Australian Government

Department of the Environment, Water, Heritage and the Arts

Banrock Station

Ramsar Wetland Complex

Ecological Character Description

Image credits: J. Baker; B. Furby; N. Sloane; A. Dudley

Ecological Character Description for the Banrock Station Wetland Complex.

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Cover photo: Banrock Station Banrock Lagoon, Water's Edge Consulting.

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Abbreviations

CAMBA	China Australia Migratory Bird Agreement
DEH	Department for Environment and Heritage, South Australia
DEWHA	Department of Environment, Water, Heritage and the Arts (Commonwealth)
DIWA	*Directory of Important Wetlands in Australia* (Environment Australia 2001)
ECD	Ecological Character Description
EPBC Act	Environment Protection and Biodiversity Act, 1999 (Commonwealth)
JAMBA	Japan Australia Migratory Bird Agreement
LAC	Limits of Acceptable Change
RIS	Ramsar information sheet
RMP	Ramsar management plan
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement

Executive Summary

Banrock Station Wetland Complex is located on the River Murray floodplain immediately downstream of Kingston on Murray, opposite Overland Corner, in the Riverland of South Australia (Figure E1). The site was listed as a Ramsar Wetland of International Importance in 2002.

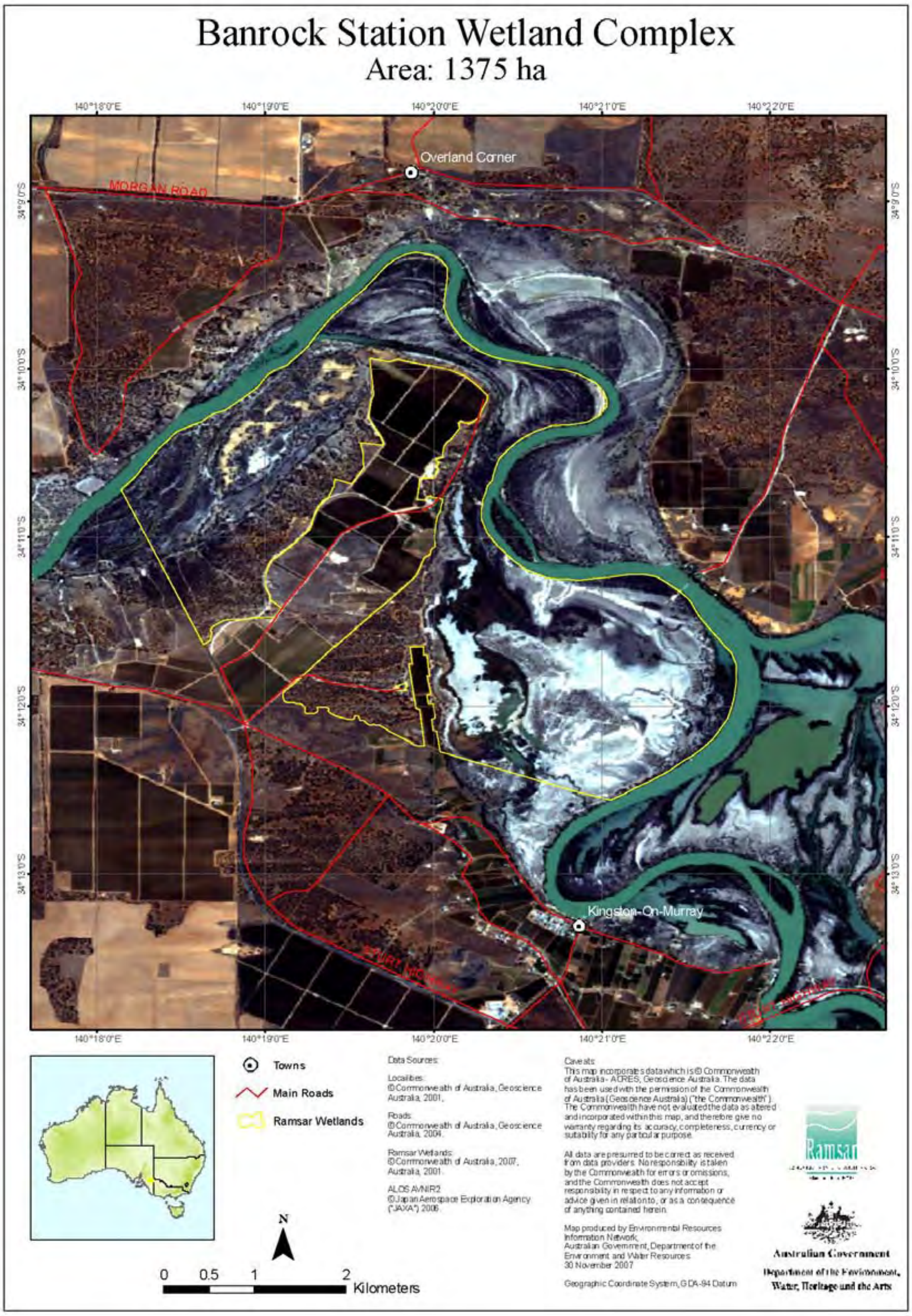


Figure E1: Map of the Banrock Station Wetland Complex. Supplied by DEWHA 2009.

The Banrock Station Wetland Complex straddles the boundary of the Mallee Trench and Mallee Gorge geomorphic tracts and supports a number of discrete depositional basins and active channels on an incised ancestral floodplain which is approximately 5 -10 m above sea level. The largest wetland basin is referred to as Banrock Lagoon. The Eastern Lagoon is joined to Banrock Lagoon during high flows and together they form the major freshwater wetland area of the site. Surrounding these lagoons are significant areas of Samphire and Lignum dominated floodplain, much of which is affected by rising saline groundwater. Additional intermittently flooded wetlands occur on Wigley Reach. The mallee areas of the site rise to 40 - 50 m above the floodplain with the highest point on the site being 62 m above sea level (Constellations Wines Australia 2008a). The site straddles Lock 3 on the River Murray and is a flow through wetland system.

The site supports a number of species and communities typical of the lower River Murray floodplain. Over 120 species of plants, 138 species of birds including 14 species of waterbirds and wetland dependent species listed as threatened in South Australian have been recorded on the site. There are over 85 species of woodland birds, eight of which are considered rare in South Australia. Seven native mammals and four introduced species have been recorded from the site, 14 species of reptiles and eight amphibians have been also been recorded on site.

The Banrock Station Wetland Complex currently meets the following Ramsar criteria:

> **Criterion 2:** The Banrock Station Wetland Complex supports two nationally listed species, the Vulnerable Regent Parrot (*Polytelis anthopeplus monarchoides*) and the Vulnerable Southern Bell Frog (*Litoria raniformis)*.
>
> **Criterion 3:** This site meets sub criterion 3aiii) in that it supports the range of biological diversity (including habitat types) found in the region. The site is located at the transition between the Mallee Trench and Mallee Gorge resulting in a large number of habitat types found in the lower part of the Murray Darling Basin occurring in a relatively small area. The flora and fauna of the site are typical of a lower River Murray freshwater and salt affected wetland complex in a semi-arid environment. Also the site is one of the few locations in South Australia where the rare River Snail (*Notopala sublineata*) has been successfully bred.
>
> **Criterion 4:** The Banrock Station Wetland Complex provides non-breeding habitat for 10 migratory waterbirds listed under JAMBA, CAMBA and ROKAMBA agreements. However the numbers of individuals are not large nor are most of the species recorded regular visitors. The exception is the Eastern Great Egret (*Ardea modesta*) which occurs at the site on a regular basis with records for eight of the past ten years. In addition, the site has also supported large numbers of moulting Australian Shelduck (*Tadorna tadornoides*) (M. Harper,

DEH, pers. comm.), however the frequency of moulting events has not been recorded and this remains a knowledge gap. Lateral migration of small bodied native fish species occurs via the inlet and outlet creeks.

A summary of the critical components and processes, benefits and services of the Banrock Station Wetland Complex is provided in Table E1.

Table E1: Summary of components, processes and services of the Banrock Station Wetland Complex at the time of listing.

Category	Summary Description
Benefits and services	
Supporting services	• Hydrological processes - The hydrological regime supports a number of floodplain wetland habitats. Wetting and drying of the wetland has been shown to have some influence on local groundwater levels and stress to riparian vegetation. • Physical habitat - Supports a range of wetland habitats representative of the lower River Murray floodplain. • Biodiversity - Supports a range of species typical of lowland River Murray floodplain wetlands and mallee shrublands. • Threatened wetland species, habitats and ecosystems - Supports the nationally listed species, Regent Parrot and Southern Bell Frog, the latter being considered globally endangered (IUCN 2009).
Components and processes	
Geomorphology	Straddles the boundary of the Mallee Trench and Mallee Gorge geomorphic tracts
Hydrology	The major wetland basin, Banrock Lagoon, was permanently inundated, as were inlet and Banrock Creek. Eastern Lagoon was inundated at higher flows. Intermittently filled freshwater wetlands on Wigley Reach fill with overbank flows.
Water Quality	Largely a freshwater system and although salinity fluctuates (predominantly reflecting changes in the River Murray source water), the system remains fresh at all times with electrical conductivity typically between 500 and 1000 µS/cm. For the majority of the time, salinity in the wetland reflects salinity in the River Murray. However, when the wetland is in the process of being filled beyond 8.5 m AHD, the surrounding floodplain (Eastern Lagoon and beyond) becomes inundated and salts stored in surficial sediments are released raising salinity in the wetland. Similar to salinity, turbidity often reflects water quality condition in the source water (River Murray).
Vegetation	16 broad vegetation associations and 7 broad structural forms are found onsite. The vegetation associations considered critical to the ecological character of the Banrock Station Wetland Complex are described below and include: • River Red Gum and Black Box woodlands – support Regent Parrots • *Tecticornia* (Samphire) shrublands – important waterbird habitat when flooded • Lignum shrublands – important fish and waterbird habitat when flooded • *Typha* sedgelands and *Phragmites* grasslands – important fish and frog habitat • Aquatic macrophyte herblands – important fish and frog habitat
Birds	The site supports species typical of inland floodplain wetlands. A total of 61 wetland associated bird species have been recorded within the site several of which are listed under the migratory waterbird treaties.
Fish	Fish surveys of the Banrock Station Wetland Complex have recorded 9 species of native fish and four invasive species. The fish community at

Category	Summary Description
	Banrock is characterised by a lack of adult large bodied native species, with the majority of species recorded being small bodied species. As the wetland is shallow, the large bodied native species such as Murray Cod and Silver Perch have not been recorded in the wetland as these species prefer deeper habitats. Common Carp are a significant threat to the character of the site.
Invertebrates	Fauna is typical of lower River Murray floodplain habitats. The rare River Snail *Notopala sublienata* is found at the site as an introduced population.

The critical components, processes and services central to the character of the site are shown conceptually in Figure E2.

