peppercress and several state listed species.
Priority wetland species.	Priority species include Murray cod and 11 waterbirds which are listed under JAMBA/CAMBA/ROKAMBA/BONN.

Biodiversity.	Supports representative species typical of the semi-arid zone of the northern Murray Darling Basin.

This following sections detail ecosystem services and how they interact (often overlap) with the critical components and processes found at Narran Lake Nature Reserve. It is important to note that in many instances the services equate to functions or processes, a separation that is often difficult to make. In section 4.5 a series of simple conceptual models are presented which show the relationships between components, processes and services.

4.2 Cultural services

4.2.1 Cultural heritage and identity

The Ramsar site is part of an area which holds great significance for local Aboriginal people, with very high archaeological, traditional and contemporary social and spiritual significance (NSW NPWS 2000). The Narran Lake Nature Reserve is called Dhwarriwaa which means 'Meeting Place' and Narran Lake is called Burrul Guumin, meaning 'Big Water'. The site covers the traditional lands of the Yuwaalaraay/Euahalia. A number of Aboriginal groups frequent the site. These groups include the Gomilaroi, Baranbinya, Murrawari, Ngyiimpaa/Wongiabon, Ngemba, Gwambiraay, Wielwan, and Cooma/Gwamu who would have visited the site on the invitation of the Yuwaalaraay to conduct cultural business that would have coincided with large bird breeding, wetting, and seasonal events.

The Narran Lake terminal ecosystem is significant because of (Barwon Aboriginal Community Limited pers. comm. cited NSW NPWS 2000):

- widespread and unique evidence of Aboriginal peoples existence in the area;
- the traditional status of the lakes as a meeting place of the tribes in the region;
- dreaming paths which culminate at the lakes; and
- Aboriginal peoples need for involvement with land which has areas largely unspoilt.

The Narran Lake terminal ecosystem and neighbouring landscape have been a key focal point for Indigenous people for around 40,000 years, as a meeting place for ceremonial and economic purposes, and as a rich source of food and other materials (Thoms et al. 2002). There are numerous Aboriginal site complexes in the area including shell middens, shell mounds, hearth sites, significant silcrete quarries, artefact scatters and sacred trees. Sites within the Nature Reserve are relatively undisturbed (NSW NPWS 2000). The Murrawari have a burial ground on the western point on Narran Lake proper.

Twenty-five floodplain plants of the Walgett area have been listed as having traditional significance for food, medicinal properties and importance in ceremonies, shelter and implements, and one species, the River Red Gum, is of mythological importance (Centre for Water Policy Research 1999 cited Thoms et al. 2002). The importance of mussels in the local Aboriginal diet is evidenced by the extent of shell middens along the banks of Clear Lake (Thoms et al. 2002).

There have been shifts in the faunal composition of middens within the Narran Lake Nature Reserve, from principally riverine/lacustrine species (for example mussels) to a greater contribution by terrestrial items (Allan Hutchins, pers. comm. cited in Thoms et al. 2002). Mussel middens contain two separate species that require very different flow conditions. During floods fish traps made as stick barriers were placed across channels with the fish being retrieved when the waters receded (Thoms et al. 2002).

A model of wise use: knowledge transfer

In contemporary times, the Ramsar site is used as a vital education setting for the intergenerational transfer of traditional knowledge, where Indigenous people from the surrounding area use the site for brief camps to teach traditional ways of gathering foods and for visiting sacred sites and retracing dreamtime stories (Thoms et al. 2002).

In March 2008 there was a back to Narran Lake Nature Reserve celebration with schools from Walgett, Goodooga and Lightning Ridge along with Elders and Parks Staff attending. The schools in the district have a long association with visitation for educational events. Following on from the Narran Open Day (19-03-08) on country at the Narran Nature Reserve, the North West Aboriginal Heritage Region and Parks and Wildlife Group Narrabri have been providing Aboriginal people the opportunity to discuss their interests, issues and actions that can be put into place for the Plan of Management for Narran Nature Reserve. Emerging from these discussions and events was the creation of an Aboriginal Co Management Committee.

The Co Management Committee has been functioning for two and a half years, and is made up of Aboriginal members who hold Narran dear to their hearts, they are: Ted Fields Jr (Chairperson), Michael 'Gillah' Anderson-Eckford, Jason Wilson, Brenda MacBride, Glenda Simpson, Allan Hall, Timmy Creighton, Lizzy Wallace, Steven Fields, Richard 'Sonny' Hall and Virginia Robinson and a number of proxies with six active committee members. The Committee has overseen many aspects of delivering the best outcomes for on ground works such as improving fencing, roads and walking paths, general consultation and an Interpretation-Education node for the Plan of Management.

4.2.2 Spiritual significance

Indigenous people in Australian consider themselves an integral part of their natural environment having both a close physical and spiritual connection to the landscape. Wetlands are often places of great significance as they are places with a high concentration of natural resources in an often arid landscape. Wetlands are often key places in stories and are evidence of the work of the ancestral creators (Ramsar Convention 2002). Narran Lakes is such a place.

Narran Lake is of particular significance as it is the confluence of several Aboriginal Dreaming Paths linking the area to other parts of the region (NSW NPWS 2000). An Aboriginal Dreaming Track is recognised by Indigenous groups, extending from above the Queensland border along the Narran River to Narran Lake (Thoms et al. 2007). The Wiradjuri to the south have a song line that connects Bathust NSW to Narran via the Macquarie River (Bidi Wambool), so too have the Gomilaroi to the east, that Nations song line is called *having water within* (Guli Gurinnaar). To the west the Baakindji Nations has a story regarding a Cod Fish being speared at Menindee, with the Cod Fish "Goodoo" originating from Narran and making the Barwon and Darling (Baaka) River channel.

Parker (1905) presents a European perspective on many aspects of the Euahlayi (correctly referred to as the Yuwaalaraay/Euahalia), one of the few texts which records information regarding the beliefs of the Indigenous groups of the Narran Lakes area. A number of important beings in the Yuwaalaraay/Euahalia belief system are central to the creation of Narran Lakes. Byamee, is seen as their god, culture hero 'Great One' or 'The Creator' by the Yuwaalaraay/Euahalia, features in the story of the origin on Narran Lakes, as do Byamee's wives, Birrahgnooloo (woman's name meaning hatchet-faced) and Cunnumbeillee (woman's name meaning pigweed root). Woman is given a high place in the sacred lore of the Yuwaalaraay/Euahalia. Birrahgnooloo is the chief wife and considered mother to all and also has a totem for each part of her body, so that no one totem can claim her. Cunnumbeillee, the second wife, was the bearer of children and a caterer, with Birrahgnooloo being the favoured of Byamee (Parker 1905).

The significance of Narran Lakes is reflected by the fact that there are many stories about the site including the story of the creation of Narran Lake reproduced below.

> ***The Origin of the Narran Lake – Australian Legendary Tales, by K. Langloh Parker, [1897], at sacred-texts.com***
> *OLD BYAMEE said to his two young wives, Birrahgnooloo and Cunnunbeillee, "I have stuck a white feather between the hind legs of a bee, and am going to let it go and then follow it to its nest, that I may get honey. While I go for the honey, go you two out and get frogs and yams, then meet me at Coorigel Spring, where we will camp, for sweet and clear is the water there." The wives, taking their goolays and*

yam sticks, went out as he told them. Having gone far, and dug out many yams and frogs, they were tired when they reached Coorigel, and, seeing the cool, fresh water, they longed to bathe. But first they built a bough shade, and there left their goolays holding their food, and the yams and frogs they had found. When their camp was ready for the coming of Byamee, who having wooed his wives with a nullah-nullah, kept them obedient by fear of the same weapon, then went the girls to the spring to bathe. Gladly they plunged in, having first divested them selves of their goomillahs, which they were still young enough to wear, and which they left on the ground near the spring. Scarcely were they enjoying the cool rest the water gave their hot, tired limbs, when they were seized and swallowed by two kurreahs. Having swallowed the girls, the kurreahs dived into an opening in the side of the spring, which was the entrance to an underground watercourse leading to the Narran River. Through this passage they went, taking all the water from the spring with them into the Narran, whose course they also dried as they went along.

Meantime Byamee, unwitting the fate of his wives, was honey hunting. He had followed the bee with the white feather on it for some distance; then the bee flew on to some budtha flowers, and would move no further. Byamee said, "Something has happened, or the bee would not stay here and refuse to be moved on towards its nest. I must go to Coorigel Spring and see if my wives are safe. Something terrible has surely happened." And Byamee turned in haste towards the spring. When he reached there he.saw the bough shed his wives had made, he saw the yams they had dug from the ground, and he saw the frogs, but Birrahgnooloo and Cunnunbeillee he saw not. He called aloud for them. But no answer. He went towards the spring; on the edge of it he saw the goomillahs of his wives. He looked into the spring and, seeing it dry, he said, "It is the work of the kurreahs; they have opened the underground passage and gone with my wives to the river, and opening the passage has dried the spring. Well do I know where the passage joins the Narran, and there will I swiftly go." Arming himself with spears and woggarahs he started in pursuit. He soon reached the deep hole where the underground channel of the Coorigel joined the Narran. There he saw what he had never seen before, namely, this deep hole dry. And he said: "They have emptied the holes as they went along, taking the water with them. But well know I the deep holes of the river. I will not follow the bend, thus trebling the distance I have to go, but I will cut across from big hole to big hole, and by so doing I may yet get ahead of the kurreahs." On swiftly sped Byamee, making short cuts from big hole to big hole, and his track is still marked by the morilla ridges that stretch down the Narran, pointing in towards the deep holes. Every hole as he came to it he found dry, until at last he reached the end of the Narran; the hole there was still quite wet and muddy, then he knew he was near his enemies, and soon he saw them. He managed to get, unseen, a little way ahead of the kurreahs. He hid himself behind a big dheal tree. As the kurreahs came near they separated, one turning to go in another direction. Quickly Byamee hurled one spear after another, wounding both kurreahs, who writhed with pain and lashed their tails furiously, making great hollows in the ground, which the water they had brought with them quickly filled. Thinking they might again escape him, Byamee drove them from the water with his spears, and then, at close quarters, he killed them with his woggarahs. And ever afterwards at flood time, the Narran flowed into this hollow which the kurreahs in their writhings had made.

When Byamee saw that the kurreahs were quite dead, he cut them open and took out the bodies of his wives. They were covered with wet slime, and seemed quite lifeless; but he carried them and laid them on two nests of red ants. Then he sat down at some little distance and watched them. The ants quickly covered the bodies, cleaned them rapidly of the wet slime, and soon Byamee noticed the muscles of the girls twitching. "Ah," he said, there is life, they feel the sting of the ants."

Almost as he spoke came a sound as of a thunder-clap, but the sound seemed to come from the ears of the girls. And as the echo was dying away, slowly the girls rose to their feet. For a moment they stood apart, a dazed expression on their faces. Then they clung together, shaking as if stricken with a deadly fear. But Byamee came *to them and explained how they had been rescued from the kurreahs by him. He bade them to beware of ever bathing in the deep holes of the Narran, lest such holes be the haunt of kurreahs.*

Then he bade them look at the water now at Boogira, and he said:
"Soon will the black swans find their way here, the pelicans and the ducks; where there was dry land and stones in the past, in the future there will be water and water-fowl, from henceforth; when the Narran runs it will run into this hole, and by the spreading of its waters will a big lake be made." And what Byamee said has come to pass, as the Narran Lake shows, with its large sheet of water, spreading for miles, the home of thousands of wild fowl.

4.2.3 Science and education

The Narran Lake Nature Reserve Ramsar site is an excellent example of a terminal wetland ecosystem with a unique geomorphic setting. However due to its remote location only a handful of research programs have been undertaken at the site. The Narran Lakes Ecosystem Project (Thoms et al. 2007) is the largest investigative program undertaken at the site and provides detailed information on conditions in 2004. However, continued work is required to fully understand the ecology of the site (see section 8).

The site is not used for European style education; however the site is very important in the intergenerational transfer of Indigenous culture. The education value of the site is considered in section 4.2.1.

4.3 Supporting services (ecological)

4.3.1 Natural or near natural wetland ecosystems

As detailed in section 2.5, Narran Lake Nature Reserve Ramsar site contains a number of wetland types that by virtue of the remote location, limited access, terrain and protected status of the site can be considered in near natural condition. The wetland types present in the site are brought about predominantly by interactions between geomorphology, climate and hydrology. Hydrological connectivity is a key element of the functioning of the Narran Lake Nature Reserve Ramsar site.

4.3.2 Provides physical habitat for waterbird breeding

<u>Physical habitat</u>
Thoms et al. (2002) identified a number of important habitats found within the Narran terminal wetland system including:

- deep holes in the river, which provide a refuge for animals in dry times and a source of colonists for the terminal wetland system;
- woody debris from fallen riparian vegetation, which is a major habitat within the river channels;
- the lake bed, which provides a refuge for seeds and eggs of plants and invertebrates;
- floodplain vegetation, which provides nesting and roosting habitat for birds and habitat complexity for aquatic organisms;
- open forests and woodlands on the floodplain, which provide important habitat for reptiles and birds; and,
- cracking soils, which are important for small mammals, planigales in particular, frogs and reptiles.

The geomorphic features of the site include bifurcating channels and secondary channels which largely persist independently from the main river channel. These secondary channels, of which there are over 8000 (Thoms et al. 2007), provide most of the habitat and are the dominant functional unit in association with the vegetated floodplain surface through which they flow (Thoms et al. 2002). The diverse habitats available provide a range of feeding habitats for waterbirds.

The lignum vegetated areas of the floodplain provide critical breeding habitat for waterbirds. Various reports assign the Narran Lakes ecosystem as critically important for colonial species:

- the size of the 2008 breeding event establishes the wetland as among only two or three of Australia's most important colonial waterbird breeding sites for ibis in terms of the size of the breeding colony (Kingsford et al. 2008); and
- the Murray Darling Basin is the stronghold for colonial waterbird breeding sites, with Narran Lakes in the top five national sites for species diversity, breeding records and number of years in which breeding occurs (Brandis unpublished).

Physical habitat for waterbird feeding

The major waterbird functional feeding groups (see section 3.10) have different physical habitat requirements. The Narran Lake Nature Reserve Ramsar site provides a spatial and temporal mosaic of habitats that support a diversity and abundance of waterbirds. Some of the general habitat requirements for species within each of the function feeding group classes are provided in Table 16.

Table 16: General habitat requirements of a number of waterbirds in the Narran Lake Nature Reserve Ramsar site (Marchant et al. 1994 unless otherwise specified).