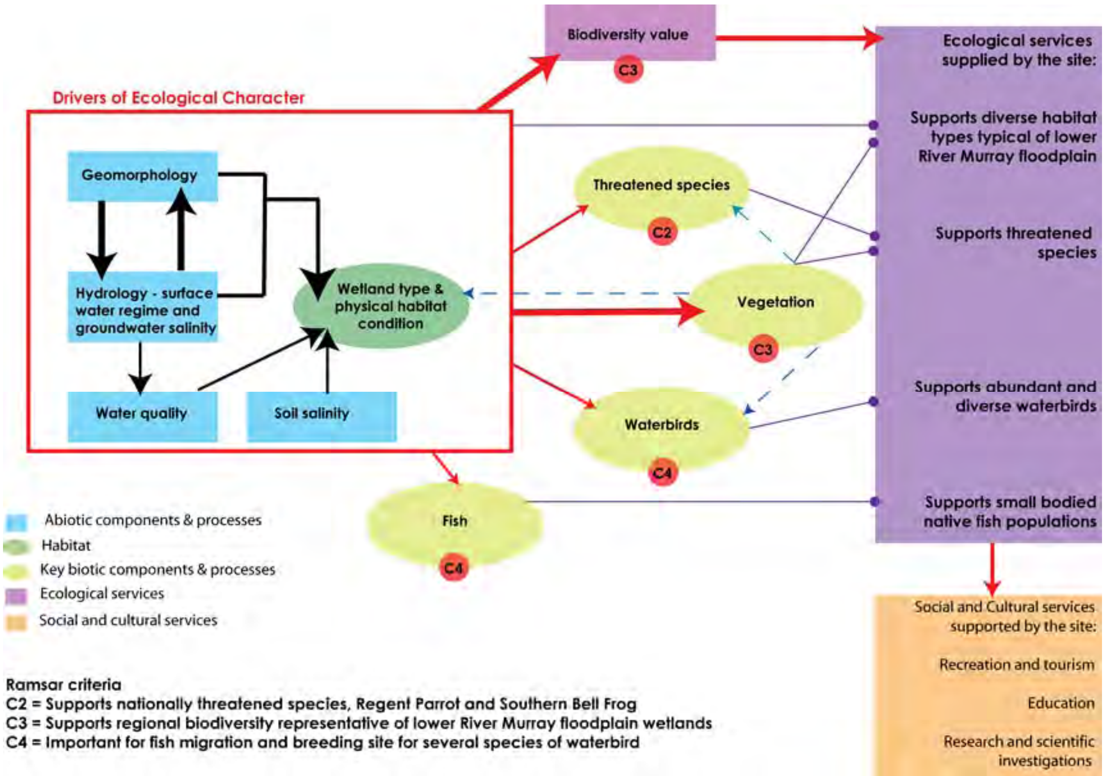


Figure E2: Critical elements of ecological character of the Banrock Station Wetland Complex. C2-4 indicates the link between the key components processes and ecological services and the Ramsar criteria for which the site is nominated. Strength of arrows indicates importance, not all interactions/connections shown.

"Limits of acceptable change" (LAC) is the terminology used under the Ramsar convention to set limits on how much key aspects of the ecology of the site can change without risking the ecological character. LAC for the Banrock Station Wetland Complex have been determined based on existing data and guidelines. These have been set for the time of listing. Several of the LAC have been triggered since water management practices have changed at the site; shifting from a permanently inundated system to an intermittently inundated system. New LAC have been set for the relevant components and services affected by the change in character. Original and current LAC are presented in Tables E2 and E3.

A stressor model of the major threats, stressors and the ecological effects which have the potential to influence, or are currently affecting, the ecological character of the site is presented in Figure E3.

While there are many potential threats that may impact on the habitat and biodiversity values of the wetland system, many of them are controlled under current management arrangements for the site. The main threats to the ecological character of the Banrock Station Wetland Complex are the ongoing impacts from river regulation, rising groundwater and salinisation of the floodplain, invasive species and to a lesser extent recreation and tourism activities. These are summarised in Table E4.

Table E2: Limits of acceptable change at time of listing.

Component, process, service	Baseline and supporting evidence	Limit of Acceptable Change	Comments/ LAC exceeded
Hydrological processes – Banrock and Eastern Lagoons – at listing	Permanently inundated wetlands with water levels managed to promote littoral vegetation responses. The permanent inundation regime may contribute to maintaining local water balance between surface and groundwater however the relative importance of this is not known.	Maintenance of Banrock Lagoon as permanently inundated, allowing for seasonal fluctuations of inflows from the River Murray. Depth 8.5 – 8.8 m AHD. Frequency of inundation - alternating years of stable and fluctuating levels. No complete drying of wetland bed. Maintain Eastern Lagoon as drier site with inundation for 3-6 months during managed spring flood to 9.3 m AHD in Banrock and Eastern Lagoons.	LAC is based on expert opinion and published literature (Gippel 2006, Crosbie et al. 2007; Constellation Wines Australia 2008a). This LAC has been exceeded – see Table E3
Hydrological processes – Wigley Reach floodplain	Wigley Reach supports a range of intermittent River Red Gum dominated wetlands. Loss of small to medium floods has reduced the frequency of inundation in this part of the site. Under natural conditions the floodplain would have been flooded once in 3–4 years, but the area is now watered only once in about 12 years (George et al. 2005). George (2003) suggested that positive growth of RRG and Black Box rely on moderate river flows (40,000-80,000 ML/day) coupled with average rainfall (250 – 300 mm/year), with active growth interrupted with saturated conditions occurring when flows exceed 80,000 ML/day	LAC is based on watering requirements to sustain dominate vegetation association. In wet years (rainfall greater than 300 mm) peak flows of 30, 000 ML/day, in dry years (rainfall 250 - 300 mm) peak flows of 40, 000 – 80, 000 ML/day. Frequency of inundation 1 in 4 years. Duration 4 – 7 months. Magnitude as above. Maximum interval without inundation 5 years.	At listing the natural cycle of flooding was already altered, with the LAC being set for the flooding regime for maintaining mature River Red Gum dominated wetlands. This LAC has been exceeded. Current onsite water management does not affect this LAC, so a new LAC has not been set.
River Red Gum woodlands	Approximately 177 ha, with mature trees declining and juveniles increasing at time of listing. There are several ways to measure change in vegetation communities (extent, health,	No more than 10% loss of extent of live trees from baseline of 177 ha of River Red Gum.	The area of healthy River Red Gums and Black Box trees is believed to have declined significantly since listing in 2002. Data from 2009 indicate further decline in the extent of live trees and tree health (K. Thorn, Banrock Station, pers. comm.); however there is

Component, process, service	Baseline and supporting evidence	Limit of Acceptable Change	Comments/ LAC exceeded
	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.		insufficient data across the whole site to inform whether there has been sufficient loss of extent of live River Red Gum to indicate a possible change in ecological character. At this point in time it is believed the LAC has not been triggered, however this needs further investigation. Declines are believed to be in line with regional trends, or potentially less.
Black Box woodlands	Approximately 222 ha.	No more than 20% of loss of extent of live trees from baseline of 222 ha.	A lack of monitoring data on Black Box communities means it is not possible to establish if this LAC has been exceeded since listing. This remains a knowledge gap. The LAC is based on expert opinion.
Samphire shrubland	Approximately 223 ha.	Increase in extent – no more than 5 % increase in 5 year period from baseline of 223 ha.	Increases in Samphire shrubland is taken as indication of increased salinisation of the floodplain. Percentage change is based on expert opinion.
Supports threatened species – Regent Parrot	Approximately 100 adult birds (Constellation Wines Australia 2008a). Data collected by DEH suggest the breeding population on site at Banrock constituted 21 % of the regional population at the time of listing. Nesting trees on site contributed to 23 % of habitat used by the regional population (2003/2004 data). Note that there is no count data pre the time the site was listed and therefore the baseline is set on a single sampling event.	No greater than 10% decline in number of breeding pairs over three consecutive seasons. Unless there is evidence that decline in breeding species is caused by changes outside the boundary of the site, and an on-site rate of decline does not exceed the regional trend.	Further monitoring is required to establish trends and causative factors affecting declines on site. Declines in numbers of breeding pairs from 2002 to 2008 reflect regional declines and are not attributed to on site change and therefore this LAC has not been exceeded.
Supports threatened species - Southern Bell Frog	Population estimates are not available, only records of calls and sightings of frogs. Frogs appear to be present and breeding in most years (Banrock unpublished data; Constellation Wines Australia 2008a).	No loss of breeding population, males not heard for two consecutive years and no confirmation of breeding every two years (i.e. tadpoles observed).	Based on opinion of Steering Committee.

Component, process, service	Baseline and supporting evidence	Limit of Acceptable Change	Comments/ LAC exceeded
Biodiversity - Supports waterbird breeding	Five species of waterbird commonly breed on site: Black Swan, Australian Wood Duck, Australian Shelduck, Grey Teal, and Purple Swamphen. Musk Duck have also been recorded breeding on site.	Annual breeding in 3 of the 5 species which commonly breed on site. Unless there is evidence that decline in breeding species is caused by changes outside the boundary of the site.	Based on opinion of Steering Committee.
Biodiversity – supports native fish	Supports up to 9 species of native fish, with small bodied species being the most common.	7 of 9 recorded native species with multiple size classes indicative of a healthy population.	Based on expert opinion.

Table E3: Limits of acceptable change under current water management practices (2007-current).

Component, process, service	Baseline and supporting evidence	Limit of Acceptable Change	Comments
Hydrological processes – Banrock and Eastern Lagoons – current management	Introduction of a wetting and drying regime was considered beneficial to the wetlands on site as this would return the hydrological regime to a near natural state. Desired wetting and drying regime is Banrock Lagoon wet for 18 months (can fluctuate water levels) then dried for 6 months. During wet phase increase height to wet Eastern Lagoon for approximately 3 month period.	Banrock Lagoon not > 9 months without flow-through phase (8.5m AHD). Banrock and Eastern Lagoon not > 24 months without inundation to 9.2 AHD.	Based on current management plan for the Banrock Station Wetland Complex (see Constellation Wines Australia 2008a).
Biodiversity – supports native fish	Whilst condition of native fish population is unknown, it is assumed that reduced numbers and biomass of Common Carp will improve habitat and condition of	Common Carp comprise > 20 % by number or > 50 % by biomass of fishes in Banrock wetland.	This is a LAC set in response to new water management practices, this more typical of a management trigger but is included here as Common Carp management is a major factor in

	native fish community.		improving the condition of Banrock wetlands.

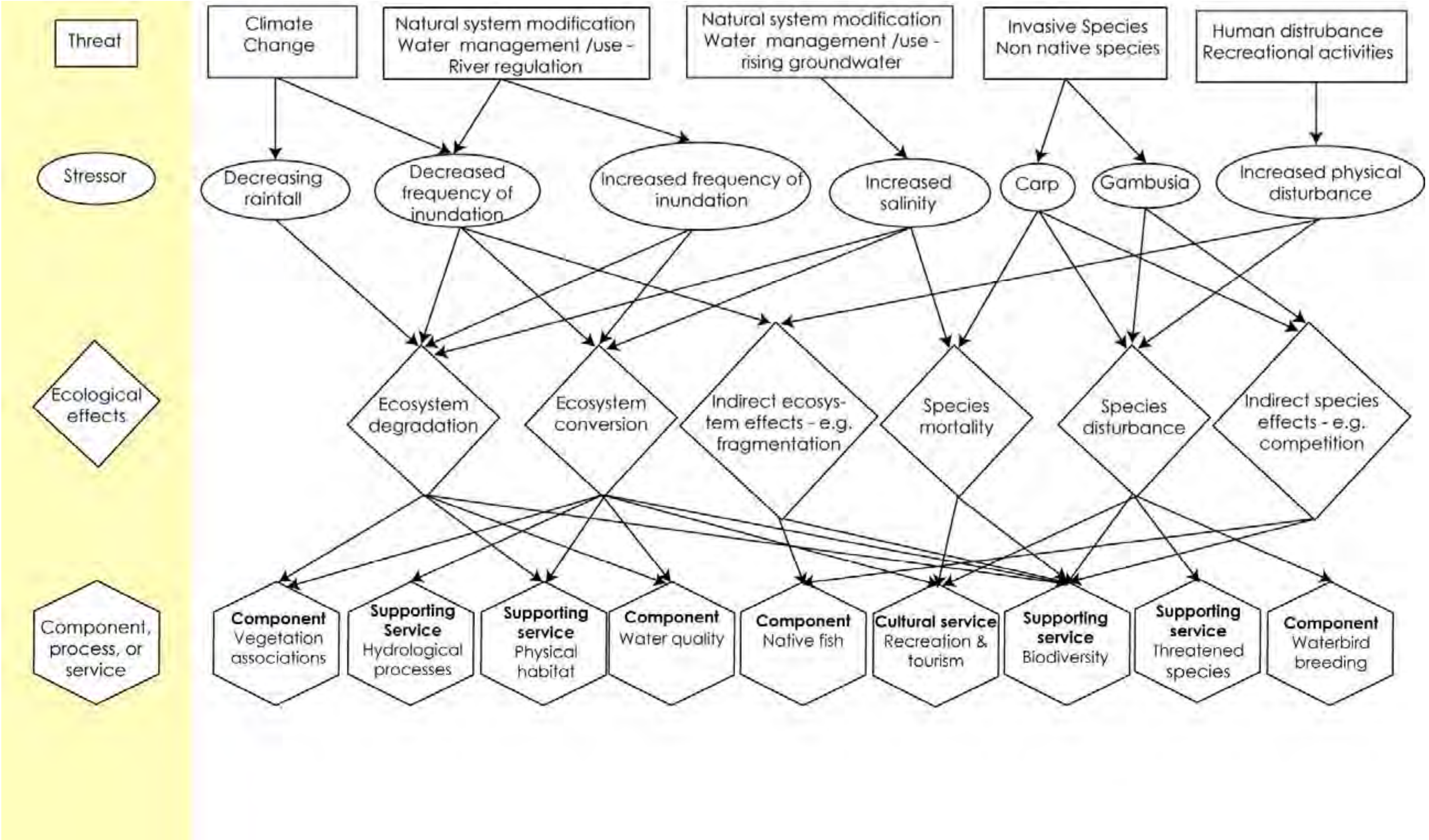


Figure E3: Major threats and stressors to ecological character at the Banrock Station Wetland Complex. Not all threats shown.

Table E4: Summary of the main threats to the Banrock Station Wetland Complex. Certain = known to occur at the site or has occurred in the past. Medium = not known from the site but occurs at similar sites. Low = theoretically possible, but not recorded at this or similar sites.

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, and/or service	Likelihood	Timing of threat
Natural system modification. Water management/ use – river regulation	• Permanent flow through wetland • Loss of small to medium floods • Altered ecological connectivity • Loss of habitat diversity • Facilitation of invasive species • Stressed riparian vegetation	Certain	Immediate
Natural system modification. Water management/ use – Rising saline groundwater	• Increased soil and water salinity • Stressed riparian vegetation • Changed species composition • Decreased diversity	Certain	Immediate
Invasive species – non native species	• Competition with native fish • Predation of Southern Bell Frog tadpoles • Water quality issues • Predation of turtles at all life stages • Predation on ground-nesting birds	Certain	Immediate – medium term (5 years)
Pollution. Acid sulphate soil development	• Deoxygenation of water column • Decreased pH to levels harmful to biota	Medium	Medium to long term (5 years to decades)
Human Disturbance. Recreation and tourism – vehicle impacts	• Compaction of soils • Loss of vegetation • Potential erosion issues • Disturbance during bird breeding events	Medium	Immediate – long term
Human Disturbance. Recreation and tourism – visitor impacts	• Compaction of soils • Loss of vegetation	Medium	Immediate – long term
Natural system modification. Water management/ use Vineyard operations - pumping	• Extraction of water required permanent inundation – see above for associated potential impacts	Certain, past	From listing until 2006
Agriculture and aquaculture. Vineyard operations – vehicle tracks	• Compaction of soils • Loss of vegetation • Potential erosion issues	Medium	Immediate – long term
Agriculture and aquaculture. Vineyard operations – irrigation drainage	• Increased recharge into wetlands • Increased riparian soil salinity	Low	Immediate – long term
Climate change – temperature rise and reduced rainfall	• Altered water regime, less water available • Altered seasonality of flooding • Reduced wetland condition and resilience • Changes in range and life cycle of biota, including threatened and invasive species	Medium	Medium to long term (5 years to decades)

There are a number of key knowledge gaps that limit the description of ecological character and the setting of limits of acceptable change for the Banrock Station Wetland Complex (Table E5).

Table E5: Summary of knowledge gaps for components and services relevant to the maintenance of the ecological character of the Banrock Station Wetland Complex.

Component/Service	Knowledge Gap	Recommended Action
Geomorphology	None identified	
Soils - Potential ASS	Understanding of implications of changed hydrological regime on rates and amounts of PASS development is not known.	Undertake detailed risk assessment.
Hydrology	Surface water-groundwater trends, and local water balance.	Long term monitoring of groundwater trends in response to repeated wetting and drying.
Water Quality	The relationship between organic matter breakdown and buffering of acidity caused by ASS.	Partnership research with CSIRO during 2-3 consecutive years.
Vegetation communities	The fate of declining Black Box Tree communities east of the Banrock Lagoon, and strategies to protect them. The role and value of mallee ecosystems as feeding sites for Regent Parrots.	Partnership research through post-graduate studies. Coordination of investigations into declining tree health as per work undertaken at the Riverland Ramsar site – i.e. using same methods of assessment. Partnership studies with DEH Endangered Species Program.
Threatened species	Population size for Southern Bell Frog and on site variability. Relationship between tree health on site and breeding colony size of Regent Parrots.	Continued monitoring in response to wetting and drying regime.
Waterbirds	The role of the wetland as habitat for cryptic bird species such as crakes and rails, and their distribution and abundance.	Partnership research with Birds Australia, post-graduate students.
Fish	Use of wetland for nursery and spawning site for small bodied native fish. Presence of Freshwater Catfish at the site. Evaluation of the importance of Banrock wetland as a pathway for the dispersal of fishes around Weir 3. Identify which species can successfully negotiate the current flow control regulators, both in an upstream and downstream direction. Required modifications to control	Continued monitoring in response to wetting and drying regime. More detailed surveys in deeper water around the connecting channels. Monitoring associated with this will also allow evaluations of temporal variation in the relative abundances of alien versus native fishes. Investigate the appropriateness of the design requirements described in Mallen-Cooper

Component/Service	Knowledge Gap	Recommended Action
	regulators which will better accommodate the passage requirements of small-bodied native fishes.	(2001).
Invertebrates and food web	Baseline information on *Notopala* population on site. Baseline survey of all invertebrate taxa to species level to determine any key indicators.	Assessment of irrigation pipes and establishment of risk to population. Partnership with research organisations institutions.

To address these knowledge gaps and inform against the limits of acceptable change the monitoring needs for the Banrock Station Wetland Complex have been documented and prioritised.

Banrock Station Wetland Complex has undergone a significant change in water regime over the period 2007 - 2009 resulting in a significant change in ecological character of the site.

At the time of listing this wetland system was a permanent flow through system with a fluctuating water level. In January 2007 the regulators were closed at the inlet creek as part of a plan to reduce evaporation losses and to simulate a natural drying cycle with the aim to improve the long term health of the wetland. Under the guidance of the Ramsar Management Plan the wetland was due to refill in late August 2007, however, ongoing drought conditions in the Murray Darling Basin led the South Australian Government to close 29 River Murray wetlands including Banrock Station wetland to reduce water losses through evaporation (Constellation Wines Australia 2008a).

In June 2008 the Banrock Lagoon was refilled after being dry for 18 months. The riparian River Red Gum community surrounding Banrock and Eastern Lagoons had not been inundated for a period of 30 months (Sharley et al. 2009). In May 2008 an environmental water allocation of 617 ML was granted by the Murray Darling Basin Commission's Living Murray Program. Banrock Station purchased an additional 215 ML for the refilling of the wetland. Refilling commenced in June 2008 in Banrock Lagoon to coincide with lowest period of evaporation losses, thus maximising the volume of water available to recharge the soil.

This pattern of wetting and drying led to changes in a number of key components. The current condition as documented in Section 7 represents a positive change in ecological character for the Banrock Station Wetland Complex. This wetland system can now be considered an intermittent, instead of permanent, freshwater and saline wetland floodplain complex.

Regardless of this change in hydrological regime, the wetland complex continues to support the services which meet criteria 2, 3, and 4 under the Ramsar Convention.

Continued wetting and drying of the main wetlands, shifting the hydrology of the system from a permanent flow through system to an intermittent freshwater wetland system, will ultimately induce further ecological responses/change. Timing of wetting and drying will require careful monitoring to ensure the benefits continue to be positive with no loss of any of the critical components, processes or services. In particular riparian vegetation health, production of acid sulphate soils and rising salinity are key threats that require monitoring.

This site is highly managed, and represents an excellent example of the wise use concepts. Banrock Station combines wetland conservation and rehabilitation with raising awareness of wetland values and functions, and private enterprise. In 2002 Banrock Station Wines received one of three prestigious Ramsar Wetland Conservation Awards.

1 Introduction

The Banrock Station Wetland Complex was listed as a Wetland of International Importance under the Ramsar Convention on Wetlands in October 2002.

As a Contracting Party to the Ramsar Convention, Australia has a range of obligations in relation to the management of sites which are designated as Wetlands of International Importance. Key among these is the provision of a description of the ecological character of the site. Ecological character descriptions (ECD) form the benchmark or baseline description of the wetland at a particular point in time (usually the time of listing) and form the basis of assessing change in ecological character. Within Australia, it is a requirement that all nominated sites have an ECD prepared as part of the site documentation, which ultimately is forwarded to the Ramsar Secretariat (DEWHA 2008).

1.1 Preparing the ECD

The method used to develop the ecological character description for the Banrock Station Wetland Complex followed the twelve-step approach of the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008) illustrated in Figure 1.

This ECD was developed primarily through a desktop assessment of existing data and information, including the initial description of the ecological character provided in the site Management Plan (Constellation Wines Australia 2008a). A series of visits to the site were undertaken to engage on-site staff, technical experts and a stakeholder advisory group (Details of members of meetings and individuals engaged are listed 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 1: Twelve step process for developing an ECD (adapted from DEWHA 2008).

1.2 Site details

The Banrock Station Wetland Complex is located near the township of Kingston on Murray on the River Murray floodplain opposite the township of Overland Corner approximately 26 km north west of Berri in South Australia.

The site was listed as a Ramsar site in 2002 under criterion 1 – 4 (inclusive). Summary details for the nominated site are provided in Table 1.

Table 1: Site details for the Banrock Station Wetland Complex.