Species	Habitat characteristics
Piscivores	
Australian pelican	Colonial feeder, often working in groups to drive prey (small schools of fish) to shallow water. Feeds in shallow water by scooping water and fish into the pouch and discarding the water.
Pied cormorant	Roost in trees near water or on cliffs, offshore rocks. Diet consists mainly of small to medium size fish. Feed by pursuit diving.
Diving ducks	
Eurasian coot	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. In Australia, Eurasian coots feed almost entirely on vegetable matter, supplemented with only a few insects, worms and fish.
Black swan	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.
Dabbling ducks	
Australasian shoveler	Prefer deep, large permanent water bodies. Roost on open water or in low trees over water. Diet – plants and animals (molluscs and insect larvae). Foraging – filter feeder dabbling in mud or in surface water.
Grey teal	Favour wooded wetlands, streams and pools. Diet – mostly insects and larvae. Mostly feed by filtering surface water or mud through their bill.
Pink-eared duck	Prefer inland, shallow turbid wetlands. Roost – rest on water, may roost in low branches of trees. Diet – mostly invertebrates (for example chironomids). Foraging – filter feeding mostly at surface taking planktonic invertebrates.
Grazing ducks	
Australian wood duck	Wide range of wetland habitats. Roost – rest on water, may roost in low branches of trees. Diet – mostly plants. Foraging – prefers to graze on land adjacent to wetlands, or in shallow water.
Non-diving rails	
Purple swamphen	Wide range of habitats including open water, swamps, rivers and temporary wetlands. Diet - soft shoots of reeds and rushes and small animals (e.g. frogs

Species	Habitat characteristics
	and invertebrates), also known to predate on eggs of other waterbirds and ducklings. Foraging - feeds on open ground near wetlands or at the edge of water.
Storks, cranes, ibis and spoonbills	
Straw-necked ibis	Favours inland, freshwater or brackish wetlands. Feeds mainly on terrestrial invertebrates (Carrick 1959), but also on aquatic invertebrates, frogs, small reptiles and mammals. It forages by probing in the mud or taking prey from the surface of shallow water.
Yellow spoon-bill	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.
Waders (shorebirds)	
Sharp-tailed sandpiper	Forage on wet mud, preferring areas with short, surrounding vegetation to bare substrate (Collins and Jessop 1998). Diet is predominantly polychaetes, crustaceans and molluscs.
Red-necked avocet	Forage in shallow water. Beak, leg and foot morphology are adapted to foraging in deeper water than some other wading species of bird (Loyn et al. 2001).

Jenkins et al. (2009) investigated ibis feeding and foraging behaviours during the 2008 breeding event. Ibis do not feed within the boundary of breeding colonies, but rather travel to shallower areas and dryland environments where they forage. Direct observations of the feeding behaviour of the ibis in 2008 showed them utilising the Long Arm and the dry floodplain areas to the east and west of the colony and also around Clear Lake (Jenkins et al. 2009). Grasshoppers were identified as the main food item, however the number of grasshopper skeletons found reduced over the sampling period suggesting a shift in diet (Jenkins et al. 2009). The role of the floodplain within the Ramsar site and surrounding areas as critical habitat for feeding is essential to supporting large waterbird breeding events.

Waterbird breeding

Forty-four species of waterbird have been recorded breeding within the Narran Lake Nature Reserve Ramsar site. Breeding records are not consistent and it is difficult to determine how many of these species regularly breed at the site during flood events. The species recorded breeding at the site utilise a range of different habitats within the system (Table 17).

Table 17: General habitat requirements of a number of waterbirds recorded breeding in the Narran Lake Nature Reserve Ramsar site (Marchant et al. 1994 unless otherwise specified; site specific information from Ley 1998). Note that groups represent taxonomic groupings rather than functional feeding groups.

Species	Habitat characteristics
Ducks and allies	
Black swan	Nest mound built in open water, on an island, or in swamp vegetation. Requires minimum water depth of 30 – 50 centimetres until cygnets are independent. First flight 20 – 25 weeks.
Pink-eared duck	Opportunistic breeder utilising a range of vegetation over water, including tree hollows stumps, shrubs. Commonly using old nests of other waterbirds. Ducklings leave the nest soon after hatching by dropping to the ground/water.
Pelicans, cormorants and darters	
Little black cormorant	Nests in horizontal branches and forks of trees (live or dead) in or over water. In the Ramsar site observed nesting in river red gum, with up to 100 nests in a single tree. Requires water to remain until nestlings are independent.
Great cormorant	Form large breeding colonies with breeding usually occurring from

Species	Habitat characteristics
	August to January but will occur all year round depending on food resources. The nest is a large structure of sticks placed in a low tree (2-3 m above ground) or on the ground. Eggs hatch between 27-31 days, fledging occurs approximately at 80 days. No information on preferences within the Ramsar site is available.
Pied cormorant	Nests in horizontal branches and forks of trees (live or dead) in or over water. In the Ramsar site observed nesting in river cooba on the western shore of clear lake and in river red gum on Back Lake. Colonial nester with multiple nests in single trees / shrubs. Requires water to remain until nestlings are independent. Hatchlings leave nest after four weeks, first flight at approximately eight weeks.
Herons, ibis, egrets and spoonbills	
Australian white ibis	Nests in a wide variety of habitats including wooded swamps and dense emergent vegetation. In the Ramsar site, most noted for nesting in lignum together with other colonial nesting species. Young leave nests after 48 days but dependent on parents for several weeks.
Straw-necked ibis	Breed in colonies at any time of the year, depending on flooding. Commonly breed in mixed colonies with other ibis, egrets and herons. Nest in shrubs, reeds or trees over water, or on ground on islands. In the Ramsar site, favours the area between Back and Clear Lakes using trampled lignum. Typically lay three or four eggs and incubate for 24 days (Carrick 1962). Fledge 28 days after hatching, fed for two weeks by parents after leaving nest.
Glossy ibis	Typically breed October-December in response to flooding. Breed in simple pairs, colonial usually with other ibises, herons, spoonbills and egrets. Two to six green/blue eggs are laid in a nest that consists of a shallow platform of sticks and leaves. Incubation shared by both parents and requires a period of 21 days, fledging 28 days. No information on preferences within the Ramsar site is available.
Royal spoonbill	Nests in wooded swamps or reed beds. In the Ramsar site mostly in the lignum among the main ibis colonies. Requires inundation until young fledge.
Shorebirds	
Red-capped plover	Nests in scrape made in sand or mud. In the Ramsar site observed on the mudflats at Back Lake. Young leave nest within one day and self fed, require vegetation for cover
Banded lapwing	Nests in a scrape on the ground lined with dry grasses. In the Ramsar site, observed in the sparsely vegetated flats near the northern edge of the site.

The Narran Lake Nature Reserve Ramsar site is known particularly for supporting large numbers of colonial nesting waterbirds (Ley 1998; Kingsford et al. 2008). The location of nesting habitats used by these birds was mapped by Ley (1998) for the 1996 breeding event (Figure 40). During this event, the large ibis colony (containing over 100 000 straw-necked ibis nests, was located in the area of inundated lignum between Back and Clear Lakes. This is the same location of the large colony of ibis that were recorded breeding at the site following the 2008 flood (Kingsford et al. 2008). Other species, such as cormorants and darters used a wider range of inundated vegetation as nesting sites, including river cooba and river red gum trees.

Cormorants are nomadic and disperse and breed in response to rainfall and rarely return to the same breeding location each year (Dorfman and Kingsford 2001). At a fine scale cormorants do not exhibit any preference for a particular habitat type, but are associated with patches of food. Dorfman and Kingsford (2001) found a positive relationship between water and abundance of species at the local but not regional scales (arid inland study), with site fidelity at the scale of days, not months or years. In the arid and semi-arid zones cormorants are highly dispersive using habitats flexibly with short-term localised events dictating their movements. The nomadism is most likely a response to highly variably hydrological regimes of rivers and wetlands in inland Australia (Dorfman and Kingsford 2001).

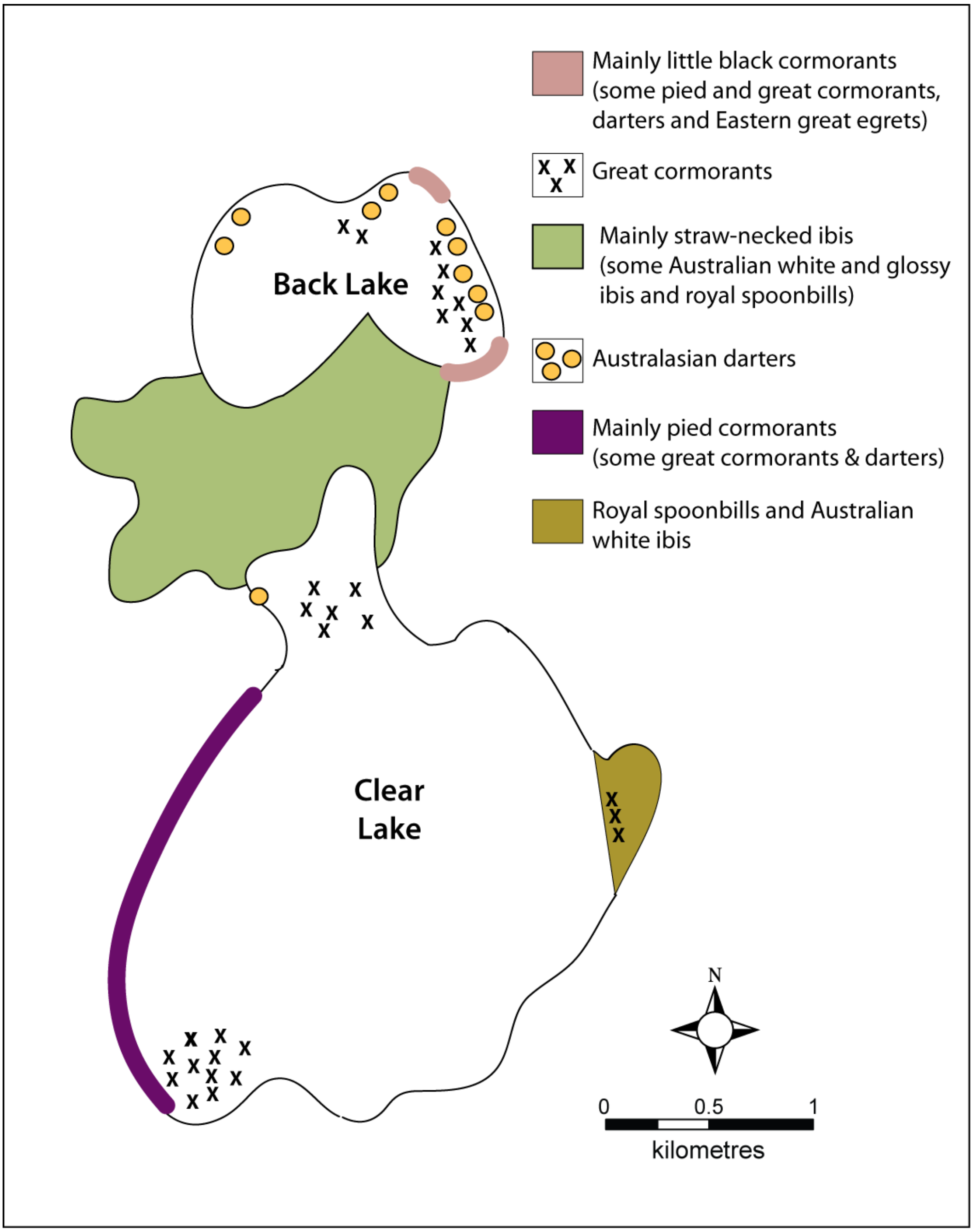


Figure 400: Nesting locations of colonial breeding waterbirds at Narran Lake Nature Reserve Ramsar site during 1996 (Ley 1998).

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), which depending on the season and diet of the species 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 may be required to allow for courting/mating, nest site selection and building, incubation and raising of young to independence (Jaensch 2002).

The role of productivity and sufficient food resources to raise young to fledgling stage should not be overlooked. Australian intermittent and temporary wetland systems are well adapted to cycles of wetting and drying and a persistent seed and egg bank is characteristic of these systems (Brock et al. 2003). Following inundation a “boom” in productivity occurs initiated by a release of nutrients from recently wetted sediments and flowing through to phytoplankton growth, zooplankton and macroinvertebrates and fish and waterbirds. However, too frequent inundation can result in reduced productivity, or at least the boom part of the cycle (Boulton and Lloyd 1992). This is reflected in the cycle of waterbird breeding within the Ramsar site, where successive floods over short periods of time (less than two years) have resulted in little or no breeding at the site in the second flood (Brooker 1993; Ley 1998). This may be due in part to the time required by adults to recover from breeding as well as a diminishing of productivity to support breeding events. Also smaller floods may not inundate Narran Lake, which has been identified as being critical to the success of breeding events within the Ramsar site (Rayburg and Thoms 2008).

A unique breeding event

A significant breeding event for ibis occurred in 2008, the first for eight years (Kingsford et al. 2008). Inundation of the Ramsar site occurred after three local rainfall events generated flows throughout the distributary rivers of the Lower Balonne commencing in December 2007 (Terrill 2008a). Ibis species involved in this breeding event included straw-necked ibis (95 percent of nests) (Figure 411), glossy ibis (three percent of nests) and Australian white ibis (two percent of nests), with a total of 78 000 nests recorded (Kingsford et al. 2008). Heavy December rains in the catchment led to the inundation of the Ramsar site, with breeding commencing in mid to late January with the establishment of a colony of 21 181 nests. Further flooding in January 2008 resulted in some losses of nests in the first colony but also led to the establishment of a larger second colony with an additional 50 914 nests.

DECCW purchased an additional 11 000 megalitres of water to extend the period of inundation of the breeding colonies which had established. The environmental water prolonged the inundation of the colony site within the Ramsar site leading to the recruitment of 49 144 chicks from 148 000 eggs laid (Kingsford et al. 2008). Kingsford et al. (2008) reported that mortality rates in the second colony were significantly higher than the first, and that the provision of additional flows resulted in lower mortality rates than would have otherwise been observed.

Figure 41: Straw-necked ibis and Australian white ibis (Ian Montgomery, Birdway).

There is a strong link between inundation and waterbird breeding, but it is not absolute. Thoms et al. (2007) and Rayburg and Thoms (2008) suggested a threshold of 100 000 megalitres annual flow to inundate the floodplain and instigate waterbird breeding of colonial nesting species. In addition, they suggested that a secondary pulse some months after the primary flood increased the success of breeding by prolonging inundation. The exception to this was the breeding event in 2008 which occurred on a very small event, approximately 50 000 megalitres (Terrill 2008b), half the 100 000 megalitre threshold (Rayburg and Thoms 2008). In addition, in all previous breeding events Narran Lake was inundated as well, to an extent of approximately 6000 hectares. However the 2008 flood only inundated about 2000 hectares (Rayburg and Thoms 2008). The fact that Narran Lake also contained water at the same time as the major breeding events suggests the lake is also important, potentially for food resources.

Overall this breeding event is unique in the history of the site, occurring at a much smaller magnitude of flood than all previous breeding events, most likely as a response to severe drought conditions in much of the Murray Darling Basin. The breeding event is also highly significant with regards to sustaining populations of ibis and royal spoonbills. The flooding in the wetland represented the first and possibly last chance for many of the birds to breed and represents the largest ibis breeding event in the Murray Darling Basin since 1998 (DECC 2008a; Terrill 2008b). Survival of the juveniles ibis and royal spoonbills into the adult population was considered critical to maintain Australian population levels (DECC 2008a; Terrill 2008b).

4.3.3 Supports threatened species

Three nationally or internationally listed species are recorded from the site, Murray cod, Australasian bittern and winged peppercress.

<u>Murray cod</u>
Murray cod are rare in the system with records from the Narran River being sporadic. However sampling for this species may not have been undertaken on a regular basis. Observations and anecdotal reports suggest the cod may occur in the Narran River, with local community members reporting the species was once more frequently encountered than in contemporary times. Anglers report that the cod are typically found in refugia holes, with largest caught being around 18 kilograms (J. Treweeke, pers. comm.).

Murray cod are found through the majority of the Murray Darling Basin except in the cooler upland reaches of the Great Dividing Range. They typically prefer slow flowing water up to depths of five metres with cover. Radio tracking studies of Murray cod in the southern part of the Murray Darling Basin have shown that they clearly prefer wood debris as habitat (Koehn 1996). Koehn (1996) found 80 percent of fish within one metre of snags and 97 percent of fish were within 12 square metres of wood debris of some sort. Murray cod will also utilise other cover including overhanging vegetation and banks (Kearney and Kildea 2001; Koehn 2009a).