Site Name	Banrock Station Wetland Complex.
Location in coordinates	Longitude: 34˚ 11' S Latitude: 140˚ 20' E
General location of the site	The Banrock Station Wetland Complex is located on the River Murray floodplain downstream of Kingston on Murray in South Australia, opposite the township of Overland Corner, 26 km north west of Berri. The site lies within the Lower Murray River basin within the Murray-Darling drainage division.
Area	1,375 hectares.
Date of Ramsar site designation	22 October 2002.
Ramsar/DIWA Criteria met by wetland	Ramsar criteria met at time of listing 1, 2, 3, and 4. (Note that under the current bioregionalisation framework used to apply criteria the site no longer meets criterion 1 – see Section 2.5.2).
Management authority for the site	Constellation Wines Australia.
Date the ECD applies	2002 and current.
Status of Description	This represents the first ECD for the site.
Date of Compilation	October 2009.
Name(s) of compiler(s)	Rhonda Butcher on behalf of DEWHA, all enquires to Kate Thorn, Conservation and Wetland Manager, Banrock Station Wine and Wetland Centre, PO Box 346, Kinston on Murray, SA 5331, Australia. (Tel: +61 8 8583 0299; email kate.thorn@banrockstation.com.au
References to the Ramsar Information Sheet (RIS)	Banrock Station Wetland Complex, South Australia – 63 RIS completed by Bill Phillips in 2002 for SA DEH and Constellation Wines Australia http://ramsar.wetlands.org/Database/Searchforsites/tabid/765/Default.aspx
References to the Management Plan(s)	Constellation Wines Australia (2008) Banrock Station Wetland Complex Wetland of International Importance. Ramsar site 1221, Management Plan 2008 to 2014. Revision June 2008.

1.3 Defining ecological character and the purpose of the ECD

Once a wetland is designated as a Ramsar site a key obligation is to maintain its 'ecological character' and to have procedures in place to detect if any threatening processes are likely to, or have the potential to alter the 'ecological character' of the site.

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 wetland 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."*

A Ramsar information sheet (RIS) and Ramsar Management Plan (RMP) are required for each Wetland of International Importance in Australia. The RIS essentially summarises the key information (site details, criteria for which a site is listed, key components, processes and services) and historically these have been used as the main source of information for describing the ecological character of Ramsar sites. However, RISs are considered inadequate to form the basis of management decisions and monitoring programs as they lack the detail regarding interactions between ecological components (including physical and chemical), processes and services. As a result the Australian Government moved to develop a *National Framework and Guidance for Describing Ecological Character of Australia's Ramsar Wetlands. Module 2 of Australian National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia* (DEWHA 2008). The relationship of ECD within the context of other requirements for the management of Ramsar sites is illustrated in Figure 2 below. The legal framework for ensuring the ecological character of a listed site is maintained is the *Environment Protection and Biodiversity Act Conservation, 1999* (the EPBC Act 1999).

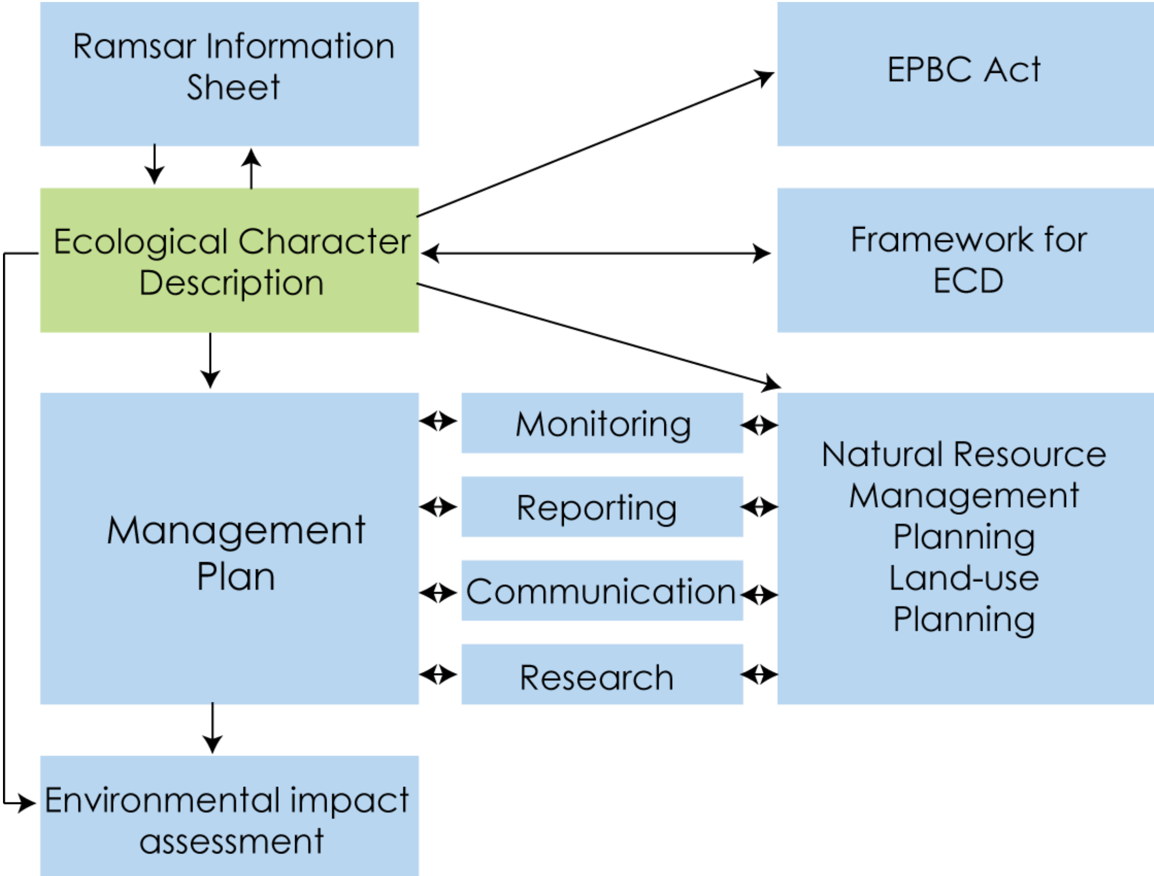


Figure 2: The ecological character description in the context of other requirements for the management of Ramsar sites (adapted from DEWHA 2008).

The ECD is a fundamental management tool for site managers forming the basis of management planning and action as well as including guidance on site monitoring requirements to detect negative impacts on the ecological character of the site (DEWHA 2008). In general, ecological character descriptions developed using the nationally agreed framework are used to (DEWHA 2008):

1. Provide the baseline description of ecological character of Ramsar wetlands;
2. Assess the likely impacts of proposed actions on the ecological character of Ramsar wetlands;
3. Guide development of management plans; and
4. Evaluate the results of monitoring.

Specifically, ECDs serve the following functions (as outlined by McGrath 2006):

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 Environment Protection and Biodiversity Conservation Act (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.

This document, therefore serves to describe the ecological character of the Banrock Station Wetland Complex, based on an assessment of the key ecological components and processes that determine the unique nature of the site, and provides support for its nomination as a Wetland of International Importance. Specifically the objectives of the ECD for the Banrock Station Wetland Complex are to provide a description of the ecological character that:

1. Defines the critical ecological components, processes, benefits/services of the wetlands within the Banrock Station Wetland Complex;

2. Develops conceptual models of the Banrock Station Wetland Complex which describe the ecological character in terms of ecological components, benefits/services and the relationships between them;

3. Quantifies the limits of acceptable change for the critical ecological components, processes and benefits/services of the wetland;

4. Provides an outline of a monitoring program that will facilitate the detection and ability to report any significant changes in the ecological character of the Banrock Station Wetland Complex; and

5. Identifies actual or likely threats and risks to the ecological components, processes or benefits/services of the Banrock Station Wetland Complex.

1.4 Relevant legislation at time of Listing

Effective management of the Banrock Station Wetland Complex requires the recognition and adoption of principles and actions identified in numerous pieces of international, national, State and regional agreements, legislation, NRM strategies and management plans. The most relevant of these are described briefly below.

1.4.1 International agreements

Ramsar convention

The Convention on Wetlands (the Ramsar Convention), came into being in Ramsar Iran in 1971 and was ratified in 1975. It provides the framework for local, regional and national actions, and international cooperation, for the conservation and wise use of wetlands. As of October 2009, 159 nations (including Australia) have joined the Convention as Contracting Parties, and more than 1,867 wetlands around the world, covering over 183 million hectares, have been designated for inclusion in the Ramsar List of Wetlands of International Importance (http://www.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1_4000_0__). Wetlands of international importance are selected on the basis of their international significance in terms of ecology, botany, zoology, limnology and or hydrology. To date, 65 Australian wetland sites covering approximately 7.4 million hectares have been listed under the Convention (http://www.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-36-123^23808_4000_0__).

Migratory bird agreements

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

- JAMBA - The Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment (1974) http://www.austlii.edu.au/au/other/dfat/treaties/1981/6.html ;
- CAMBA - The Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment (1986) http://www.austlii.edu.au/au/other/dfat/treaties/1988/22.html ;

- ROKAMBA - The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment (2006); and
- The Bonn Convention on Migratory Species - 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.

1.4.2 National legislation

EPBC Act 1999

The Environment Protection and Biodiversity Conservation Act 1999[1] (EPBC Act 1999) regulates actions that will have or are likely to have a significant impact on any matter of national environmental significance, including actions that may affect the ecological character of a Ramsar wetland (EPBC Act 1999). The EPBC Act 1999 establishes a framework for managing Ramsar wetlands, through the Australian Ramsar Management Principles, which promote national standards of management, planning, environmental impact assessment, community involvement, and monitoring.

The EPBC Act is administered by the Commonwealth Department of Environment, Water, Heritage and the Arts. In addition, the Australian Heritage Council was established under the Australian Heritage Council Act 2003 to advise the Federal government on issues related to the protection of places of National and Commonwealth heritage. This role includes such activities as:

- Promotion of the identification, assessment, conservation and monitoring of heritage places;
- Inclusion or removal of a place on the National Heritage List or list of Overseas Places of Historic Significance to Australia;
- Any other functions conferred on the Council by the EPBC Act 1999.

Some matters protected under the EPBC Act 1999 are not protected under local or State/Territory legislation; for example, many migratory birds are not specifically protected under State legislation. All species listed under international treaties (Ramsar, JAMBA, CAMBA and CMS) are covered by the EPBC Act 1999. Thus Ramsar listing of the Banrock Station Wetland Complex would confer additional protection to threatened species and communities under the EPBC Act 1999.

Other important national strategies and legislation that confer protection of values associated with systems such as the Banrock Station Wetland Complex include:

- National Framework for Management and Monitoring of Australia's Native Vegetation (2001) (http://www.environment.gov.au/land/publications/nvf/index.html);

[1] The EPBC Act 1999 is accompanied by the EPBC Regulations 2000.