Murray cod are long lived and highly territorial, being the top predators in the rivers of the Murray Darling Basin (Kearney and Kildea 2001). They feed on zooplankton as juveniles, progressing to invertebrates, especially crayfish, yabbies and shrimp, fish, and amphibians. They have also been known to take tortoise, snakes, and a number of waterbirds (Kearney and Kildea 2001). Murray cod are demersal in that they are predominantly found in and around the bottom of rivers (but not benthic) during the day (Koehn 2009b). They are apex predators with upward facing eyes and a protruding jaw, watching for prey from their position near the bottom of the river (Koehn 2009b). Work in Victoria has shown that the Murray cod are not completely sedentary in nature (Koehn et al. 2009). Radiotracking has shown that while the species exhibits a limited home range and is strongly territorial, it also undergoes considerable movements ranging upstream and then returning to the home reach (Koehn et al. 2009).

Within the Ramsar site, recent records have been of juveniles only, and it is considered unlikely that the site regularly supports large adult fish due to the shallow nature and periodic no flow conditions (G. Wilson, University of New England, pers. comm.). Juveniles are likely to be entering the system during floods.

<u>Australasian bittern</u>
The Australasian Bittern (*Botaurus poiciloptilus*) (Figure 42) is listed as globally endangered by the IUCN. It is also listed as endangered under the EPBC Act. This species meets the IUCN criteria C1 which states the population size estimate is fewer than 2500 mature

individuals and that there is an estimated continuing decline of at least 20% within five years or two generations (IUCN 2010). It is unclear if this species is a resident at the site with only a few sightings. As yet no breeding has been recorded at the site. The species is also listed as vulnerable in New South Wales. The species prefers permanent freshwater wetlands with dense, tall vegetation, notably *Typha* and *Eleocharis.* It is a cryptic species feeding at night on frogs and aquatic and terrestrial invertebrates.

Figure 422: Australasian bittern (Ian Montgomery, Birdway).

<u>Winged peppercress</u>
Winged peppercress (*Lepidium monoplocoides*) is a small annual herb found in a range of habitats including floodplain wetlands on seasonally damp or waterlogged soils. It is considered to be widespread in western New South Wales but locally rare. The main threats to the species are grazing, from stock, native animals and rabbits. Altered hydrological regimes can lead to loss of local species through loss of essential habitat. This species has been recorded in a number of other reserves in New South Wales and Victoria (Thoms et al. 2002). Within the Ramsar site it is found as isolated individuals (Thoms et al. 2002).

4.3.4 Priority wetland species

Waterbirds have been discussed in detail in sections 3.11 and 4.3.2. Of note is that the site supports a total of 14 species that are listed under international migratory agreements CAMBA (14), JAMBA (112), BONN (9) and ROKAMBA (9) (see Table 18).

Table 18An additional 26 species are listed as marine or migratory under the EPBC Act (Appendix B). All species of Anatidae, pelican, several egrets and ibis and a number of other species are migratory within Australia. The site, however, is considered of most importance for the Australian colonial nesting species which congregate in substantial numbers when conditions are right.

Table 18: Species listed under international agreements. J = JAMBA, C = CAMB, R = ROKAMB, B = BONN.

Scientific Name	Common Name	Breeding	EPBC Act Listing
Ardea ibis	Cattle egret		M, C, J
Ardea modesta	Eastern great egret	Yes	M, C, J
Plegadis falcinellus	Glossy ibis	Yes	M, B, C
Haliaeetus leucogaster	White-bellied sea eagle	Yes	M, C
Calidris acuminata	Sharp-tailed sandpiper		M, B, C, J, R
Calidris ferruginea	Curlew sandpiper		M, B, C, J, R
Gallinago hardwickii	Latham's snipe		M, B, C, J, R
Limosa lapponica	Bar-tailed godwit		M, B, C, J, R
Limosa limosa	Black-tailed godwit		M, B, C, J, R
Tringa glareola	Wood sandpiper		M, B, C, J, R
Tringa nebularia	Common greenshank		M, B, C, J, R
Tringa stagnatilis	Marsh sandpiper		M, B, C, J, R
Chlidonias leucopterus	White-winged black tern		M, C, J, R
Sterna caspia	Caspian tern		M, C, J

4.3.5 Biodiversity

The Ramsar site supports considerable biodiversity. As a large, relatively intact inland terminal wetland in a semi-arid environment it supports a high proportion of terrestrial and aquatic species (see section 2.5 and section 3 for discussion of major biotic groups). In addition, over 100 species of land birds have been recorded in the area with many showing a preference for the floodplain woodlands (Thoms et al. 2002); including eight vulnerable and one endangered species under the NSW *Threatened Species Act 1995*. These include black-breasted buzzard (*Hamirostra melanosternon*), little eagle (*Hieraaetus morphnoides*), pink cockatoo (*Lophochroa leadbeateri*), brown treecreeper (*Climacteris picumnus*) white-fronted chat (*Epthianura albifrons*), Australian bustard (*Ardeotis australis*), hooded robin (*Melanodryas cucullata*), grey-crowned babbler (eastern subspecies) (*Pomatostomus temporalis temporalis*), and the barking owl (*Ninox connivens*).

4.4 Identifying critical ecosystem services and benefits

Ramsar Resolution 1X.21 identifies the following cultural characteristics as relevant in the designation of Ramsar sites:

a) sites which provide a model of wetland wise use, demonstrating the application of traditional knowledge and methods of management and use that maintain the ecological character of the wetland;

b) sites which have exceptional cultural traditions or records of former civilizations that have influenced the ecological character of the wetland;

c) sites where the ecological character of the wetland depends on the interaction with local communities or indigenous peoples; and

d) sites where relevant non-material values such as sacred sites are present and their existence is strongly linked with the maintenance of the ecological character of the wetland;

These criteria were used to help identify the critical cultural services of Narran Lake Nature Reserve Ramsar site. Local Indigenous representatives believe the site meets two of the four cultural characteristics criteria: a) and d).

The critical ecological ecosystem services and benefits of the Ramsar site have been identified using criteria specified in 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):

1. are important determinants of the site's unique character;
2. are important for supporting the Ramsar or DIWA 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
4. that will cause significant negative consequences if change occurs.

Using these criteria it was considered that the three of the five supporting services (i.e. those that are ecologically based) could be considered 'critical'.

In summary the following critical services occur at the site:

- Cultural service: Cultural heritage and identity.
- Cultural service: Spiritual and inspirational.
- Supporting service: Near natural wetland ecosystem.
- Supporting service: Threatened species.
- Supporting service: Provides physical habitat for waterbird breeding.

4.5 Interactions and conceptual models

Documenting the ecological character of a site requires an understanding of how components, processes and services interact: how the unique combination present at a site determines the ecological character of the site. Wetlands are dynamic and complex ecosystems and documenting how they work at the fine scale is a daunting task, often beyond the limits of the data in hand. In order to aid describing the ecological character of the site a number of character conceptual models, specific to the site, have been developed. These models show the components, processes and services which contribute to the ecological character of the site. The models are simple models and do not attempt to show every interaction.

The drivers of the site's ecology are geomorphology and hydrology, which produce the physical habitat template. These in turn support, and in some cases are influenced by species, communities, ecological processes which in turn culminate in the ecosystem services provided at the site. Three models are presented: the first is an overarching model which provides a simple outline of the linkages between components, processes, services and the Ramsar criteria for which the site was listed (Figure 43).

In many cases the value of a site is what can be seen, in the case of Narran, the spectacular large breeding events and the unique juxtaposition of channelised floodplain and open water wetland habitats are the main features for which the site is recognised as a Wetland of International Importance. The second model depicts components, processes and services for inundated floodplain, with the focus on the channelised floodplain dominated by lignum (Figure 44).

The final model is of a floodplain lake, Clear Lake, and presents another perspective of the ecological character of the Ramsar site (Figure 45). There is some overlap between the floodplain model and the floodplain lake model as these are highly connected systems.

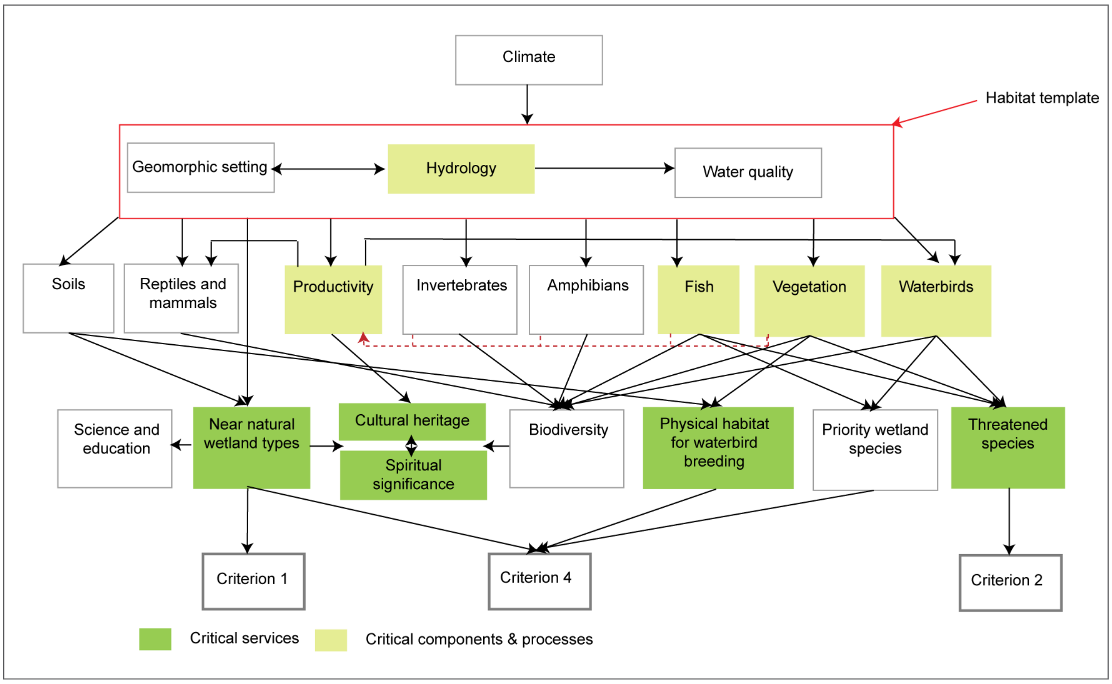
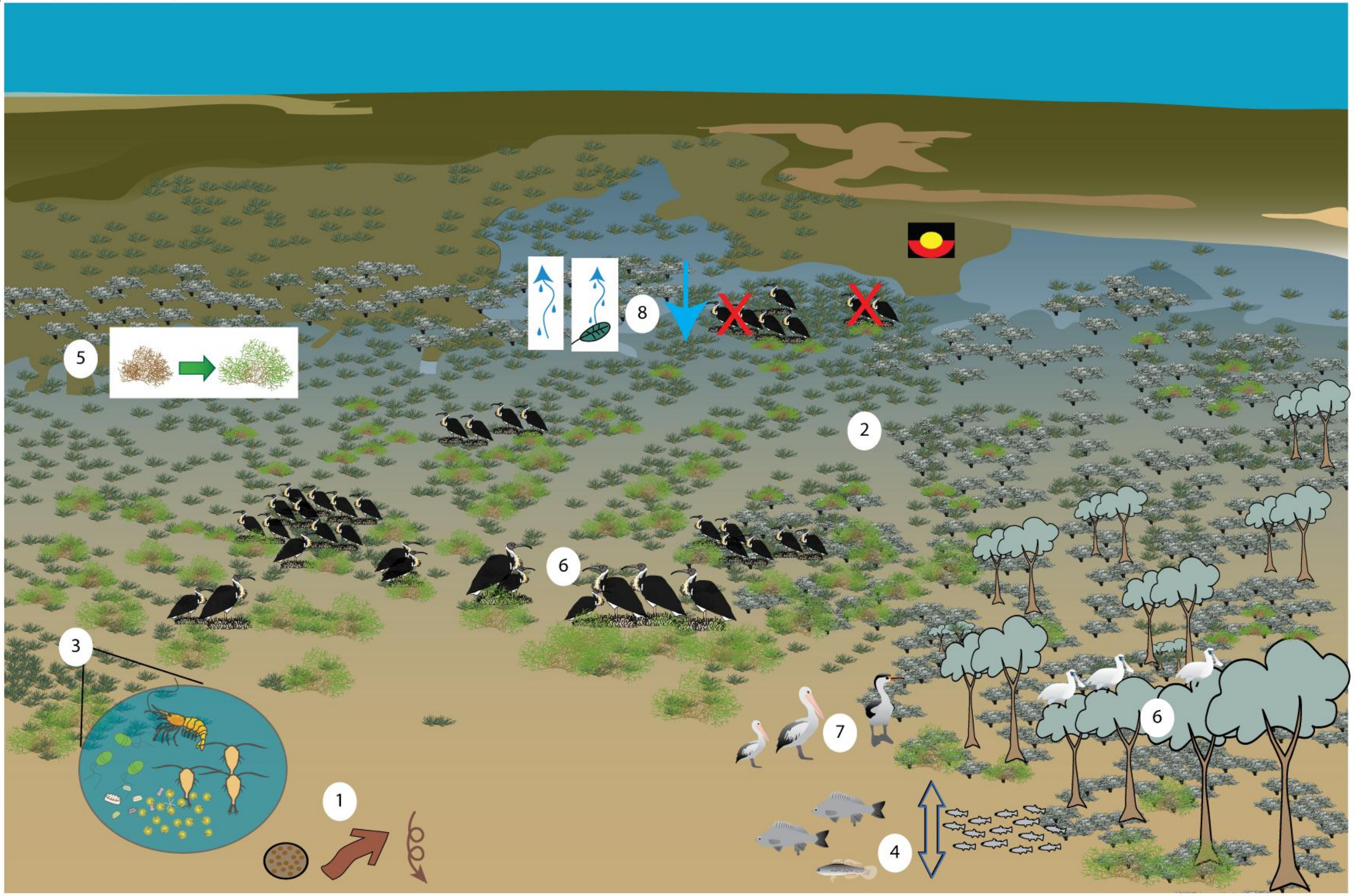


Figure 43: Simple conceptual model showing the main relationships between components, processes, and services and the Ramsar criteria for which the site was listed.

Inundated floodplain: Open water of Clear Lake in foreground, looking north to Long Arm, through lignum dominated channelised flood-plain (not to scale).



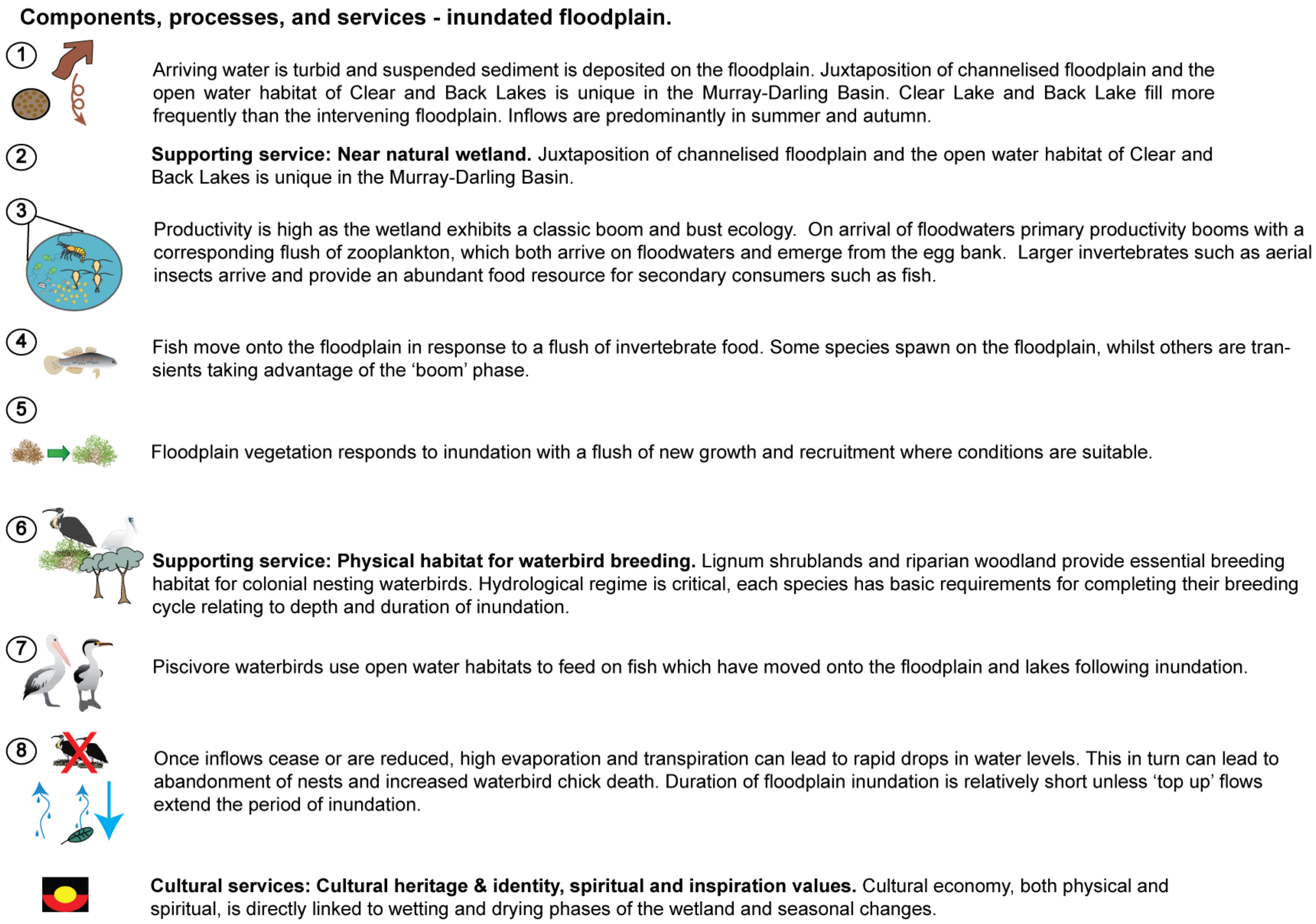
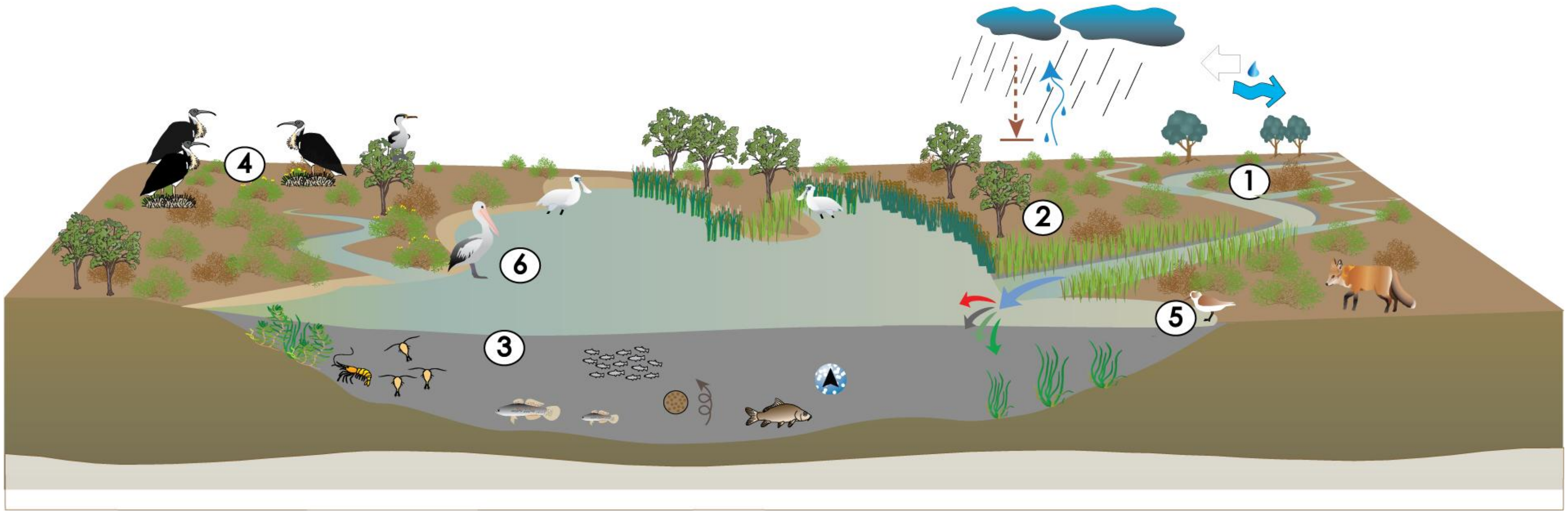


Figure 444: Character conceptual model for inundated floodplain for Narran Lake Nature Reserve Ramsar site. To be considered in conjunction with model for floodplain lake below.

Floodplain lake: Clear Lake, Narran Lake Nature Reserve (Ramsar type P) - floodplain not inundated.



Components, processes, and services - floodplain lake.

Soil types vary within boundary of the Ramsar site, but the majority of the site has grey cracking soils.

Water is fresh, however electrical conductivity is temporally and spatially variable.

Turbidity levels are typically high but are spatially variable across the site. High turbidities are typical for the region.

① **Supporting service: Near natural wetland type.** Floodplain is highly channelised with low impacts from historic grazing activities. Inundation regime has been altered prior to listing with significant upstream extraction occurring.

② **Supporting service: Physical habitat for waterbird breeding.** Floodplain vegetation includes vast areas of lignum shrublands with some areas of trees. Stands of emergent vegetation such as *Typha* and *Phragmites* occur in the littoral zone of the lakes and among the lignum. Submergent macrophytes are limited, but provide habitat to aquatic fauna.

Sediments, dissolved nutrients and allochthonous material are transported into floodplain wetlands via channels in the floodplain and over land flows. Biota disperse into and out of floodplain wetlands with floodwaters.

③ Productivity is high as the wetland exhibits a classic boom and bust ecology. On arrival of floodwaters primary productivity booms with a corresponding flush of zooplankton, which both arrive on floodwaters and emerge from the egg bank. Larger invertebrates such as aerial insects arrive and provide an abundant food resource for secondary consumers such as fish. Native fish species found on site are the wide-spread, and abundant, small bodied species, such as Australian smelt and carp gudgeons. Several species have been recorded spawning on the floodplain in response to flooding.

④ Forty-four species of waterbird have been recorded breeding at the site. The most spectacular breeding events occur in tandem with significant flooding and involve large rookeries of colonial nesting species such as straw-necked ibis, glossy ibis, cormorants and spoonbills.

⑤ **Supporting service: Threatened species.** Three species, listed either nationally or internationally, occur at the site: Murray cod, Australasian bittern and winged peppercess.

⑥ Piscivorous birds move onto floodplain and floodplain lakes in response to fish moving into the wetlands on floodwaters.

Threats

Drought and increased water extraction from upstream pose a significant threat to the site by altering the hydrology of the site. Reduced magnitude and frequency of medium to large flood events.

Invasive species such as common carp, foxes, pigs and feral cats pose a threat to waterbirds in particular.

Figure 45: Character conceptual model for floodplain lake component of Narran Lake Nature Reserve Ramsar site. To be considered in conjunction with model for inundated floodplain above. Base map kindly supplied by MDFRC, based on work by Price and Gawne (2009).

5. 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 (for example 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 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.

There are a number of potential and actual threats that may impact on the ecological character of Narran Lake Nature Reserve Ramsar site. The stressor model (Figure 46) only illustrates the major threatening activities (boxes), stressors (ellipses) and resulting ecological effects (diamonds) on the components processes and services (hexagons) in Narran Lake Nature Reserve Ramsar site. A description of these major threats is provided below. Note not all threats are described in detail, only those considered likely to have a potential impact on the ecological character of the site.

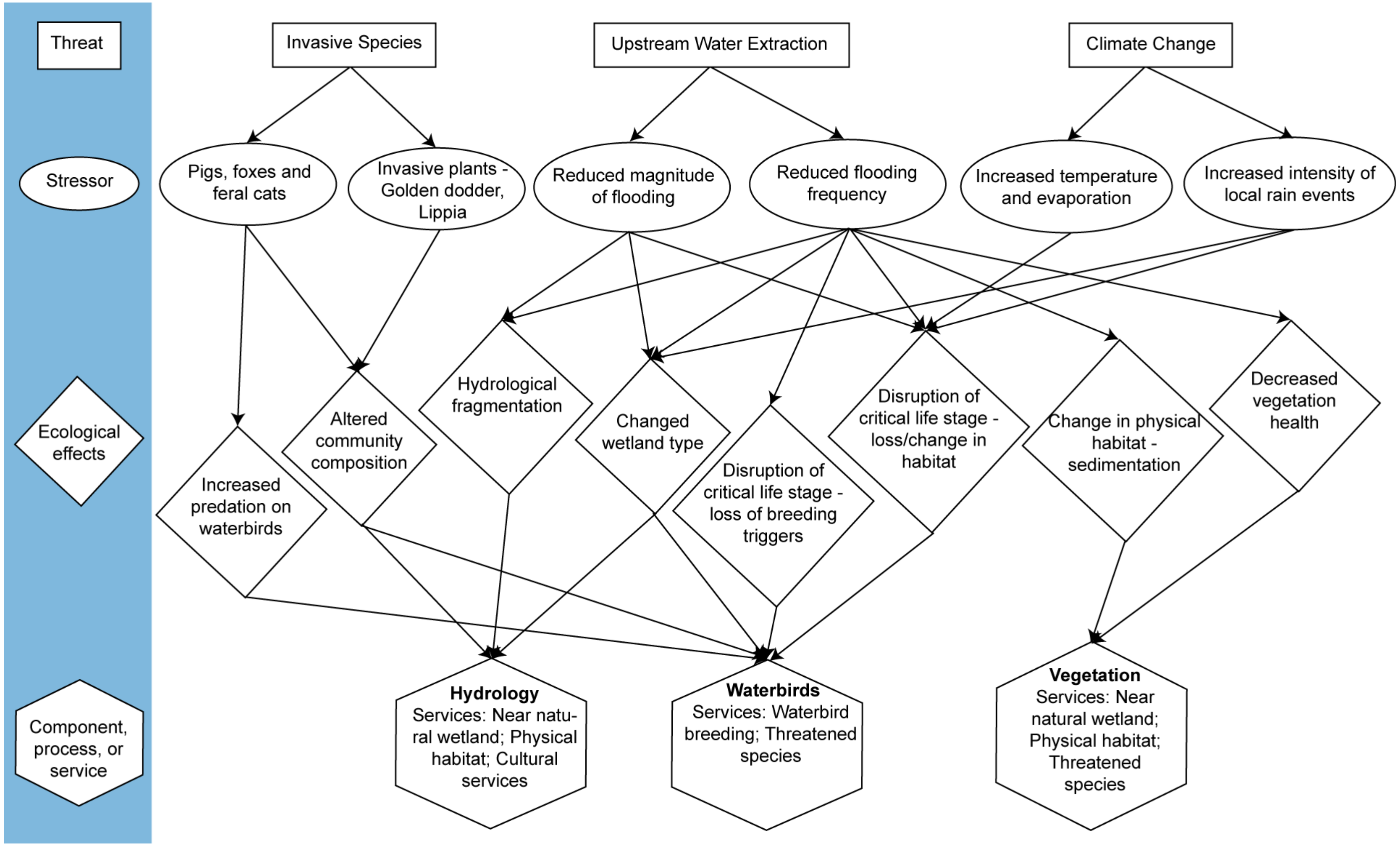


Figure 46: Stressor model of major threats to ecological character of Narran Lake Nature Reserve Ramsar site (after Gross 2003 and Davis and Brock 2008).

5.1 Upstream water extraction

There has been significant water-resource development in the Condamine-Balonne catchment and this has occurred since the advent of irrigated agriculture in the 1960s. There are three main irrigation developments within the catchment. The Upper Condamine Irrigation Project is in the upper part of the catchment and utilises water from a 196 kilometre section of river downstream of Warwick. The Chinchilla Weir Irrigation Project is in the middle part of the catchment and utilises water from an 88 kilometre section of river around Chinchilla. The St George Irrigation Area is in the lower part of the river and utilises water from a 140 kilometre section of the river around St George.

There are four significant public water storages in the Condamine-Balonne River, that service irrigation, agricultural and domestic supply. Leslie Dam (106 250 megalitre capacity) is located in the upper part of the catchment on Sandy Creek. Chinchilla Weir (9800 megalitre capacity) is located in the middle part of the catchment. Beardmore Dam (81 800 megalitre capacity) and Jack Taylor Weir (10 100 megalitre capacity) are located in the lower part of the catchment, close to St George. Overall, 30 percent of the main stem of the Condamine-Balonne River is influenced by river regulation.

There are also numerous private off-stream water storages in the lower parts of the system with the Lower Balonne water storage capacity now in the order of 1 500 000 megalitres. Overland flow extraction was not developed via a licensing process with virtually no legislative controls on development and has had significant impact on return flows to rivers during floods. Combined these developments have led to a change in the hydrological regime of the Lower Balonne and the Narran River, reducing the frequency and magnitude of inundation at the Ramsar site. For more discussion on the changes see section 7.2.1.

5.2 Climate change

The following are the general impacts from climate change predicted for the western region of New South Wales relevant to the site (from DECCW 2010b):

- By 2050, the climate is virtually certain to be hotter and is also likely to be drier, with storms increasing in frequency and intensity.
- Run-off and stream flow are likely to increase in summer and autumn but decrease in winter and spring.
- Evaporation is likely to increase, with the greatest increases likely to occur in spring.
- The severity of hydrological droughts will be unchanged.
- Increases in the intensity of flood-producing rainfall events are likely to change flood behaviour, but catchment conditions at the time of each rainfall event (soil moisture conditions and levels in major water storages) will affect the degree of change.
- Plant cover is likely to decline on the drier central western slopes and plains but is likely to be enhanced on the warmer tablelands. Sheet, rill and gully erosion are likely to worsen on the western slopes and plains but gully erosion is likely to ease on the most vulnerable soils on the tablelands. Soil acidification is expected to lessen on the tablelands and slopes.
- Widespread changes in natural ecosystems are likely. The biological communities most vulnerable to species loss are those of rivers and wetlands, and smaller woodland communities already under substantial threat.

As much of the inflows for the Narran River come from the upper Condamine catchment in Queensland it is necessary to take into account predictions for the whole catchment.

The Sustainable Yields Project (CSIRO 2008) provides a basis for examining the rainfall and hydrological implications of climate change on the Narran Lake Nature Reserve Ramsar site. The Sustainable Yields Project modelled the best estimate for 2030 as well as a wet and dry extreme. The Narran Lake Nature Reserve was specifically addressed in the CSIRO (2008) report with the major findings under the best estimate 2030 climate being (CSIRO 2008)

- The average period between flood events on the Lower Balonne floodplain would increase slightly, by 9 percent.
- Both the average flood size and annual flood volume would reduce, which has the potential to impact on floodplain vegetation associations.
- The number of years that Clear and Back Lake provide optimal waterbird breeding habitat and the number of years in which Narran Lake provides optimal waterbird feeding habitat will be reduced by 11 percent.