- The National Strategy for the Conservation of Australia's Biological Diversity (1996) (http://www.environment.gov.au/biodiversity/publications/strategy/index.html)
- The Native Title Act (1993) (http://www.austlii.edu.au/au/legis/cth/consol_act/nta1993147/);
- The National Water Quality Management Strategy (1992) (http://www.environment.gov.au/water/quality/nwqms/)

1.4.3 State and regional legislation, strategies and plans

A significant body of State and regional legislation, NRM strategies and plans are relevant to or have the potential to affect the management of the Banrock Station Wetland Complex. Those in place at time of Listing include (listed chronologically):

- NatureLinks: Implementing the WildCountry philosophy in South Australia (2002) (http://www.environment.sa.gov.au/naturelinks/)
- Biodiversity Plan for the South East of South Australia (1999)
- Local Government Act (1999) (http://www.austlii.edu.au/au/legis/sa/consol_act/lga1999182.txt)
- The Environment Protection Act (1993) (http://www.austlii.edu.au/au/legis/sa/consol_act/epa1993284.txt)
- The Development Act (1993) (http://www.austlii.edu.au/au/legis/sa/consol_act/da1993141.txt)
- The South Eastern Water Conservation and Drainage Act (1992) (http://www.austlii.edu.au/au/legis/sa/consol_act/sewcada1992446/)
- The Native Vegetation Act (1991) (http://www.legislation.sa.gov.au/LZ/C/A/NATIVE%20VEGETATION%20ACT%201991.aspx)
- The Aboriginal Heritage Act (1988) (http://www.austlii.edu.au/au/legis/sa/consol_act/aha1988164.txt)
- The Coast Protection Act (1972) (http://www.austlii.edu.au/au/legis/sa/consol_act/cpa1972199.txt)
- National Parks and Wildlife Act (1972) http://www.austlii.edu.au/au/legis/sa/consol_act/npawa1972247/)
- The Mining Act (1971) (http://www.austlii.edu.au/au/legis/sa/consol_act/ma197181.txt)
- Road Traffic Act (1961) (http://www.legislation.sa.gov.au/LZ/C/A/ROAD%20TRAFFIC%20ACT%201961.aspx)

2 General description of the Banrock Station Wetland Complex

2.1 Location and general description

The Banrock Station Wetland Complex lies on the floodplain of the south western side of the River Murray downstream from the township of Kingston on Murray, and opposite the township of Overland Corner in the Riverland of South Australia. The site is bounded by three river bends and is adjacent to Weir and Lock 3 on the River Murray (located at 431.4 km - River Murray kilometers from the Mouth). The river boundary extends approximately 3.2 km upstream from Lock 3 and 11.5 km downstream. On the landward side the Banrock Station Wetland Complex encompasses Sections 275, 662, 681 and 682 of the Hundred of Moorook. The Ramsar site covers 1, 375 ha which includes 1, 068 ha of floodplain and 307 ha of mallee, but excludes 426 ha of viticulture area (see Figure 3).

The River Murray is 2,225 km from its headwaters to the Southern Ocean, traversing five distinct geomorphic regions (Eastburn, 1990 cited MDBC 2005):

The headwaters: from the source of the Murray above Hume Dam to Corowa, a distance of about 660 river kilometres. The headwaters in totality comprise less than 2 % of the Murray-Darling Basin, but contribute nearly 40 % of the inflow to the River.

The Riverine plains: a vast, 800 km flat tract of river and lake deposits where the River flows in shallow, branching Channels, from Corowa to the Wakool River junction, just west of Swan Hill.

The Mallee Trench: a wide plain of marine origin crossed by the River Murray in a single, well-defined Channel which cuts deeper into the surrounding plain, as it moves downstream. The Mallee Trench extends for 850 km from the Wakool junction to Overland Corner, in South Australia.

The Mallee Gorge: the River Murray Channel has cut down through hard limestone rock. The river bed intersects the regional water table, and salty groundwater enters the River through aquifers exposed in the cliff face. The Mallee Gorge covers a river distance of about 280 km, from Overland Corner to Mannum.

The Lower Lakes and Coorong: the terminal lakes, Lakes Alexandrina and Albert, together with the Coorong once formed a huge estuarine system. Barrages now separate the lakes from the Coorong and retain fresh water in the lakes. The distance from Wellington to the Mouth is 73 km.

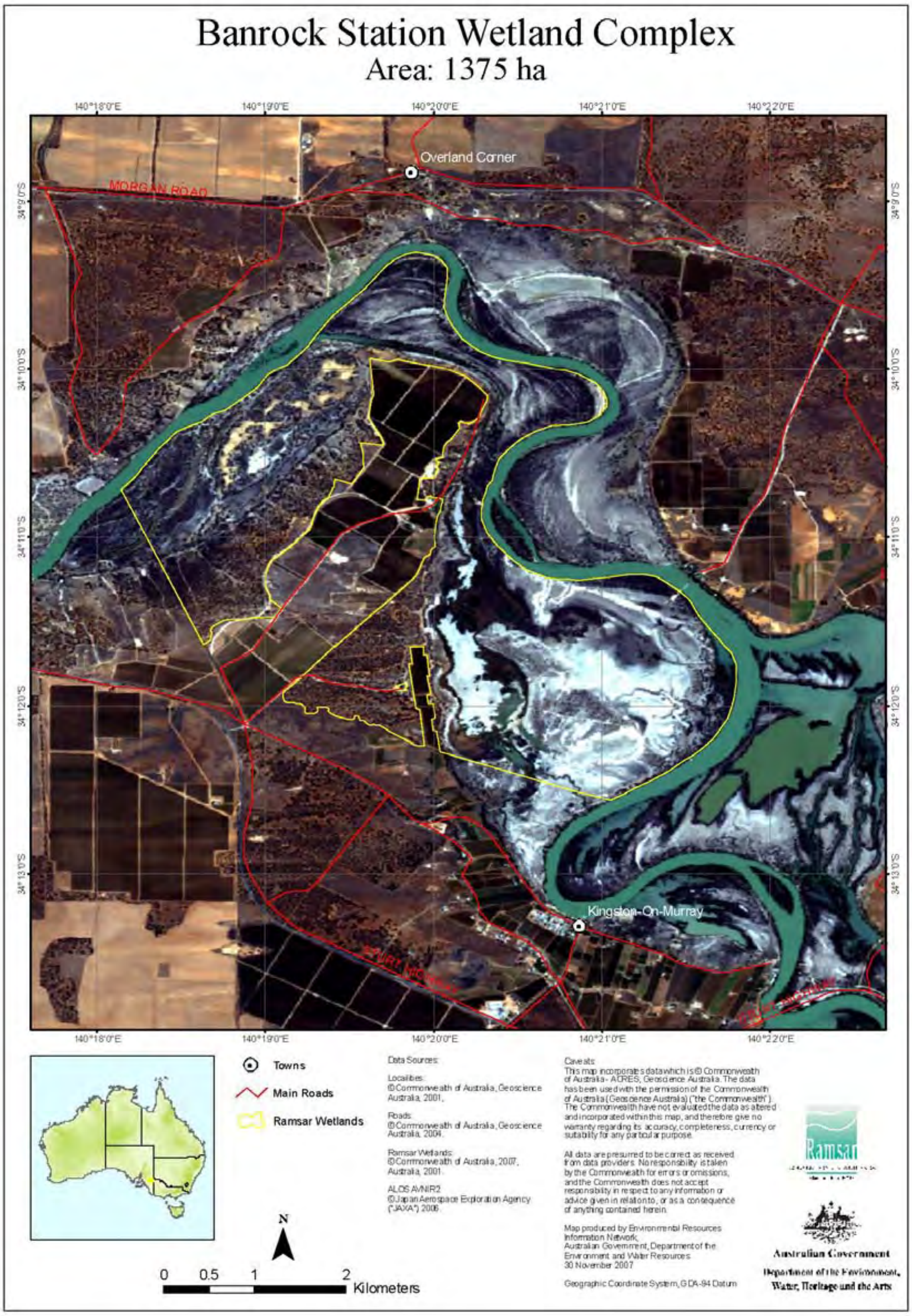


Figure 3: Official Ramsar site boundary for the Banrock Station Wetland Complex. Supplied by DEWHA 2009.

The Banrock Station Wetland Complex straddles the boundary of the Mallee Trench and Mallee Gorge geomorphic tracts. Within the Ramsar site boundary the wetlands exist as discrete depositional basins and active channels on an incised ancestral floodplain which is approximately 5-10 m above sea level. The largest wetland basin is referred to as Banrock Lagoon

(Figure 4 and Figure 5). Eastern Lagoon is joined to Banrock Lagoon during high flows and together they form the major freshwater wetland area of the site. Surrounding these lagoons are significant areas of Samphire (*Tecticornia* spp.) and Lignum (*Muehlenbeckia florulenta*) dominated floodplain, much of which is affected by rising saline groundwater. On the narrow floodplain within the Mallee Gorge geomorphic tract lie several long finger-like depressions which are not connected to Banrock and Eastern lagoons in the Mallee Trench upstream. These are intermittent wetlands that fill during overbank flows. The mallee highland areas of the site rise to 40-50 m above the floodplain with the highest point on the site being 62 m above sea level (Constellations Wines Australia 2008a).

Figure 4: Banrock Lagoon from Wine and Wetland Centre 2005. Photograph R. Butcher.

The junction of the inlet creek and the River Murray occurs on Crown Land just upstream of the Ramsar site's upstream boundary at 434.7 km (River Murray kilometers from the Mouth). The outlet, Banrock Creek enters the River Murray downstream of Lock 3 at 428.8 km. The normal regulated river level upstream of Lock 3 is 9.8 m AHD and downstream is approximately 6.1 m AHD (Gippel 2006). The raised water level upstream of Lock 3 resulted in permanent inundation of the main wetland areas since 1925. Prior to regulation the main wetland areas were considered ephemeral (Gippel 2006; Crosbie et al. 2007) and would have supported a significantly different flora and fauna to that at the time of listing. Permanent inundation created more stable water levels resulting in a simplification of the littoral and riparian vegetation. Combined with impacts from landuse change (e.g. grazing) the character of the site would have changed significantly post the installation of Lock 3.

Figure 5: Banrock Lagoon with *Phragmites*, sedges and *Azolla* evident. Photograph supplied Banrock Station.

Crude control structures were installed in the inlet creek in the 1950s with the wetland being managed to maintain a water level of 8.6 m AHD, except when high river flows overtopped the control structures (Gippel 2006).

Banrock Station Vineyard was established in 1994 and covers an area of approximately 240 ha of planted vines, with a further 185 ha of the property being cleared land or infrastructure associated with the vineyard operations. The property had been intensively farmed and grazed for around 100 years. In 1992 flow control gates were installed on the lagoon inlet channel and Banrock Creek which allowed some manipulation of water levels to wet and dry the margins of Banrock Lagoon. This management action was taken to enhance wetland productivity and improve habitat diversity in the margins of the wetlands (Gippel 2006). The rate of inflows and outflows can also be managed.

Flora and fauna

The dominant wetland vegetation types on the floodplain include River Red Gum (*Eucalyptus camaldulensis*) woodland, Black Box (*Eucalyptus largiflorens*) woodland, Lignum (*Muehlenbeckia florulenta*) shrubland, Common Reed (*Phragmites australis*) and Narrow-leaf Bulrush (*Typha domingensis*) sedgeland. Tucker (2003) describes the vegetation at the time of listing as having significant areas of stressed mature and young River Red Gums and mature Black Box caused by raised saline ground water levels and past grazing impacts.