Under the dry extreme 2030 climate (CSIRO 2008):

- The average period between floods on the lower Balonne River floodplain would be increased by nearly two years or 94 percent.
- The average annual flood volume would be more than halved with serious consequences likely for floodplain vegetation.
- There would be a substantial reduction (35 percent) in the number of years with optimal breeding habitat at Clear and Back Lake and in the number of years with optimal feeding habitat at Narran Lake with serious consequences likely for waterbird populations.

Under the wet extreme 2030 climate (CSIRO 2008):

- Flood frequency and magnitude would increase somewhat, improving conditions on the lower Balonne River floodplain and for the Narran Lakes system.
- However, conditions would still be significantly worse than under without‑development conditions.

5.3 Invasive species

NSW NPWS (2000) listed foxes, feral cats, pigs, rabbits, hares and carp as invasive species present within the Ramsar site. Recent fish surveys have also identified goldfish and gambusia as occurring at the site. Rabbits occur in only a few areas of the reserve. Predation on juvenile waterbirds by foxes and cats when water levels around nest sites fall is a concern, although feral cats are likely to be restricted to the drier edges of wetlands (Scott 1997). Feral pigs can have significant impacts on waterbird breeding; however control programs are in place for feral pig control, and for fox and hare baiting (NSW NPWS 2000). Overall the impacts of feral cats, pigs and foxes are likely to be minimal (Scott 1997).

Invasive weeds found within the Ramsar site include noogoora burr (*Xanthium occidentale*) and Bathurst burr (*Xanthium spinosum*), and golden dodder (*Cuscuta campestris*). Noogoora burr is considered a riparian weed, infesting riparian and floodplain habitats. As a seedling it is toxic to stock and has been the focus of past biological control programs in northern Australia. Golden dodder is frequently found amongst the lignum shrublands, occurring in the Long Arm and in shallow areas of the site. Golden dodder is a parasitic plant which often smothers lignum at the site, but will also use other species including noogoora burr as hosts. Ultimately golden dodder can kill its host as it removes nutrients and smothers the host plant. The seeds of golden dodder are rootless and require a host to survive, however in wet conditions such as at the Ramsar site; the seeds can survive without a host for longer. Bathurst burr is an annual upright herb which reproduces from seeds which can lie dormant for several years. It is mainly a pasture weed, but is also common on watercourses and floodplains. As propagules of all three species are transported from upstream they are not able to be eradicated from the Ramsar site. African boxthorn (*Lycium ferrocissimum*) also occurs within the site (NSW NPWS 2000).

Lippia (*Phyla canescens*) has also been identified as an invasive species within the Ramsar site. Lippia is a fast growing groundcover which causes degradation of soil and water, displacement of native species and can lead to bank erosion.

Unlike many other wetlands within the Murray Darling Basin the number of native fish species are greater than the introduced species. Continued alienation of the floodplain through changed hydrological regimes could lead to a change in dominance from native to introduced species.

A clear understanding of the relative impacts of the invasive species within the Ramsar site on the critical CPS is lacking and remains a knowledge gap. However, other than predation on waterbirds the impacts of invasive species are thought to be relatively minor and unlikely to lead to a change in ecological character.

5.4 Sedimentation

Catchment disturbance, particularly deforestation and agricultural development has been shown to increase the rate of accumulation and change the quality of sediments deposited in floodplain-wetland areas. High rates of sediment accumulation can influence habitat quality, surface topography, and the distribution of water across floodplains during times of inundation. Floodplain-wetlands can receive high nutrient inputs; especially in particulate form therefore sediment deposition is important for nutrient retention. Floodplain wetlands are natural storage areas and management of these systems must consider both the influence of hydrology and sediment.

Soils in the Ramsar site are spatially variable both in terms of their physical and chemical composition being derived from sediments which originated in the Maranoa and Condamine sub-catchments. Thoms et al. (2007) found that there has been a relatively stable rate of delivery through time, and that the slow rate of accretion within the site indicates this process has been naturally occurring for many millennia. As a closed terminal system the Narran Lakes is a repository for sediments derived from upstream. Recent work has shown an increase in the rate of sedimentation in certain parts of the Lower Balonne Floodplain, with sediments different to pre-European times and with a different origin (mainly from the Maranoa catchment). High rates of sedimentation were recorded in the floodplain regions and refugial waterholes but not in the Narran Lakes ecosystems. It is suggested here that this is because this impact has not yet reached the Narran Lakes (Thoms unpublished data).

5.5 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 for each location within the Ramsar site in accordance with the DEWHA (2008) framework Table 19.

Table 19: Summary of the main threats to the Narran Lake Nature Reserve Ramsar site.

Actual or likely threat	Potential impact(s) to wetland components, processes and/or service	Likelihood[1]	Timing[2]
Increased upstream water extraction	Reduced vegetation health and loss of habitat for waterbird breeding. Reduced value as drought refuge and support of critical life stages.	Certain	Current
Climate change – increased extreme local rainfall events	Changed pattern of inundation with potential disruption of breeding triggers.	Medium	Long term
Climate change – increased temperature and evaporation	Reduced duration of inundation, reduced vegetation health and water breeding opportunities. Contraction of water dependent vegetation to narrow strip along rivers and channels (DECCW	Medium	Long term

	2010b).		
Invasive species	Increased predation on waterbirds, particularly during breeding events by pigs, foxes and cats. Increased numbers of invasive fish species leading to loss of value of sites as having a high proportion of native species representing a near intact fish community.	Medium	Short
Sedimentation	Changed pattern of inundation, loss of habitat, and degradation of the near natural wetland system.	Medium	Long term

[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 or is based on predicted data (e.g. DECC 2008b). [2] Current is known to occur at time of writing (2011), Short term is less than 10 years and Long term is greater than 10 years.

6. Limits of Acceptable Change

6.1 Process for setting Limits of Acceptable Change (LAC)

Limits of acceptable change 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".

LAC and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that LAC 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 such that trends away from "natural" can be reliably detected is far from straight forward.

Hale and Butcher (2008) considered that it is not sufficient to simply define the extreme measures of a given parameter and to set LAC 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.

It should be noted that LAC are not synonymous with management values or "trigger levels". The LAC described here represents what would be considered a 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 must develop and implement a set of management triggers with this aim.

Additional Explanatory Notes for LAC

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 LAC, 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 LAC 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 LAC 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.

LAC 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.

LAC have been set for Narran Lake Nature Reserve Ramsar site based on conditions at the time of listing (Table 20). It is preferable to use site specific information to statistically determine LAC. However, in the absence of sufficient site specific data, LAC are based on recognised standards or information in the scientific literature that are relevant to the site. In these cases, the source of the information upon which the LAC has been determined is provided. For Narran Lake Nature Reserve there is very limited site specific data for most of the critical components, processes and services.

The columns in Table 20 contain the following information:

Component / Process/ Service	The component or processes for which the LAC is a direct measure.
Baseline / supporting evidence	Relevant 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 stated as it is to be assessed against.
Confidence level	The degree to which the authors are confident that the LAC represents the point at which a change in character may occur. Assigned as follows: **High** – Quantitative site specific data; good understanding linking the indicator to the ecological character of the site; LAC is objectively measurable. **Medium** – Some site specific data or strong evidence for similar systems elsewhere derived from the scientific literature; or informed expert opinion; LAC is objectively measurable. **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 20: Limits of Acceptable Change (LAC) for Narran Lake Nature Reserve Ramsar site.

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
Hydrology	The magnitudes used for setting LAC were chosen to account for different levels of inundation across the site as described by the MDBA targets below. Thoms et al. (2007) determined ARI for the period 1992 – 2003 for a range of flows using a partial series analysis: • 50 gigalitre ARI 1.85 years • 100 gigalitre ARI 2.63 years • 200 gigalitre ARI 6.67 years These have been taken as representative for the time of listing and as such forms the basis for the LAC for 50, 100, and 200 gigalitre flow events. The magnitudes used to set LAC are similar to those set to achieve the ecological outcomes of the MDBA (2010) targets, but are relevant to the time of listing as opposed to current or natural modelled used by the MDBA. The ARI set by Thoms et al. (2007) take into consideration the substantial water resource development which has taken place in the catchment prior to and immediately post listing. The MDBA (2010) current conditions cover the post 2004 period. The MDBA (2010) set hydrological targets to obtain ecological outcomes for Narran Lakes relating to maintaining current vegetation extent, condition, community composition and for successful colonial waterbird breeding. The hydrological targets are based on flood magnitude and duration based on flows at Wilby Wilby. This approach was adopted by the MDBA in recognition of the need for multiple events to maintain wetting on the floodplain and retain water in the lakes. Each combination of magnitude and duration aims to achieve different outcomes: • 25 gigalitres over 60 days will fill Clear and Back Lakes to 80	• In any 10 year period no less than 8 separate flow events each characterised by 25 gigalitres calculated as total volume in any 60 day period in the Narran River at Wilby Wilby. Maximum dry (inter-pulse) period between events of 2 years; and • In any 10 year period no less than 4 separate flow events characterised as 50 gigalitres calculated as total flow in any 90 day period in the Narran River at Wilby Wilby; and • In any 20 year period no less than 7 separate flow events characterised as a total of 100 gigalitres calculated as total flow in any 360 day period in the Narran River at Wilby Wilby; and • In any 20 year period at least 3 separate flow events characterised as a total of 200 gigalitres calculated as total flow in any 180 day period in the Narran River at Wilby Wilby.	Medium

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
	percent capacity (Sims and Thoms cited MDBA 2010) and possibly extend into Long Arm. Thus inundating some lignum and river red gum and providing open water habitat in the lakes. • 50 gigalitres over 90 days will inundate most of the lakes and also significant areas of the lignum dominated channelised floodplain. This would help sustain rookery sites by inundating lignum. Clear Lake would reach approximately one metre depth and retain water for up to 12 months (Thoms et al. 2007, MDBA 2010). The channelised floodplain is one of the most productive areas of the site in terms of soil egg and seed bank of the area. • 100 gigalitres over 12 months will provide conditions conducive to promote the likelihood of successful colonial waterbird breeding (MDBA 2010). This is based on observations that the majority of large breeding events occurred in years where total flow exceeded 100 gigalitres (Rayburg and Thoms 2008) with the bulk of inflows occurring over summer autumn in a single or series of events. • 200 gigalitres over six months will inundate a significant proportion of the Ramsar site, including the broader floodplain and partly fill the main Narran Lake to the south of the Ramsar site. Such an event would sustain lignum, riparian forest and woodlands as well as ephemeral herbfields and grasslands on the floodplain. The LAC for flow magnitude of 25 gigalitres is based on the MDBA (unpublished, updated targets for Narran Lakes) high uncertainty number of events. A maximum dry period was added to this LAC based on expert opinion. This was added to the LAC to ensure extended dry periods do not occur and is based on the fact that historically the Ramsar site typically received annual inflows.		

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
	All LAC are set at a 20 percent reduction from the ARI at the time of listing, or in the case of the 25 gigalitre LAC 20 percent less than the MDBA target (see above). This level of change was adopted to reflect the inherent natural variability in the hydrological regime of the site. Annual inflows to the site are highly variable and there are often multiple flood events in a single year. Critical components, processes and services which have high inherent natural variability may show a change in the parameter of concern which may not ultimately translate to a sustained change in ecological character – there may be a high level of resilience. The LAC are set on using the modelled data for the ARI (Thoms et al. 2007; MDBA 2010) and expert opinion.		
Lignum shrublands – extent.	Lignum is the dominant vegetation association within the Ramsar site. There are several ways to measure change in vegetation communities (extent, health, productivity) with the exception of extent these can be difficult to measure objectively. However, changes in health and productivity will eventually result in changes in extent and as such extent is considered a suitable indicator. Baseline mapping of the vegetation associations has not been established and this remains a knowledge gap. In 2004 lignum within the site was judged to be in good condition (Thoms et al. 2007), and it is suggested that the hydrological LAC suggested, if met, may sustain this vegetation association. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through duration and magnitude of flow events.	Data insufficient – No direct LAC has been developed and instead the critical component will be assessed indirectly through changes in hydrology see LAC above.	
Riparian forest and	Riparian forest and woodlands are scattered throughout the site but	No further decline in condition from baseline	Low

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
woodland – condition.	dominate the floodplain on the western side of the Narran River and in the upper north west corner of the site. There is no baseline for tree health at the time of listing, and whilst decline in tree health can be rapid, the poor condition of trees on the floodplain at the Ramsar site are likely to reflect changes to the inundation patterns which occurred after upstream water extraction increased between 1980 to 1990. Lag effects are likely to be an important consideration, with tree health already in decline at the time of listing. Four thousand trees were assessed by Thoms et al. (2007) from 12 tree patches mapped across the Ramsar site: 54 percent of all river red gums, 45 percent of all river coobas and 38 percent of all coolabahs surveyed were classed as dead. 'No change' is used to set the LAC as tree health should be relatively stable and small declines may indicate significant change at the site due to lag effects. LAC based on available data and expert opinion.	of 2004 set by Thoms et al. (2007), measured as percentage of dead trees surveyed (baseline 54 percent of river red gum, 45 percent of river coobas, and 38 percent of coolabahs classed as dead).	
Riparian forest and woodland – extent.	Baseline mapping of the vegetation associations has not been established and this remains a knowledge gap. There is inadequate data to set a LAC for extent of riparian forest and woodland vegetation at this time. A LAC should be set when more data becomes available.	Data insufficient – No LAC set.	
Ephemeral herbfields – extent.	This vegetation association is highly variable in response to wetting and drying cycles within the site and closely linked to the other major vegetation associations within the site. There is no accurate mapping of the extent of this critical component. LAC set for hydrology may account for this vegetation association. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through duration and magnitude of flow events.	Data insufficient - No direct LAC has been developed and instead the critical component will be assessed indirectly through changes in hydrology see LAC above.	
Productivity	Small to medium sized floods are being lost through upstream water extraction and drought periods. These flood magnitudes are essential	Data insufficient - No direct LAC has been developed and instead the critical process	

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
	to maintain floodplain condition including productivity. Hydrological connectivity and variation in inundation is a key to maintaining floodplain productivity. Therefore, without a direct baseline of productivity, it is assumed that the LAC for hydrology would be a suitable surrogate accounting for changes in productivity.	will be assessed indirectly through changes in hydrology, see LAC above.	
Fish	Native fish species dominate the system with 11 species recorded from several surveys (Thoms et al. 2007; MDBA 2008; Rolls and Wilson 2008a & b, 2010). In all surveys the native species have accounted for over 90 percent per unit catch. Survey results indicate that the fish species present are relatively predictable, with a reasonable probability that all species recorded to date would be encountered over several sampling events (G. Wilson, University of New England, pers. comm.). Sampling is often event driven and as such a temporal scale is not provided in the LAC. This LAC is set on expert opinion.	All species of native fish recorded over any three sampling events. Native species account for at least 75 percent of the catch in two thirds of sampling events.	Low
Waterbirds – colonial breeding events	Colonial waterbird breeding events have been associated with a flood threshold of 100 000 megalitres annual discharge at Wilby Wilby gauge (Rayburg and Thoms 2008) and occur in clusters following large floods. The 100 000 megalitre sized events have occurred at an ARI of 2.63 years (Thoms et al. 2007). Over a 45 year period these large flood events have occurred 18 times, however the large colonial waterbird breeding events (50 000 nests) have only occurred six times in the same period (Rayburg and Thoms 2008, K. Brandis unpublished data). Rayburg and Thoms (2008) reported that eight years without breeding may represent an ecological threshold for some species of colonial waterbirds. Based on this information the LAC is set at a 20 percent change from the current rate of 1 in 6 years for large breeding events.	Large colonial waterbird breeding event of 50 000 nests occur no less than 1 in 8 years based on frequency of large flood events (>100 000 megalitres total annual flow at Wilby Wilby).	Medium

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
	This LAC is based on available data and expert opinion.		
Waterbirds – number of species breeding	The Ramsar site supports breeding for a total of 44 waterbird species; however the number of species recorded breeding in any single year can be highly variable. The site is particularly important for colonial waterbird species. LAC is based on the assumption that a 20 percent decline in breeding species would represent a potential change in character; however this is an estimate as there is insufficient scientific knowledge to understand what would constitute a change in ecological character as a result of loss of bird species breeding at this site. The premise for setting this LAC is that as number of breeding species has high inherent natural variability strongly influenced by factors external to the site, and that a large change may not necessarily translate to a change in ecological character. The LAC is based on expert opinion.	In any 20 year period at least 35 of the 44 species of waterbird breeding are recorded breeding at the site.	Medium
Near natural wetland type	This critical service is linked principally to changes in the hydrology 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 flow events.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology, see LAC above.	
Physical habitat which supports waterbird breeding.	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 hydrological regime and occurrence of large colonial waterbird breeding events.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and waterbird breeding success see LAC above.	
Threatened species – Murray cod	Murray cod (*Maccullochella peelii peelii*) are rare within the Ramsar site, having only been reported in the literature once (Thoms et al. 2007); however anecdotal evidence suggests they do occur in the	Data deficient – No LAC set.	

Critical Components, Processes and Services	Baseline/Supporting Evidence for LAC	Limit of Acceptable Change	Confidence level
	system. In addition Murray cod were reported as present in the lower Condamine-Balonne in the Sustainable Rivers Audit (Davies et al. 2008). No population data is available. Juveniles would be expected to be present in flood events dispersing into the site from upstream (G. Wilson, University of New England, pers. comm.). There is inadequate data to set a LAC for Murray cod. A LAC should be set when more information is available.		
Threatened species – Australasian bittern	Australasian bittern (*Botaurus poiciloptilus)* has been recorded only once from the site in 2008 (Birds Australia; DECCW 2010a). Birds Australia considered it uncommon at the site, but this is based on the single 2008 record. Count data are not available. This species is known to be cryptic and not easily detected. Currently there is inadequate data to set a LAC. A LAC should be set once additional data becomes available.	Data deficient – No LAC set	
Threatened species – Winged peppercress	Winged peppercress, *Lepidium monoplocoides* occurs as isolated individuals throughout the Nature Lake Nature Reserve (Hunter 1999). LAC based on expert opinion.	Presence of winged peppercress within the site when conditions are suitable.	Low
Cultural heritage and spiritual significance.	Important site for transfer of intergenerational knowledge and important confluence for several dreamtime stories. Cultural economy and values are closely associated with ecological values and intact hydrological regimes. Therefore it is assumed that LAC for hydrology and biota would account for changes in cultural services.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and biota. See all LAC above.	

7. Current Ecological Character and Changes since Designation

7.1 Site changes since listing

The NSW NPWS also owns the majority of lands surrounding the Ramsar site the result of a series of acquisitions over the past ten years. These lands have been gazetted as Nature Reserve and are managed for their conservation values. In recognition of the importance of the floodplain to sustaining colonial waterbird breeding at the site, the Ramsar site boundary will be extended in 2011. At the time of listing in 1999 the site covered an area of 5343 hectares; with a proposed extension in 2011 to approximately 8447 hectares. No additional components, processes or services will be added with this extension, although there is a significant increase in the amount of riparian forest and woodland vegetation captured in the 2011 boundary.

7.2 Change in critical components, processes and services

Change in ecological character is defined as the human-induced adverse alteration of any ecosystem component, process and/or ecosystem benefit or service (Ramsar Convention 2005, Resolution IX.1 Annex A). Changes to the ecological character of the wetland outside natural variations may signal that uses of the site or externally derived impacts on the site are unsustainable and may lead to the degradation of natural processes and thus the ultimate breakdown of the ecological, biological and hydrological functioning of the wetland (Ramsar Convention 1996, Resolution VI.1). Guidance from the Australian Government indicates that positive change to ecological character should also be documented. Change should be established against the ecological character at the time a site was listed as a Ramsar site.

7.2.1 Hydrology

Overland extraction of flood waters has expanded considerably in the past 30 years, with large scale development on the Lower Balonne floodplain via the construction of levees and water storages. Although there had been minor developments before the late 1980s, there has been rapid expansion of irrigated crops and water storage on the floodplain since that time. While the areas involved occupy only 9.5 percent of the total surface area of the Lower Balonne floodplain they are an important loss of reactive floodplain surface area. Current capacity of water storages on the Lower Balonne floodplain is approximately 1 500 000 megalitres (Lower Balonne Floodplain Association, unpublished). On farm storage capacity is 19 times that which existed in 1988 and 5 times that of 1993/1994 (Lower Balonne Floodplain Association, unpublished). Groundwater extraction, predominantly in the upper catchment, is also predicted to have an impact of surface flows. Based on the current level of groundwater extraction the impact is likely to be a reduction of 30 gigalitres per year across the entire region; however this may not eventuate for several decades (CSIRO 2008).

The majority of the overland extraction development occurred post 1992, after the moratorium on new licenses and before the 2002 moratorium on overland flow water (Lower Balonne Floodplain Association, unpublished). Harvesting of overland flows prevents the return of flows to the downstream sections of rivers during floods. Comparison of floods in 1988 and 2004 showed a 50 percent decreased in cross border flows and greater attenuation of flow peaks leading to a reduction of floodplain inundation of 75 and 88 percent in Queensland and New South Wales respectively (Lower Balonne Floodplain Association, unpublished).

Water development has had a significant influence on the hydrology and functioning of the Lower Balonne floodplain including the Narran terminal wetland ecosystem. The rapid rate of water-resources development in the region, combined with the naturally variable flow in the rivers, makes historical data inadequate for evaluating the impact of water-resources development on the hydrological regime of the Lower Balonne floodplain. Thus, simulated daily discharge data from the Queensland Department of Natural Resources and Mines Integrated Quantity Quality Model (IQQM) can be used for evaluating hydrological change. Thoms and Parsons (2003) used Simulated ‘natural’ flows and compared these with simulated ‘current’ flows for the period 1922–2000 for 12 stations (nodes) located throughout the Lower Balonne floodplain region.

The ‘current’ flows are simulated using water and land use conditions present in 1999–2000 combined with long-term mean climatic conditions. In their hydrological analysis of the Lower Balonne Floodplain Thoms and Parsons (2003) reported that water-resources development has had significant but different effects on different flow groups (Table 21). For the current-flow scenario there is a loss of 29.53% of median annual volumes of water entering the Lower Balonne Floodplain (as measured by flows at St George). Moreover, the impact of water-resources development differs for floods of different magnitudes (Table 21). At St George, flows with an ARI of 1.5 years are affected most, being reduced by 47.59 percent while flood events with an ARI of up to 10 years have been reduced by 9.22 percent. Spell Analysis further demonstrates the implications of water-resources development on floodplain hydrology albeit at a finer scale. For the period 1922– 2000 the Lower Balonne Floodplain has been inundated on fewer occasions and all the floods have lasted less time. For example, reductions of up to 40 percent were recorded in the number of inundation events at St George. Overall, median reductions in the number of times a flow event occurred ranged from 11 percent at St George to 34 percent on the Ballandool River. Changes in the duration of individual inundation events were also recorded and these ranged from 10 percent to 60 percent with median reductions for individual nodes between 13 percent and 44 percent.

Table 21: Hydrological change in the Condamine-Balonne system at St George. Simulated flow data (IQQM) are given for the 1922–2000 period. ML = megalitre, ML/d = megalitres per day, ARI = average recurrence interval.

	Natural	Current	% Change
Median annual flow (ML)	976 997	688 457	– 29.53%
Flood discharges			
1.5 ARI (ML/d)	31 813	16 672	– 47.59%
2 ARI (ML/d)	56 287	43 879	– 22.04%
5 ARI (ML/d)	123 663	18 268	– 4.63%
10 ARI (ML/d)	183 788	166 832	– 9.22%

Flow data is available from the 1960s for the Wilby Wilby gauging station on the Narran River (the nearest upstream station to the Ramsar site). Flows into the Narran terminal wetland system occurred in nearly 90 percent of all years on record (Thoms et al. 2007). Medium to large floods were common historically with more than 66 percent of all years recording 50 000 megalitres or more of discharge at the Wilby Wilby gauge. Since 1992 there has been a notable decline in the occurrence of medium-sized floods and an overall decrease in discharge volumes compared to pre 1992. The result being floods are rarer, irrespective of size since 1992 (Thoms et al. 2007). This means at the time of listing the hydrology of the site was already significantly altered. Under the water development levels at the time of listing the longest dry period (times without significant inundation) was nearly 20 years.

CSIRO (2008) states that water resource development has reduced the number of years in which Clear and Back Lakes provide optimal waterbird breeding habitat by over 60 percent, greatly reducing the contribution the Ramsar site is able to make sustaining waterbird populations in eastern Australia (CSIRO 2008).

In summary, licensed and unlicensed water-resources development in the Condamine-Balonne catchment has altered the hydrological character of the Lower Balonne floodplain and the Narran Lake Nature Reserve Ramsar site, with floods being fewer and smaller now. There appears to be a significant increase in water resource development post the site being listed, however further data analysis is required to establish the full effect of water development since listing. In particular the past decade has been the driest on record and this needs to be taken into consideration.

7.2.2 Productivity

Recent work on the floodplain of the Lower Balonne, including the Narran system, investigated the effects of hydrological connectivity on the transfer of dissolved organic carbon between a floodplain and river channel (Thoms 2003). The present-day floodplain of the Lower Balonne is characterised by morphological features formed by vertical and lateral accretion and channel avulsions each with distinctive textural and geochemical differences (Thoms 2003). The average total organic carbon in the topsoil from the different morphological features of the floodplain were all significantly different (McGinness and Thoms 2002). For example channel islands, channel banks and levees all consistently had between 70 and 123 percent more total organic carbon than palaeo-channels, flood runners and flat floodplain surfaces (Thoms 2003). Investigations showed that 97 percent of the total organic carbon released upon wetting topsoils was in the dissolved form, but that the potential amount of carbon that could be released from the different parts of the floodplain also varied (Thoms 2003).

Due to the development of the floodplain there has been a proportionately large loss of highly reactive floodplain surfaces, in terms of the release of dissolved organic carbon from the surface sediments. Overall there has been a 23 percent loss of reactive floodplain surface in the upper reaches of the Lower Balonne floodplain. In addition the connectivity and distribution of floodwaters across the floodplain during periods of overbank flow, especially in the area downstream of the Culgoa–Narran bifurcation, have been severely disrupted (Thoms 2003). Floods with annual recurrence intervals (ARI) less than two years are no longer effective in dissolved organic carbon release from the floodplain, with the potential loss ranging between 23 to 100 percent depending on the size of the flood (Thoms 2003).

Despite the work of Thoms (2003) there is insufficient data to determine conclusively if productivity has changed since listing. As the relative importance of the sources of carbon for primary productivity have not been established for the Ramsar site it is not known how important the loss of upstream carbon will be to maintaining ecological process within the site. Data collected on groundcover, seed and egg banks in the Narran Ecosystem Project and the biotic response to the 2008 flooding would suggest that productivity has not declined. The site was able to support the waterbird breeding event in 2008 through to fledging, the first major breeding event in eight years.

7.2.3 Vegetation

There is insufficient documentation to accurately assess changes in ecological character amongst vegetation attributes since listing of the Narran Lake Nature Reserve Ramsar site. Anecdotal evidence, however, suggests two major changes in the wetland vegetation in recent memory. Firstly, the extent of lignum shrubland is considered to have expanded since the Nature Reserve was gazetted in 1988 and significant grazing activities (including burning of lignum) ceased. This expansion is thought to have occurred mainly in the centre of Back Lake which was previously open and dominated by herbfield vegetation (Mike Maher and James Foster, pers. comm.). Secondly, the extent of *Phragmites* reed-beds within the lignum shrublands fringing Clear Lake and Long Arm is thought to have increased following the recent 2004 and 2008 flood events (Neil Saintilan and S. Capon pers. comm.). Additionally, recent surveys of trees in the Ramsar site strongly suggest declining condition amongst riparian forest and woodland communities in relation to prolonged drying and insufficient wetting events. Understanding of the condition of key vegetation community types is summarised below.

Riparian open forest and woodland
High levels of stress and mortality were apparent amongst trees surveyed in tree patches (Figure 31 above) during the Narran Lakes Ecosystem Project (Thoms et al. 2007). A high percentage of river red gums (54 percent), river coobas (45 precent) and coolibahs (38 percent) surveyed in September 2005 were recorded as being dead (had no leaves present). Furthermore, little evidence of recruitment was observed during this survey, especially

amongst river red gums, and particularly high levels of stress were evident amongst seedling and sapling cohorts of red gums and coolibahs in comparison with mature trees (Thoms et al. 2007). Mature river coobas, on the other hand, displayed greater levels of mortality (50 percent) than juveniles (43 percent) or seedlings (32 percent) of this species (Thoms et al. 2007).

There is no baseline for tree health at the time of listing, and whilst decline in tree health can be rapid, the poor condition of trees on the floodplain at the Ramsar site are likely to reflect changes to the inundation patterns which occurred after upstream water extraction increased between 1980 to 1990. Lag effects are likely to be an important consideration, with tree health already in decline at the time of listing.

Lignum shrublands

Although limited disturbance resulting from tanks, ditches and cattle was noted, lignum shrublands within the Narran Lake Nature Reserve were considered to be in a generally good condition when surveyed by Hunter (1999).

More recently, surveys conducted as part of the Narran Lakes Ecosystem Project revealed considerable variation in the condition of shrubs across the site (Thoms et al. 2007), however, at all lignum shrubland survey sites which were inundated by the 2004 flood event indicating a good condition overall.

Ephemeral herbfields

Based on recent vegetation response to the 2008 flood event, ephemeral herbfields in the Narran Lakes Ramsar site appear to be in relatively good condition (Capon 2010). Exotic species of potential ecological concern including lippia and Noogoora burr are present but appear to be quite limited in their extent (Capon, 2010). Hunter (1999) also identifies erosion and scalds as a potential concern in this community. However there is no evidence of change in this vegetation association.

7.2.4 Fish

Results from the Sustainable Rivers Audit results for the Condamine Valley (MDBC 2008) and the work done by Rolls and Wilson (2008a & b; 2010) indicate that the fish community is still in very good condition compared to other catchments in the Murray-Darling Basin. The fish community is dominated by native species and appears to be unchanged since listing despite the site being subject to a prolonged drought and increased water resource development.

7.2.5 Waterbirds

As stated in section 7.2.1 water resource development (both pre and post listing) has significantly reduced the capacity to support optimal waterbird breeding habitat. However, as the site has been in drought, virtually since listing, it is not possible to determine if there has been a change in ecological character based on waterbirds. A significant breeding event occurred in 2008 on the back of a relatively small flood, which probably represented an ecological bottleneck event. That is a last opportunity for many birds to breed, as there had not been a significant breeding event in the area for eight years due to the drought. There needs to be several more years in which inundation of the wetland occurs before an assessment of the use of the site by waterbirds is possible. In addition flooding in 2010 has triggered two recent breeding events for straw-necked ibis.