In the mallee woodland ecosystem Blue Mallee (*Eucalyptus cyanophylla)*, Red Mallee (*Eucalyptus oleosa*), Beaked Red Mallee (*Eucalyptus socialis*), Dryland Tea Tree (*Melaleuca lanceolata*), Umbrella Bush (*Acacia ligulata*), Oswald's Wattle (*Acacia oswaldii*) and Bullock Bush *(Alectryon oleifolius ssp. canescens*) are the dominant species with various *Maireana sp*. and other annual herbaceous and perennial grasses (Kuys and Clarke 2003). The vegetation association Blue Mallee *(Eucalyptus cyanophylla*), Open Mallee (open scrub) with sparse sclerophyllous shrubs is endemic to the 'Mallee Block' where it is restricted to far north-western Victoria and the upper Murray Mallee in South Australia (Kahrimanis et al. 2001). This association is poorly conserved in South Australia and considered a high conservation priority (Kahrimanis et al. 2001).

The floodplain and mallee landscapes have a depleted understorey due to past land uses including timber cutting and sheep and cattle grazing. Dryland weed species are present in some parts of the site (Kuys and Clarke 2003, Tucker 2003). Over 120 species of plants have been recorded on the site (data from Kuys and Clarke 2003; Constellations Wines Australia 2008a; DEH unpublished). Further description of vegetation associations is presented in Section 3.6.1 and listed species are summarised in Appendix B.

A number of vertebrates recorded from the site are listed at the State level or are considered regionally important (see Appendix B). This includes the Freshwater Catfish (*Tandanus tandanus*) which is 'protected' in South Australia as well as the rare Broad-shelled Turtle (*Chelodina expansa*) (Fredberg et al. 2009). Freshwater Catfish are now extremely rare in South Australia and are only found in low numbers. It is possible that there are some resident Freshwater Catfish at the Banrock Station Wetland Complex as there are some areas of suitable habitat present on site (B. Smith, SARDI Aquatic Sciences, pers. comm.). Further discussion on fish is presented in Section 3.7.2 with the ecology of the native species summarised in Appendix C.

Bird records for the Banrock Station Wetland Complex list 138 species (Birds Australia 2009; Biological Database of South Australia (BDBSA) Department of Environment and Heritage, accessed 15 April 2009). Fourteen species of waterbirds and wetland associated birds recorded at the Banrock Station Wetland Complex are listed as threatened species in South Australia. Among these rare species include the Australasian Darter (*Anhinga novaehollandiae*), Australasian Shoveler (*Anas rhynchotis*), Baillon's Crake (*Porzana* pusilla), Blue-billed Duck (*Oxyura australis*), Great Crested Grebe (*Podiceps cristatus*), Intermediate Egret (*Ardea* intermedia), Little Egret (*Egretta garzetta*), Latham's Snipe (*Gallinago hardwickii*), Musk Duck (*Biziura* lobata), Spotless Crake (*Porzana tabuensis*), and Wood Sandpiper (*Tringa glareola*). The Freckled Duck (*Stictonetta naevosa*) and Regent Parrot are considered vulnerable in South Australia. The White-bellied Sea Eagle (*Haliaeetus leucogaster*), which breeds at nearby Loch Luna and has been recorded at Banrock, is listed as endangered in South Australia. Waterbirds are described in more detail in Section 3.74 and in Appendices C, E and F.

The Banrock Station Wetland Complex supports a diverse number of woodland birds with over 85 species recorded at the site. Eight species are considered rare in South Australia: Blue-faced Honeyeater (*Entomyzon cynotis*), Gilbert's Whistler (*Pachycephala inornata*), Golden-headed Cisticola (*Cisticola exilis*), Little Friarbird (*Philemon citreogularis*), Peregrine Falcon (*Falco* peregrinus), Restless Flycatcher (*Myiagra inquieta*), Striped Honeyeater (*Plectorhyncha lanceolata*), and White-winged Chough (*Cororax melanorhamphos*).

Seven native mammals have been recorded from the site, including the Common Brush Tail Possum which is considered rare in South Australia. Four introduced species of mammals occur on site. Fourteen species of reptiles and eight amphibians have been also been recorded on site with the Lace Monitor (*Varanus varius*) listed as rare in South Australia (Figure 6) and the Southern Bell Frog (*Litoria raniformis*) listed as vulnerable at both the national and State level.

Figure 6: Lace Monitor *Varanus varius.* Photograph supplied Banrock Station.

2.2 Social and cultural values

For Indigenous Australians, cultural and natural heritage materials are significant and hold social value. They also consider land and water to be intimately intertwined; therefore the whole ecosystem has social and cultural value to the Indigenous Peoples of the region not just parts of the whole. The Banrock Station Wetland Complex contains significant artefacts that suggest that the site was used and occupied by Indigenous Peoples for a diverse range of natural resource uses and strategies. Stone tools, scar trees, hearths, middens and other artefacts have been found on site. Given that the site is near to Overland Corner which was a ration station, and that it is thought to lie on the past boundary of two Aboriginal groups, Erawirum and Nawait, it is likely that the Banrock Station Wetland Complex was important for trade and access to the River Murray.

European association with the site began in the 1800s. In 1851, a grazing lease was issued to Thomas Henry Wigley over the lands that are now Banrock Station. He built a small homestead on the floodplain now known as Wigley Reach and his animal yards remain. The floodplain on Banrock Station was logged to supply firewood to power paddle-steamers from the 1850s to the 1920s as can be seen by the many old stumps that remain along the river and floodplain. Samuel and Nancy Pope named the land Banrock Station in 1907. In 1992 the newly formed wetland management organisation Ducks Unlimited Australia/Wetland Care Australia commenced working with the landowners to install water control structures on the main and eastern lagoons to enable partial drying of the wetland. Since 1993 Banrock Station has been the property of the Hardy Wine Company/Constellation Wines Australia, who developed a 240 ha vineyard and a wetland interpretative centre to help in the marketing of its wine brand Banrock Station Wines.

In 1999 the Banrock Station Wine and Wetland Centre was opened to the public to showcase Banrock Station Wines. A series of self-guided walks were opened in May 2000 and a boardwalk trail was completed in 2001, which included information huts and 5 bird hides for observing waterbirds (Constellation Wines Australia 2008a).

The site has high value as a demonstration site for the Ramsar concept of 'wise use' and provides for recreation, tourism, education and scientific research. Up to 100,000 people visit the site per year, which gives Constellation Wines Australia significant potential to showcase 'wise use'. The self-guided walks through the wetland and bird hides enhance the experience and serve to educate visitors.

2.3 Climate

The regional climate is characterised as semi-arid with warm to hot, dry summers and cool winters with variable rainfall. The climate is relatively unpredictable with moderate to high inter-annual variation. The three aspects of climate that most directly affect wetland ecology are rainfall (both local and in the catchment), temperature and (to a lesser extent in temperate systems) relative humidity as these all fundamentally affect wetland hydrology and the water budget.

Approximately 80 % of the rainfall falls between May and October, with the highest monthly average rainfall between 17 - 21 mm per month (Figure 7). Total annual rainfall averages 260 mm per year. Temperatures are warm to hot in summer ranging from a mean minimum of 15.5° C to a mean maximum of 31.1° C. During winter temperatures are cooler with mean maximum temperatures of 15.2° C falling to a mean minimum of 5.3° C (data for Berri 1926 -1963) (Bureau of Meteorology 2009) (Figure 8). Total annual net evapotranspiration was calculated for Banrock Lagoon to be approximately 1300 mm (Gippel 2006) (Figure 9).

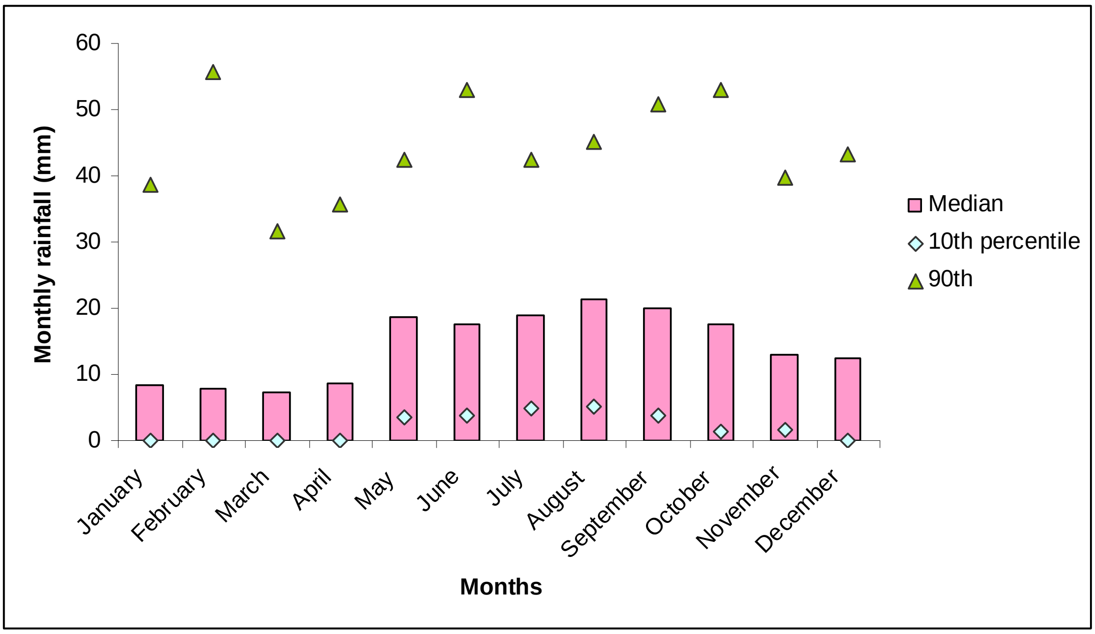


Figure 7: Median (10th and 90th percentile) monthly rainfall at Kingston on Murray 1896 – 2008 (Bureau of Meteorology 2009).

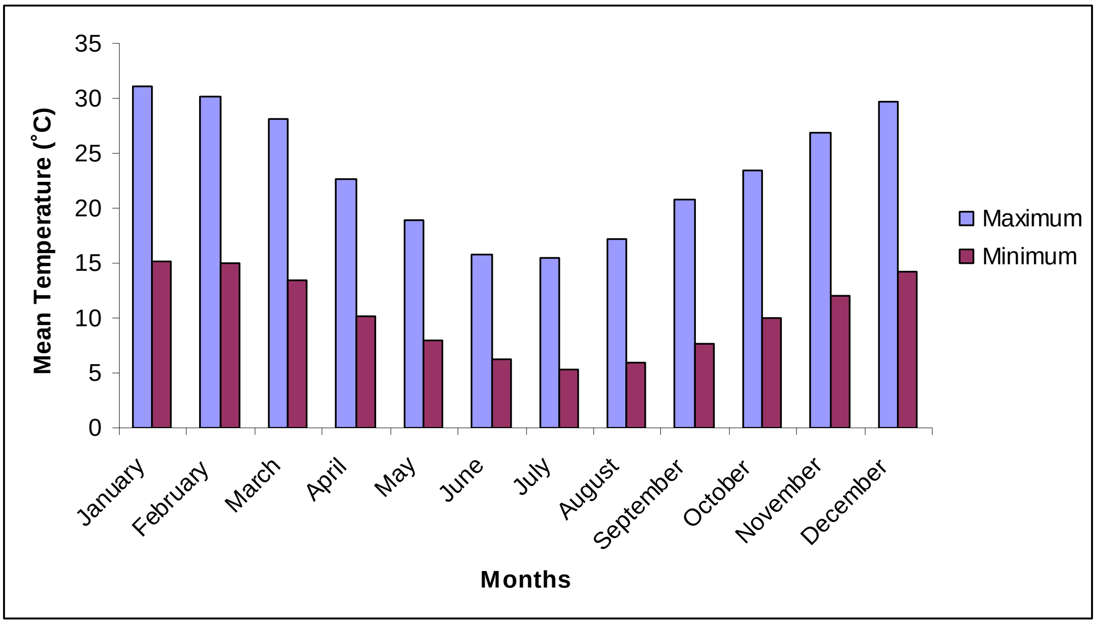


Figure 8: Average monthly minimum and maximum temperatures 1926-1963, Berri (Bureau of Meteorology 2009).