7.3 Change in ecological character

The hydrological LAC has been exceeded based on assessment of daily flows at Wilby Wilby from 1999 to 2009. The past decade is the driest on record and is reflected in inflows, with only one large event of more than 100 gigalitres occurring in 1999. Small and medium sized events of 25 and 50 gigalitres were very few. It is necessary to acknowledge the impact of drought on the hydrology of the site, however drought alone does not account for the reduction of inflows. Of particular note is the level of extraction which occurred in 2004 (see section 7.2.1) as evidence of the impact of extraction on inflows to the site.

Riparian forest and woodland health is potentially in decline, however further assessments are required to be able to assess if there has been a change since listing. Changes in hydrological regime are believed to be having an impact on waterbird breeding events, but this is again confounded by the impacts of drought. The successful 2008 and 2010 breeding events have meant the waterbird breeding LAC is not exceeded. However, the 2008 event is considered an aberration, in that it occurred on a much smaller flood than all previous events. All other LAC are either met or have insufficient data over the past ten years to make an assessment.

Despite the above, the site continues to meet criteria 1, 2 and 4 (see section 2.5).

8. Knowledge Gaps

While it is tempting to produce an infinite list of research and monitoring needs, it is important to focus on the purpose of an ecological character description and identify and prioritise knowledge gaps that are important for describing and maintaining the ecological character of the system.

There are relatively few knowledge gaps that are required to be addressed so as to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met (Table 22). Initial investigations into the hydrological regime and key ecological components were undertaken in the Narran Ecosystem Project has provided a significant amount of information on the sites hydrology and ecology; however there is a need to extend this knowledge base by continuing to monitor the condition of the several components, processes and services (see section 9).

Table 22: Knowledge gaps for Narran Lake Nature Reserve Ramsar site

Component, Process, Service	Knowledge Gap	Recommended Action
Geomorphic setting/Near natural wetland	• Extent of Ramsar wetland types.	• Benchmark wetland mapping is required, especially the saline wetlands.
Hydrology	• Role of groundwater in hydrological regime.	• Develop a water budget for the site.
Productivity	• Understanding of sources of carbon and primary productivity within the river, floodplain and lakes. • Impact of lost productive floodplain upstream on boom and bust ecology.	• Investigation of carbon sources for primary productivity and relationship to flood events.
Vegetation - Lignum and riparian forest and woodland/ Physical habitat for waterbird breeding	• Extent of healthy trees mapped for entire site.	• Improve baseline for assessment of LAC • Continued condition assessment of tree patches as per Thoms et al. (2007).
Vegetation - Lignum, riparian forest and woodland, ephemeral herbfields.	• Baseline extent for major vegetation associations.	• Mapping from remote sensed imagery. Build on the work of Hunter (1999) and more recent work.
Waterbirds	• Presence of cryptic species such as Australasian bittern. • Habitat utilisation by non colonial breeding waterbird species. • Mapping of waterbird feeding habitats within the Ramsar site	• Targeted surveys. • Behavioural observations of feeding and documenting food availability during key breeding events.
Threatened species	• Threatened species – winged peppercress. • Frequency and habitat use by Murray cod.	• Establish presence within site, abundance and frequency habitat preferences.
Cultural heritage	• Linkages between Aboriginal and scientific understanding of the site.	• Document the linkage between cultural economy and wetland condition/ecology.

9. Monitoring needs

As a signatory to the Ramsar Convention, Australia has made a commitment to maintain the ecological character of its Ramsar sites. Whilst there is no explicit requirement for monitoring the site, a monitoring program would provide data to assist in assessing changes to the site, and thereby to determine if the site's ecological character is being maintained. The ECD identifies the monitoring recommendations for critical components and processes and for assessing against the LAC.

The purpose of the monitoring recommended in this ECD is to:

- Identify objectives for monitoring critical components, processes, services or threats;
- Recommend indicators or measures to be used and the frequency of monitoring;
- Provide priorities for monitoring; and
- Address key knowledge gaps identified for the site.

The recommended monitoring for the Narran Lake Nature Reserve Ramsar site are provided in Table 23.

Table 23: Monitoring needs for Narran Lake Nature Reserve Ramsar site.

Component/ Process	Purpose	Indicator	Locations	Frequency	Priority
Hydrology	Assessment against LAC.	Daily flow at Wilby Wilby gauge. Number of events of specified magnitude and duration.	Wilby Wilby gauge.	Continuous.	High
Vegetation – lignum, riparian forest and woodlands.	Establish baseline to set LAC	Extent.	Entire Ramsar site.	Once every 8-10 years once benchmark established.	High
Vegetation – lignum and riparian forest and woodlands.	Assessment against LAC.	Tree and lignum health		Once every 5 years.	Moderate
Waterbirds	Assessment against LAC.	Abundance and species identifications, breeding observations.	Entire Ramsar site.	Event based.	High
Fish	Assessment against LAC.	Abundance, species richness, proportion native species per catch per unit effort.	Entire Ramsar site, with emphasis on Narran River and channel habitat.	Currently not resourced. Recommended once every 5 years and/or in response to major events.	Low
Threatened species	Establish baseline to set LAC.	Location, abundance.	Targeted within Ramsar site.	Opportunistic linked to monitoring of fish and vegetation.	Low

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, but key communication messages and CEPA actions, such as a community education program, can be used as a component of a management plan.

Key CEPA messages for Narran Lake Nature Reserve Ramsar site arising from this ECD, which should be promoted through this program, include:

- Narran Lake Nature Reserve is listed as a Wetland of International Importance under the Ramsar convention. At the time of listing in 1999, it met three of the nine Ramsar Nomination criteria.
- Narran Lake Nature Reserve constitutes the bulk of the northern part of the Narran Lake terminal wetland ecosystem. The two components of the site are hydrologically and ecologically connected.
- Narran Lake Nature Reserve is used as an educational site for the transfer of intergenerational knowledge among the local indigenous people, thus providing an excellent example of wise use of a wetland for maintaining cultural values.
- Upstream water extraction has altered the hydrological regime of the wetland and has the potential to lead to a change in ecological character unless carefully managed.
- The site is critical as a breeding site for colonial waterbirds, periodically supporting large breeding events. The 2008 breeding event was believed to represent the last breeding opportunity for many of the straw-necked ibis population, with over 80 000 birds fledged into the adult population.
- In 2011 the original boundary of the Ramsar site will be expanded to capture more of the critical waterbird breeding habitat and also feeding areas outside of the breeding habitat.
- Lignum shrublands are extensive and remain in good condition overall, a rarity for this type of wetland in New South Wales.
- Invasive species whilst present within the site are currently successfully managed with little overall impact on the ecology of the site.
- Climate change has the potential to exacerbate the impacts of upstream water extraction through increased temperature and evaporation. However, these may be offset by increased local storm events and increased rainfall in summer months.

- It is likely that the changes in hydrology since listing may have caused a change in the character of the site. Further analysis is required to establish if any actual changes have occurred since listing, particularly in relation to investigating data post 2002 at which time a moratorium on overland extraction came into force.
- This site is remote and relatively little research has been undertaken. Continued upstream water extraction will impact on the ecological character of the site, as such monitoring of Limits of Acceptable Change and establishment of benchmarks where required, must be undertaken.

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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 Rhonda Butcher met with the Department of the Environment Water Heritage and the Arts (DEWHA, now SEWPAC) 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 thorough desktop review of existing information on the ecology of Narran Lake Nature Reserve Ramsar site. In addition data was supplied by DECCW.

Task 2: Stakeholder engagement and consultation
A Steering Committee was formed for the preparation of Narran Lake Nature Reserve Ramsar site ECD. This group was comprised of stakeholders with an interest in the ECD and management planning process, and included representatives of the following organisations:

- Several staff from the former Department of Environment, Climate Change and Water (Narrabri, Dubbo, Sydney); and
- A representative from the Lightning Ridge community.

Members of the Steering Committee provided verbal and written comments on drafts of the ECD.

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 Narran Lake Nature Reserve Ramsar site.

Steps from the national draft (2008) framework	Activities
1. Document introductory details.	Prepare basic details: site details, purpose, legislation.
2. Describe the site.	Based on the Ramsar RIS and the above literature review describe the site in terms of: location, land tenure, Ramsar criteria, wetland types (using Ramsar classification).
3. Identify and describe the critical components, processes and services.	Identify all possible components, services and benefits. Identify and describe the critical components, services and benefits responsible for determining ecological character.
4. Develop a conceptual model of the system.	Two types of models were developed for the system: • A series of character 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. Aiding in understanding management of the system.
5. Set Limits of Acceptable Change.	For each critical component process and service, establish the limits of acceptable change.
6. Identify threats to the site.	This process identified both actual and potential future threats to the ecological character of the wetland system.
7. Describe changes to ecological character since the time of listing.	This section describes in quantitative terms (where possible) changes to the wetlands since the initial listing in 1999.

Steps from the national draft (2008) framework	Activities
8. Summarise knowledge gaps.	This identifies the knowledge gaps for not only the ecological character description, but also for its management.
9. Identify site monitoring needs.	Based on the identification of knowledge gaps above, recommendations for future monitoring are described.
10. Identify communication, education and public awareness messages.	Following the identification of threats, management actions and incorporating stakeholder comments, a general description of the broad communication / education messages are described.

Task 4: Revision of the Ramsar Information Sheet (RIS)
The information collated during Task 1, together with the draft Ecological Character Description was used to produce a revised RIS in the standard format provided by Ramsar.

Task 5 Finalising the ECD and RIS
The draft ECD and RIS were submitted to SEWPAC, and the Steering Committee for review. Comments from agencies and stakeholders were incorporated to produce revised ECD and RIS documents.

A.2 Consultant Team

Rhonda Butcher (project manager)
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, and the preparation of the ECD for Banrock Station Wetland Complex. Other ECD project's Rhonda has had technical input to include the Coorong and Lakes Alexandrina and Albert, Lake MacLeod, Peel-Yalgorup, Eighty-mile Beach, Port Phillip Bay. Rhonda is currently project managing the Ramsar Rolling Review developing a framework for reporting the status of ecological character at all 65 Ramsar sites in Australia.

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 Port Phillip Bay and Bellarine Peninsula (current), 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.

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.

Martin Thoms

Martin Thoms is a fluvial geomorphologist by training, who has spent much time collaborating with freshwater ecologists on a variety of fundamental and applied research. His research and teaching interests extend from understanding interactions of hydrology, geomorphology and ecosystem responses at a range of scales through to determining environmental water allocations for riverine landscapes in dryland regions and deriving methods for assessing the physical integrity of these systems. Martin was the leader of the Narran Lakes Ecosystem Project which investigated the ecosystem responses of variable wetting and drying in this large floodplain wetland system. He has over 200 scientific refereed publications and has had six major research projects in the Lower Balonne and Narran region. Martin has a very active research group including post doctoral researchers and post graduate students that focus on a range of ‘ecogeomorphology’ research issues. He is currently the Chair and professor of Geography and Planning at the University of New England. In addition, he is the secretary of the International Association of Hydrological Sciences’ International Commission on Continental Erosion and is editor (Asia-Pacific) for *River Research and Applications* and is on the editorial board of *Geomorphology*.

Samantha Capon

Samantha has been involved in the research and management of inland freshwater ecosystems for the past thirteen years and has experience working both in a State management agency and as an academic researcher. Her specific research interests concern the ecology of wetland, riparian and floodplain plants and the vegetation communities which these comprise, particularly in dryland catchments of inland Australia. She also has demonstrated expertise in numerous other relevant areas including environmental flows, ecosystem resilience, landscape ecology, GIS and remote sensing. She has published over thirteen journal articles and three book chapters and has authored numerous reports. She is also co-editor of a volume entitled *Vegetation of Australia’s Riverine Landscapes* currently in preparation and under contract with CSIRO Publishing. Recently, her articles have received international attention and she has now been cited by researchers in the United States, the United Kingdom, South America, China, Korea, Morocco, France and Spain. In Australia, she is regularly invited to participate in scientific meetings, workshops, panels and community forums and has been asked to provide expert advice to numerous organisations including the MDBA, NSW DECCW, NSW DWE, the NSW Scientific Committee, CSIRO and the Victorian EPA. She has led numerous large consultancy projects for clients including the MDBA, NSW DECCW and the Victorian EPA and has also been a key team member of several other large projects for clients including the National Water Commission. She has worked extensively in the Murray-Darling Basin, in both the northern and southern regions, and has expert knowledge of several key iconic sites including Narran Lakes, the Lowbidgee, the Great Cumbung Swamp and Hattah Lakes. She is currently Assistant Coordinator of the National Climate Change Adaptation Water Resources and Freshwater Biodiversity Network (NCCARF Water Network).

Appendix B: Wetland birds recorded in Narran Lake Nature Reserve Ramsar Site

Species list compiled from Birds Australia Bird Atlas (Birds Australia unpublished), Brooker (1993), Ley (1998) and Jenkins et al. (2009).

EPBC Act listing: M = Listed as migratory or marine under the EPBC Act; J = JAMBA; C= CAMBA; R = ROKAMBA, B = BONN; CE = critically endangered internationally.

Scientific Name	Common Name	Breeding	EPBC Act Listing
Anas castanea	Chestnut teal		M
Anas gracilis	Grey teal	Yes	M
Anas rhynchotis	Australasian shoveler	Yes	M
Anas superciliosa	Pacific black duck	Yes	M
Anseranas semipalmata	Magpie goose	Yes	M
Aythya australis	Hardhead	Yes	M
Biziura lobata	Musk duck	Yes	M
Chenonetta jubata	Australian wood duck	Yes	M
Cygnus atratus	Black swan	Yes	M
Dendrocygna eytoni	Plumed whistling-duck	Yes	M
Malacorhynchus membranaceus	Pink-eared duck	Yes	M
Oxyura australis	Blue-billed duck	Yes	M
Stictonetta naevosa	Freckled duck	Yes	M
Podiceps cristatus	Great Crested grebe		
Poliocephalus poliocephalus	Hoary-headed grebe	Yes	
Tachybaptus novaehollandiae	Australasian grebe	Yes	
Anhinga novaehollandiae	Australasian darter	Yes	
Pelecanus conspicillatus	Australian pelican	Yes	M
Microcarbo melanoleucos	Little pied cormorant	Yes	
Phalacrocorax carbo	Great cormorant	Yes	
Phalacrocorax sulcirostris	Little black cormorant	Yes	
Phalacrocorax varius	Pied cormorant	Yes	
Ardea ibis	Cattle egret		M, C, J
Ardea intermedia	Intermediate egret	Yes	M
Ardea modesta	Eastern great egret	Yes	M, C, J
Ardea pacifica	White-necked heron	Yes	
Egretta garzetta	Little egret		M
Egretta novaehollandiae	White-faced heron	Yes	
Nycticorax caledonicus	Nankeen night-heron	Yes	
Plegadis falcinellus	Glossy ibis	Yes	M, B, C
Threskiornis molucca	Australian white ibis	Yes	M
Threskiornis spinicollis	Straw-necked ibis	Yes	M
Platalea flavipes	Yellow-billed spoonbill	Yes	
Platalea regia	Royal spoonbill	Yes	
Haliaeetus leucogaster	White-bellied sea eagle	Yes	M, C
Circus approximans	Swamp harrier		M
Ephippiorhynchus asiaticus	Black-necked stork		

Scientific Name	Common Name	Breeding	EPBC Act Listing
Grus rubicunda	Brolga		
Porzana fluminea	Australian spotted crake		M
Fulica atra	Eurasian coot	Yes	
Gallinula tenebrosa	Dusky moorhen	Yes	
Porphyrio porphyrio	Purple swamphen	Yes	
Tribonyx ventralis	Black-tailed native-hen	Yes	
Botaurus poiciloptilus	Australasian bittern		E, CE (IUCN)
Calidris acuminata	Sharp-tailed sandpiper		M, B, C, J, R
Calidris ferruginea	Curlew sandpiper		M, B, C, J, R
Charadrius ruficapillus	Red-capped plover	Yes	
Elseyornis melanops	Black-fronted dotterel	Yes	
Erythrogonys cinctus	Red-kneed dotterel	Yes	
Gallinago hardwickii	Latham's snipe		M, B, C, J, R
Himantopus himantopus	Black-winged stilt	Yes	M
Ixobrychus dubius	Australian little bittern		
Limosa lapponica	Bar-tailed godwit		M, B, C, J, R
Limosa limosa	Black-tailed godwit		M, B, C, J, R
Recurvirostra novaehollandiae	Red-necked avocet	Yes	M
Stiltia isabella	Australian pratincole		M
Tringa glareola	Wood sandpiper		M, B, C, J, R
Tringa nebularia	Common greenshank		M, B, C, J, R
Tringa stagnatilis	Marsh sandpiper		M, B, C, J, R
Vanellus miles	Masked lapwing	Yes	
Vanellus tricolor	Banded lapwing	Yes	
Chlidonias hybrida	Whiskered tern	Yes	M
Chlidonias leucopterus	White-winged black tern		M, C, J, R
Chroicocephalus novaehollandiae	Silver gull		M
Gelochelidon nilotica	Gull-billed tern	Yes	M
Sterna caspia	Caspian tern		M, C, J
Acrocephalus australis	Australian reed-warbler		
Todiramphus sanctus	Sacred kingfisher		

Appendix C: Colonial waterbird breeding events and abundance

The following data set was compiled by Kate Brandis, Australian Wetlands and Rivers Centre University of New South Wales. Data for glossy ibis and Australian white ibis in 2008 from Kingsford et al. (2008). Shaded cells are for when more than one percent of the species population was recorded.