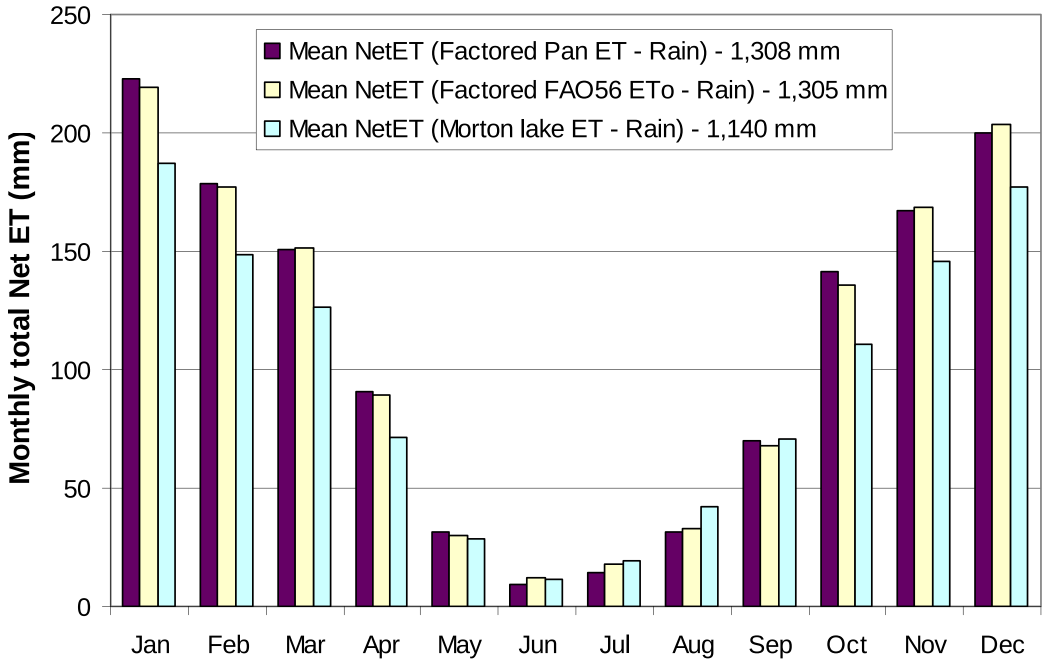
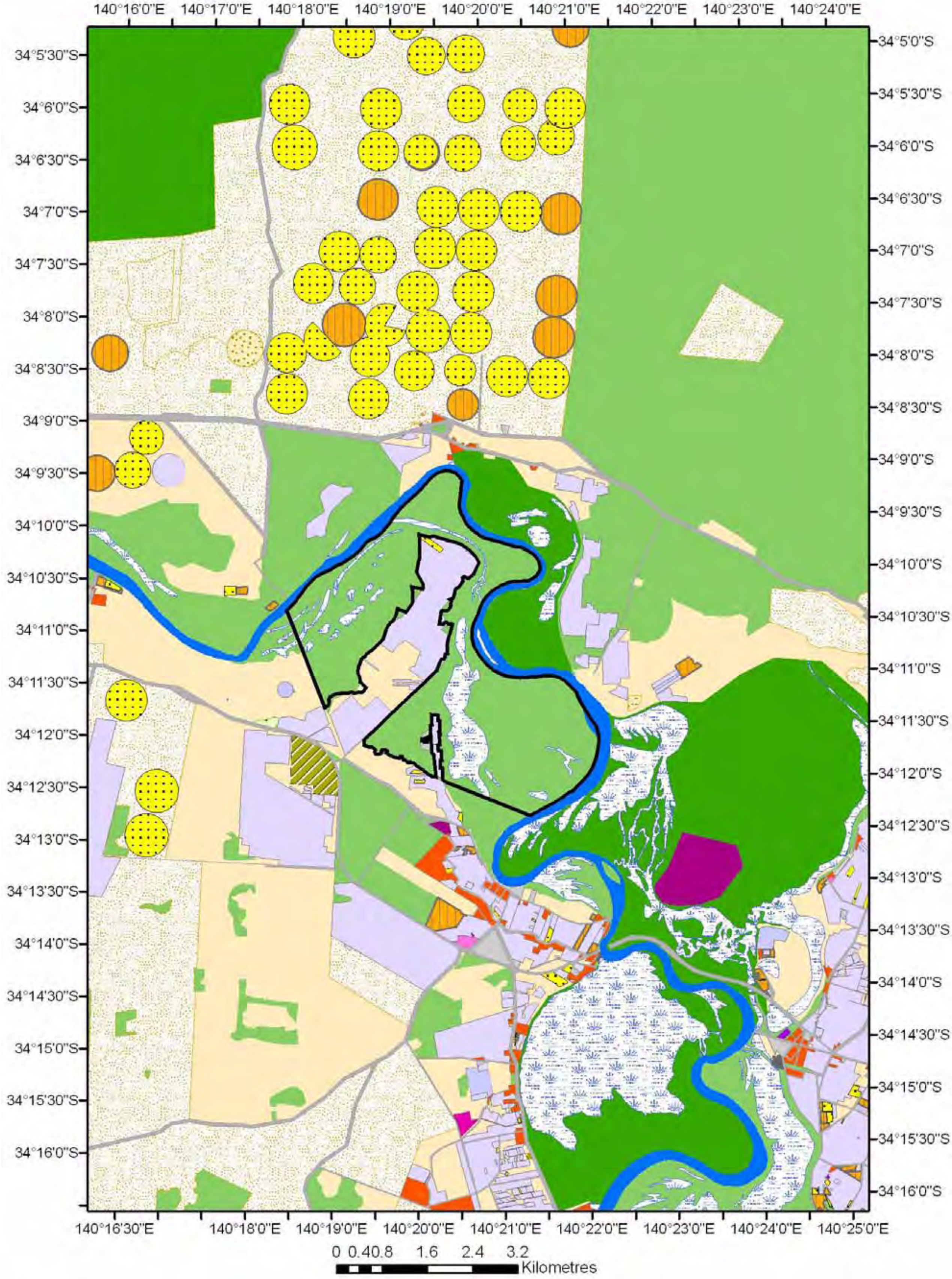


Figure 9: Monthly patterns and annual total Net Evapotranspiration for three different methods for the Banrock Station Wetland Complex (from Gippel 2006). Values in legend refer to annual totals.



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Kilometres

Figure 10: Land use surrounding the Banrock Station Wetland Complex.

2.4 Land tenure

The Banrock Station Wetland Complex is located on Crown land under perpetual lease to BRL Hardy Wine Company, and is under application to freehold the land with a Conservation Lease (K. Thorn, Banrock Station, pers. comm.). The Banrock Station Wetland Complex is bounded to the north-west, north and east by the River Murray. Land adjoining the site to the south and south-west is privately held horticultural land mainly used for grape growing. To the south-east, across the River Murray is the Loch Luna Game Reserve, managed by the South Australian Department of Environment and Heritage; the Overland Corner floodplain managed by the National Trust of South Australia, and some smaller parcels of privately held land (RIS 2003) (Figure 10 above).

2.5 Ramsar criteria

2.5.1 Criteria under which the site was designated (2002)

The Ramsar criteria for identifying wetlands of international importance as adopted by the 7th (1999) and 9th (2005) meetings of the Conference of the Contracting Parties (COP) are shown in Table 2.

Table 2: Criteria for identifying Wetlands of International Importance. Those criteria for which the Banrock Station Wetland Complex was listed are shaded. (Note that the site does not currently meet criterion 1).

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

The Banrock Station Wetland Complex was nominated and subsequently listed under criteria 1-4 (inclusive) with the following justification provided in the RIS (2002):

Criterion 1

- The site is one of 20 regional wetlands returned to an intermittent inundation pattern and as such is a unique example of a restoration to a near natural hydrological regime.

- The site is important as a 'demonstration' of wetland rehabilitation and wise use for other similar floodplain wetlands throughout the entire Murray Darling Basin.

- The site plays a substantial role in the overall 'health' of the lower River Murray including providing a natural fish passage around Lock 3.

- Restoration has increased physical and biological capacity to remove nutrients and particulates.

Criterion 2

- The site supports breeding colonies of the nationally threatened Regent Parrot (*Polytelis anthopeplus monarchoides*), and Southern Bell Frog (*Litoria raniformis*).

- The regionally threatened River Snail (*Notopala hanleyi*) was once common in wetlands of the lower River Murray, but is now considered rare due to predation by Common Carp. With the reduction of the population of the Common Carp within the Banrock Station Wetland Complex, efforts are underway to re-introduce the River Snail. Early indications are that a breeding population is becoming established.

Criterion 3

- Within the Murray Darling Depression biogeographic region, the majority of the river corridor including floodplain wetlands has been subjected to altered flow regimes, salinity, overgrazing and introduced pest species. In the South Australian portion of the region, the river corridor is considered a 'threatened habitat area' by Kahrimanis et al. (2001).

- As one of only 20 regional wetlands returned to a near-natural hydrological regime the site will play an increasingly important role as a biodiversity 'reservoir' for the region and a source of biodiversity for reintroductions and recolonisation into the adjoining areas.

- The site acts as a drought refuge in the semi-arid environment during adverse conditions.

- Restoration of plant communities and wildlife habitats at the site will continue to support the reintroduction and recolonisation of displaced flora and fauna.

- The reintroduction of near-natural hydrological regime has favoured the reestablishment of plant communities important for maintaining the biological diversity of the region. These include Lignum (*Muehlenbeckia florulenta*) Shrubland, and Common Reed *(Phragmites australis*) /Narrow-leaf Bulrush (*Typha domingensis*) Sedgeland communities both considered regionally threatened within the South Australian Murray Darling Basin.

- Revegetation programs are also being implemented to restore plant communities on the red sand dunes adjacent to the floodplain, such as Blue Mallee (*Eucalyptus cyanophylla*) Open mallee community which is considered poorly conserved in South Australia.

Criterion 4

- The site provides seasonal habitat for 8 migratory bird species listed under various international treaties (e.g. JAMBA, CAMBA):
    - Great Egret *Ardea alba*
    - White-bellied Sea Eagle *Haliaeetus leucogaster*
    - Greenshank *Tringa nebularia*
    - Red-necked Stint *Calidris ruficollis*
    - Long-toed Stint *Calidris subminuta*
    - Sharp-tailed Sandpiper *Calidris acuminata*
    - Caspian Tern *Sterna caspia*
    - Fork-tailed Swift *Apus pacificus*
- The site contains mallee and River Red Gum habitat which is critical to the lifecycle of the nationally vulnerable Regent Parrot.

- The site is an important pathway for fish migrating around the Lock 3 fish barrier during spring floods, and provides fish breeding and nursery habitats in warm shallow flood waters overlying the floodplain.