Year	Scientific Name	Common Name	Number
1971	*Pelecanus conspicillatus*	Australian pelican	200
	Plegadis falcinellus	Glossy ibis	400
	Phalacrocorax carbo	Great cormorant	400
	Ardea intermedia	Intermediate egret	600
	Phalacrocorax varius	Pied cormorant	400
	Platalea regia	Royal spoonbill	unknown no.
	Threskiornis spinicollis	Straw-necked ibis	20000
1972	*Threskiornis spinicollis*	Straw-necked ibis	unknown no.
1974	*Plegadis falcinellus*	Glossy ibis	unknown no.
	Threskiornis spinicollis	Straw-necked ibis	unknown no.
1976	*Plegadis falcinellus*	Glossy ibis	unknown no.
	Threskiornis spinicollis	Straw-necked ibis	unknown no.
1978	*Plegadis falcinellus*	Glossy ibis	100
1981	*Pelecanus conspicillatus*	Australian pelican	30
	Plegadis falcinellus	Glossy ibis	10
	Phalacrocorax carbo	Great cormorant	20
	Ardea pacifica	White-necked heron	150
	Phalacrocorax varius	Pied cormorant	50
	Platalea regia	Royal spoonbill	100
	Threskiornis spinicollis	Straw-necked Ibis	100
1984	*Pelecanus conspicillatus*	Australian pelican	unknown no.
	Plegadis falcinellus	Glossy ibis	unknown no.
	Phalacrocorax carbo	Great cormorant	unknown no.
	Phalacrocorax varius	Pied cormorant	unknown no.
	Platalea regia	Royal spoonbill	unknown no.
	Threskiornis spinicollis	Straw-necked Ibis	very large event
1988	*Pelecanus conspicillatus*	Australian pelican	600
	Platalea regia	Royal spoonbill	600
	Threskiornis spinicollis	Straw-necked ibis	>3000
1989	*Plegadis falcinellus*	Glossy ibis	720
	Ardea intermedia	Intermediate egret	20
	Threskiornis spinicollis	Straw-necked Ibis	18000
1990	*Pelecanus conspicillatus*	Australian pelican	200
	Phalacrocorax carbo	Great cormorant	100

Year	Scientific Name	Common Name	Number
	Ardea intermedia	Intermediate egret	10
	Platalea regia	Royal spoonbill	400
	Threskiornis spinicollis	Straw-necked Ibis	100000
1991	*Pelecanus conspicillatus*	Australian pelican	5000
	Threskiornis spinicollis	Straw-necked ibis	500
1996	*Phalacrocorax carbo*	Great cormorant	800
	Phalacrocorax varius	Pied cormorant	150
	Platalea regia	Royal spoonbill	300
	Threskiornis spinicollis	Straw-necked ibis	204 000
1997	*Phalacrocorax carbo*	Great cormorant	100
	Phalacrocorax varius	Pied cormorant	80
	Platalea regia	Royal spoonbill	100
	Threskiornis spinicollis	Straw-necked ibis	2500
	Threskiornis spinicollis	Straw-necked ibis	2300
1998	*Phalacrocorax carbo*	Great cormorant	100
	Phalacrocorax varius	Pied cormorant	80
	Platalea regia	Royal spoonbill	3000
	Platalea regia	Royal spoonbill	40
	Threskiornis spinicollis	Straw-necked ibis	100000
1999	*Pelecanus conspicillatus*	Australian pelican	3020
	Phalacrocorax carbo	Great cormorant	100
	Phalacrocorax varius	Pied cormorant	150
2001	*Threskiornis spinicollis*	Straw-necked ibis	very large event
	Platalea regia	Royal spoonbill	383
2008	*Threskiornis spinicollis*	Straw-necked ibis	140 000
	Platalea regia	Royal spoonbill	not given
	Plegadis falcinellus	Glossy ibis	4680*
	Threskiornis molucca	Australian white ibis	3120*

Appendix D: Fish species and ecology

Fish species recorded from the Narran Lake Nature Reserve Ramsar site: source Thoms et al. 2007; MDBC 2008; Rolls and Wilson 2010.

Migration type: P – Potamodromous.

Ecology and biological information sourced from FishBase (Froese and Pauly 2010) and Treadwell and Hardwick (2003).

Family	Scientific name	Common name	Migration type	Ecology/ biology
Retropinnidae	*Retropinna semoni*	Australian smelt	P	Pelagic in fresh to brackish waters including streams, backwaters, lakes, swamps and estuaries. One of the most widespread species in south-eastern Australia. Most common in slow-flowing streams and still waters, shoaling near the surface or around the cover of aquatic plants and woody debris. Forms large aggregations in open water. Feeds on aquatic insects, microcrustaceans and algae. Spawns throughout the Murray-Darling river system. Breeds between July and March (mostly in spring). Spawning temperature is about 15 °C. Eggs are laid among aquatic vegetation and hatch in about 10 days. Sexual maturity is attained by the end of the first year. There are no major threats to this species.
Eleotridae	*Hypseleotris* species.	Carp gudgeons	P	Possibly the most common and widespread complex of species (Bertozzi et al. 2000) in the Murray Darling Basin. Breed in spring and summer depositing eggs on aquatic vegetation in shallow waters. Flooding is not a trigger for spawning. Eggs are demersal and transparent. Little information is known regarding migration. Adults are often found in off-channel habitats, all species prefer vegetated shallow waters.
	Hypseleotris klunzingeri	Western carp gudgeon	P	Demersal small bodied native. Typically found around littoral vegetation in dams, lakes and canals as well as streams. Inhabits slow-flowing rivers or in still water including billabongs. It congregates in large schools below dams and weirs. Feeds on insects, larvae, microcrustaceans and some plant material. Spawning occurs from late spring to summer when water temperatures rise above 22°C. The male guards and fans the eggs until hatching about 2 days later. Young reach sexual maturity by the end of their first year
Melanotaeniidae	*Melantotaenia fluviatilis*	Murray river rainbowfish	P	Benthopelagic. Found in rivers, creeks, drains, ponds and reservoirs. Inhabit the lowland reaches of the Murray Darling Basin in South Australia, northern Victoria, New South Wales and southern QLD. Occurs usually in still or slow-flowing conditions. Inhabits streams, backwaters of larger rivers, drainage ditches, overflow ponds and reservoirs. Usually congregates along grassy banks or around submerged logs and branches. Omnivorous. The most southward-ranging rainbowfish are the only species adapted to low winter temperatures (normally about 10°-15°C). There is evidence that numbers are drastically reduced during

Family	Scientific name	Common name	Migration type	Ecology/ biology
				winter drought when water temperatures dip below 10°C.
Clupeidae	*Nematalosa erebi*	Bony herring	P	Pelagic in fresh to brackish waters. Occur often far up rivers, but also in estuaries. Most commonly inhabit streams coursing through relatively dry eucalyptus-scrub or desert areas, preferring sluggish or quiet waters. May have actually benefited from river regulation. Also found in saline lakes (slightly less salty than sea water). Tolerant of water temperatures between 9° and 38°C and pH 4.8-8.6. Although these fish have a wide tolerance of temperature and pH, they are susceptible to oxygen depletion and are usually the first to perish when ephemeral habitats begin to dry up. Frequently noted in large shoals that feed on benthic algae; also feed on insects and small crustaceans. Spawning may occur repeatedly in the north with a peak during the wet season; probably annual in the south
Terapontidae	*Bidyanus bidyanus*	Silver perch	P	Only known from the Murray Darling system with its northern most range in the Condamine Valley. The species is benthopelagic occurring in rivers, lakes and reservoirs, preferring fast-flowing waters of rapids and races and usually forming aggregations near the surface. Often found below rapids and weirs, this species feeds on invertebrates and plants. Spawning occurs in summer (Nov.-Jan., 23-30°C water temp.), effect upstream migration.
	Leiopotherapon unicolour	Spangled perch	P	Demersal, freshwater to brackish. Endemic to Australia this species is found in wide range of habitats from forest streams to desert bores, including billabongs, lakes and dams. May be encountered in any temporary water in the interior after rains, including wheel ruts of vehicle tracks. Reflecting this range of habitats it has been found in variable regimes of salinity (pure fresh to seawater), pH (4.0 to 8.6) and temperature (5° to 44° C). It is omnivorous, feeding on invertebrates and plants. A hardy species that may be capable of surviving droughts by aestivating in wet mud or under moist little on the bottom of ephemeral waterholes. Spawning occurs on summer nights (November onwards) when water temperatures reach 20°-26°C. Fish moves upstream in rivers or to the shallows in lakes and ponds to spawn on soft substrates. The eggs hatch in 2 days and larval development is complete in about 24 days. Neither anterolateral glandular grooves nor venom gland is present
Percichthyidae	*Macquaria ambigua*	Golden perch	P	Demersal, freshwater. Golden perch is a lowland to mid-slopes species with a wide distribution throughout the Murray Darling Basin. Distribution and abundance has declined particularly above dams in the upper reaches of most tributaries in the Basin. For example abundance has decreased by approximately 50 % since the 1940s in the River Murray at Euston. They favour deep pools with plenty of cover from fallen timber, rocky ledges or undercut banks. Prefer warm, slow-moving, turbid sections of streams. Also occur in flooded lakes, backwaters and impoundments but not common in wetlands per se, except if they are deep (> 1.5 m), or have deep connecting channels with some flow. Tolerant of temperatures between 4° and 35°C and high salinity levels (up to 35 ppt.). Solitary species. Their diet is dominated by yabbies (*Cherax*

Family	Scientific name	Common name	Migration type	Ecology/ biology
				destructor), and a variety of fish species. Juveniles disperse throughout the floodplain to find food and cover. They feed on abundant zooplankton on recently inundated floodplains. Adults feed on fishes, molluscs and crayfish. Spawn from early spring to late autumn. Golden perch is Australia's most migratory freshwater fish species, moving throughout the year. Spawn in flooded backwaters near the surface at night after heavy spring and summer rains. Usually a long upstream spawning migration is undertaken (movements of 2000 kilometres by tagged fish have been documented). Eggs float near the surface and hatch in 24-36 hours. Males mature after 2-3 years, females after 4 years. Important water quality parameters are temperature, oxygen, pH, transparency and nutrients. Larvae can be influenced by water quality. Threats to the species include altered flow regimes, thermal stratification and barriers to migration.
Plotosidae	*Neosilurus hyrtlii*	Hyrtl's tandan	P	Demersal, freshwater. Found in clear, flowing streams, turbid rivers, lakes and stagnant pools. Also inhabits billabongs. Shoal forming species. Feeds on insects, crayfish, prawns, mollusks, worms and crustaceans. In northern populations, breeding occurs at the beginning of the wet season (January to March) in shallow sandy areas in the upper reaches of streams. The spawning habits of interior populations are unknown.
	Anguilla reinhardtii	Long-finned eel	?	The Condamine Balonne Catchment is the only inland catchment from which this coastal species has been recorded. It is possible this species was translocated into the catchment. This species is demersal and normally catadromous. The species is characterised by a mottled colour and tooth bands with separated inner series. They occur in lagoons, rivers, streams, lakes and other wetlands including farm dams. Mainly feed at night on invertebrates, fish and elvers.
Percichthyidae	*Maccullochella peelii peelii*	Murray cod	P	Demersal, potamodromous. Listed as vulnerable under the EPBC Act and as critically endangered on the IUCN Red List. Murray cod live in a wide range of habitats, from clear, rocky streams to slow flowing, turbid rivers and billabongs. They are generally found in waters to 5 m deep, in sheltered areas with cover from rocks, timber or overhanging banks. Adult fish are carnivorous, having a diet of invertebrates, fish, amphibians and occasionally reptiles, birds and aquatic mammals. The young feed on zooplankton. Spawning takes place from spring to early summer. Murray cod are territorial, their 'territory' associated with a specific hole, snag (large woody debris) or area of a river or lake. Juveniles may undertake migrations.

Appendix E: Threatened fauna and flora

Data extracted from DECCW (2010a) Atlas of NSW Wildlife June 2010**.** Nomenclature is based on Christidis and Boles (2008).

Family	Common name	Species	NSW Threatened Species Act 1995	National/ International
Waterbirds				
Anatidae	Blue-billed duck	*Oxyura australis*	V	
	Freckled duck	*Stictonetta naevosa*	V	
Anseranatidae	Magpie goose	*Anseranas semipalmata*	V	
Ardeidae	Australasian Bittern	*Botaurus poiciloptilus*	V	IUCN-E EPBC-E
Ciconiidae	Black-necked stork	*Ephippiorhynchus asiaticus*	E	
Gruidae	Brolga	*Grus rubicunda*	V	
Scolopacidae	Black-tailed godwit	*Limosa limosa*	V	
Landbirds				
Accipitridae	Black-breasted buzzard	*Hamirostra melanosternon*	V	
	Little eagle	*Hieraaetus morphnoides*	V	
Cacatuidae	Major Mitchell's cockatoo	*Lophochroa leadbeateri*	V	
Climacteridae	Brown treecreeper	*Climacteris picumnus*	V	
Meliphagidae	White-fronted chat	*Epthianura albifrons*	V	
Otididae	Australian bustard	*Ardeotis australis*	E	
Petroicidae	Hooded robin	*Melanodryas cucullata*	V	
Pomatostomidae	Grey-crowned babbler (eastern subspecies)	*Pomatostomus temporalis temporalis*	V	
Strigidae	Barking Owl	*Ninox connivens*	V	
Mammals				
Emballonuridae	Yellow-bellied sheathtail-bat	*Saccolaimus flaviventris*	V	
Phascolarctidae	Koala	*Phascolarctos cinereus*	V	
Plants				
Brassicaceae	Winged peppercress	*Lepidium monoplocoides*	E	EPBC-E