2.5.2 Revised application of the listing criteria (2009)

There have been a number of developments in recent times that influence the application of the Ramsar criteria to wetland sites including:

- A ninth criterion was added at the 9th Ramsar Conference in Uganda in 2005.

- Revision of population estimates for waterbirds (Wetlands International 2006; Bamford et al. 2008), which influences the application of criterion six.

- In 2008 the NRM Ministerial Council agreed to adopt the Australian Drainage Divisions system as the best fit national regionalisation approach for inland aquatic ecosystems and for marine systems the interim marine classification and regionalisation for Australia (IMCRA). DEWHA advised that the new bioregionalisation should be applied to new sites, and to existing sites (originally listed using IBRA) when the RIS is updated. This affects the application of criteria 1 and 3.

- Updating of threatened species listings, which affects criterion two.

- Additional data have been collected for the site, which could potentially influence the application of all criteria.

Therefore, a revision and update of the Ramsar Information Sheet has been undertaken as a part of this ecological character description, which includes an assessment of the Banrock Station Wetland Complex Ramsar site against the current nine Ramsar criteria.

Criterion 1

The Banrock Station Wetland Complex lies within the Murray Darling Basin. Australian Drainage Divisions are significantly larger than the IBRA regions, and at this point in time there is no comprehensive inventory data regarding the number and extent of the different Ramsar wetland types across the Murray Darling Basin on which to base a judgment on the rarity or representativeness of the Banrock Station Wetland Complex.

The RIS (2002) noted the importance of the site as a demonstration site for the concept of wise use. Whilst the site is an excellent example of wise use, this is not relevant to the criterion per se. This criterion is about wetland type, not management principles/practices. The site is unusual in that it straddles two geomorphic zones on the lower River Murray.

It is not possible at this point in time to determine if the Banrock Station Wetland Complex meets criterion 1 based on rarity or representativeness of wetland type using the new bioregionalisation framework.

This site does not appear to meet this criterion on the basis of its ecological character playing a substantial role in the natural functioning of a major river system.

Whilst this criterion was judged to be met at designation in 2002 using the IBRA as the scale for assessment, there is insufficient information to determine if this criterion is currently met using the Murray Darling Drainage Division as the bioregion.

Criterion 2

In the Australian context, it is recommended that this criterion should only be applied with respect to nationally threatened species/communities, listed under the EPBC Act 1999 or the International Union for Conservation of Nature (IUCN) red list. There are two nationally threatened species that have been recorded within the boundary of the Banrock Station Wetland Complex, the Vulnerable Regent Parrot (*Polytelis anthopeplus monarchoides*) and the Vulnerable Southern Bell Frog (*Litoria raniformis).* The Southern Bell Frog is also listed as Endangered under the IUCN Red List (IUCN 2009).

The eastern subspecies of the Regent Parrot nests in River Red Gum (*Eucalyptus camaldulensis*). In the non breeding season the bird moves into nearby mallee country. This species is a regular visitor to the site having been sighted 8 of 10 years (1998 - 2008) (Birds Australia 2009). Records collected under the 'Regent Parrot Population Monitoring' project delivered by the SA Department for Environment and Heritage indicate that approximately 100 nesting birds were sighted on Banrock in 2004 from two colonies. Numbers at the major colony at Banrock have declined from 38 nesting pairs in 2006 to 25 nesting pairs in 2008. Data from the smaller colony is not available for 2006 or 2008, but it is possible the numbers of adult birds nesting at Banrock has declined since listing in 2002 (see Section 3.7.4 and 4.3.5 for further discussion).

No data on the Southern Bell Frogs population at the Banrock Station Wetland Complex was available for the time of listing (RIS 2003), however many individuals have been recorded on site prior to listing and in recent monitoring programs undertaken by Banrock Station rangers (Banrock Monitoring data, unpublished; Sharley et al. 2009).

This criterion was met at designation in 2002 and continues to be met at present.

Criterion 3
To meet this criterion one or more of the following sub criteria must be met.

Criterion 3a i): *are 'hotspots' of biological diversity and are evidently species rich even though the number of species present may not be accurately known.*

Within the Murray Darling Basin information on wetlands which constitute 'hotspots' is lacking for most biota. Comparative data on species richness or elements of biological diversity which are considered rare or characteristic of wetlands in the Murray Darling Basin are, in general, not available. It is unlikely the site meets this sub criterion.

Criterion 3a ii): *are centres of endemism or otherwise contain significant numbers of endemic species.*

There are no known species endemic to The Banrock Station Wetland Complex and as such the site does not meet this sub criterion.

Criterion 3a iii): *contain the range of biological diversity (including habitat types) occurring in a region.*

This site meets sub criterion 3aiii) in that it supports the range of biological diversity (including habitat types) found in the region. The site is located at the transition between the Mallee Trench and Mallee Gorge resulting in a large number of habitat types found in the lower part of the Murray Darling Basin occurring in a relatively small area. The flora and fauna of the site are typical of a lower River Murray freshwater wetland complex in a semi-arid environment. Also the site is one of the few locations in South Australia where the rare River Snail (*Notopala sublineata*) has been successfully bred. The floodplain area in the Mallee Gorge section of the site contains unique dunes. These dunes are Aeolian in origin (approx 10,000 years old) and contain significant indigenous attributes including burial sites. Whilst elevated on the floodplain, they were completely inundated by the 1956 flood and as such, they contain isolated large red gums (A. Sharley, Banrock Station, pers. comm.). The reinstatement of an intermittent hydrological regime will promote the establishment of a more 'natural' range of habitats (i.e. seasonal to intermittently filled wetlands) as opposed to the permanent inundation pattern typical of those wetlands influenced by river regulation.

Criterion 3a iv): *contain a significant proportion of species adapted to special environmental conditions (such as temporary wetlands in semi-arid or arid areas).*

Within a bioregional context this site would not appear to support a significant proportion of temporary wetland specialist biota. Whilst several areas of the Banrock Station Wetland Complex support temporary semi-arid wetlands, for example Banrock Creek downstream of Lock 3 and Wigley Reach, these areas are not large, nor are they exceptional with regards to their biota. The main wetland (Banrock Lagoon) continued to be maintained with a permanent connection to the River Murray until 2007. Eastern Lagoon is classified as an intermittent system filling when water levels were manipulated in the Banrock Lagoon or when flooding occurred. The return to an intermittent hydrological regime for the Banrock Lagoon has only been achieved since 2007, when complete draw down of the wetland occurred. Prior to this the Banrock Station Vineyard had irrigation pumps located at the outlet of Banrock Lagoon and water levels were managed to ensure irrigation supply as well as maintaining water quality similar to the river (Crosbie et al. 2007). The irrigation pumps were relocated to the river in December 2006 and the inlet structure was closed on 3 January 2007, with the wetland completely drying out by March 2007, the first dry period since 1925 (Gippel 2006; Crosbie et al. 2007).

There has not been sufficient time for a re-establishment of natural temporary wetland biota in Banrock Lagoon under the managed water regime. This sub criterion may be met in future years, but is not met currently.

Criterion 3a v): *support particular elements of biological diversity that are rare or particularly characteristic of the biogeographic region.*

The vegetation associations listed in the RIS (2002) (see previous section) are not considered rare within the Murray Darling Basin bioregion.

In 2007 a case for listing the River Snail (*Notopala sublineata* which include the subspecies *N. sublineata hanleyi*) as a critically endangered species under the EPBC Act 1999 was rejected by the Minister. Issues regarding uncertainty about the precise taxonomy, distribution and abundance, and inadequate survey for the species in artificial habitats, such as the irrigation pipes, to determine the extent and abundance of their occupancy, led to the nomination being rejected. As this species is not listed at the national level it is not considered under criterion 2.

The Murray-Darling Basin population of River Snail is believed to have reduced dramatically since the 1950s-1970s with the population likely to be extinct within the natural environment. The subspecies *hanleyi* is known to occur in irrigation pipelines in the South Australian Riverland. The River Snail is listed as endangered in NSW and threatened in Victoria (http://www.environment.gov.au/biodiversity/threatened/species/river-snail.html).

Although the case is based on the presence of an introduced population of the River Snail, its presence contributes to the site meeting this sub-criterion. Breeding of the River Snail was achieved in irrigation pipes and releases made from a breeding chamber into the wetland are estimated to have established a population of less than 1000 individuals in the wetland prior to drying (A. Sharley, Banrock Station, pers. comm.). Changes to the population within the wetland since establishing an intermittent hydrological regime have not been established. Re-evaluation of this criterion once the intermittent hydrological regime has been established for a number of years may provide greater justification for this criterion.

This criterion was met at designation in 2002 and continues to be met at present (under sub criterion 3aiii and 3av).

Criterion 4

The Banrock Station Wetland Complex provides non-breeding habitat for 10 migratory waterbirds listed under JAMBA, CAMBA and ROKAMBA agreements. However the numbers of individuals are not large nor are most of the species recorded regular visitors. The exception is the Eastern Great Egret (*Ardea modesta*) which occurs at the site on a regular basis with records for eight of the past ten years. In addition, the site has also supported large numbers of moulting Australian Shelduck (*Tadorna tadornoides*)(M. Harper, DEH, pers. comm.), however the frequency of moulting events has not been recorded and this remains a knowledge gap.

The site potentially provides a migratory pathway for native fish species around Lock 3 during high flows. Data recently collected confirms the fact that small bodied native fish species and juveniles of some large bodied species (9 native species in total) attempt to undertake lateral migration via the inlet and outlet creeks of the Banrock Station Wetland Complex (Fredberg et al. 2009). Data are not available regarding movement of fish from the wetland to the river, nor was the relative success of the attempted migration established (B. Smith, SARDI Aquatic Sciences, pers. comm.). The relative importance of migration in small native fish species has only recently begun to be established with studies into fish migration at Lock 1-3 showing for the first time that small potamodromous Australian fish species were affected by barriers (Baumgartner et al. 2008a). Prior to this work it was believed that small bodied native fish were relatively tolerant to the effects of migration barriers (Harris and Gerhke 1997 cited Baumgartner et al. 2008b).

Upstream fish migration at the time of listing, and currently, is not possible due to the design and operation of the regulating structures, however downstream migration may be possible but is yet to be confirmed (B. Smith, SARDI Aquatic Sciences, pers. comm.).

This criterion was met at the time of designation in 2002 and continues to be met at present.

Criterion 5-9
The site does not meet these criteria.

2.6 Wetland types

The wetlands within the Banrock Station Wetland Complex Ramsar site have not been mapped or formally inventoried. However, it is evident from satellite imagery and other information sources that there are a number of wetland types present. Classification of aquatic ecosystems is a difficult task, with wetland boundaries often difficult to delineate. At a landscape level and on floodplain systems in particular, the diversity in aquatic ecosystems is often part of a continuum, rather than a series of discrete units. However, the Ramsar wetland classification system does not formally recognise floodplains as a wetland type, therefore 'discrete' wetland types, as per the Ramsar classification, that occur at Banrock are described below.

At the time of listing the water regime within Banrock Lagoon was considered permanent. Since 1993 water levels have been manipulated but water was always present in Banrock Lagoon, and the inlet and outlet creeks. Several other areas of wetlands are seasonal or intermittent in nature as described below. Figure 11 shows the general location of the main wetland types found at The Banrock Station Wetland Complex, showing change in wetland type where relevant.

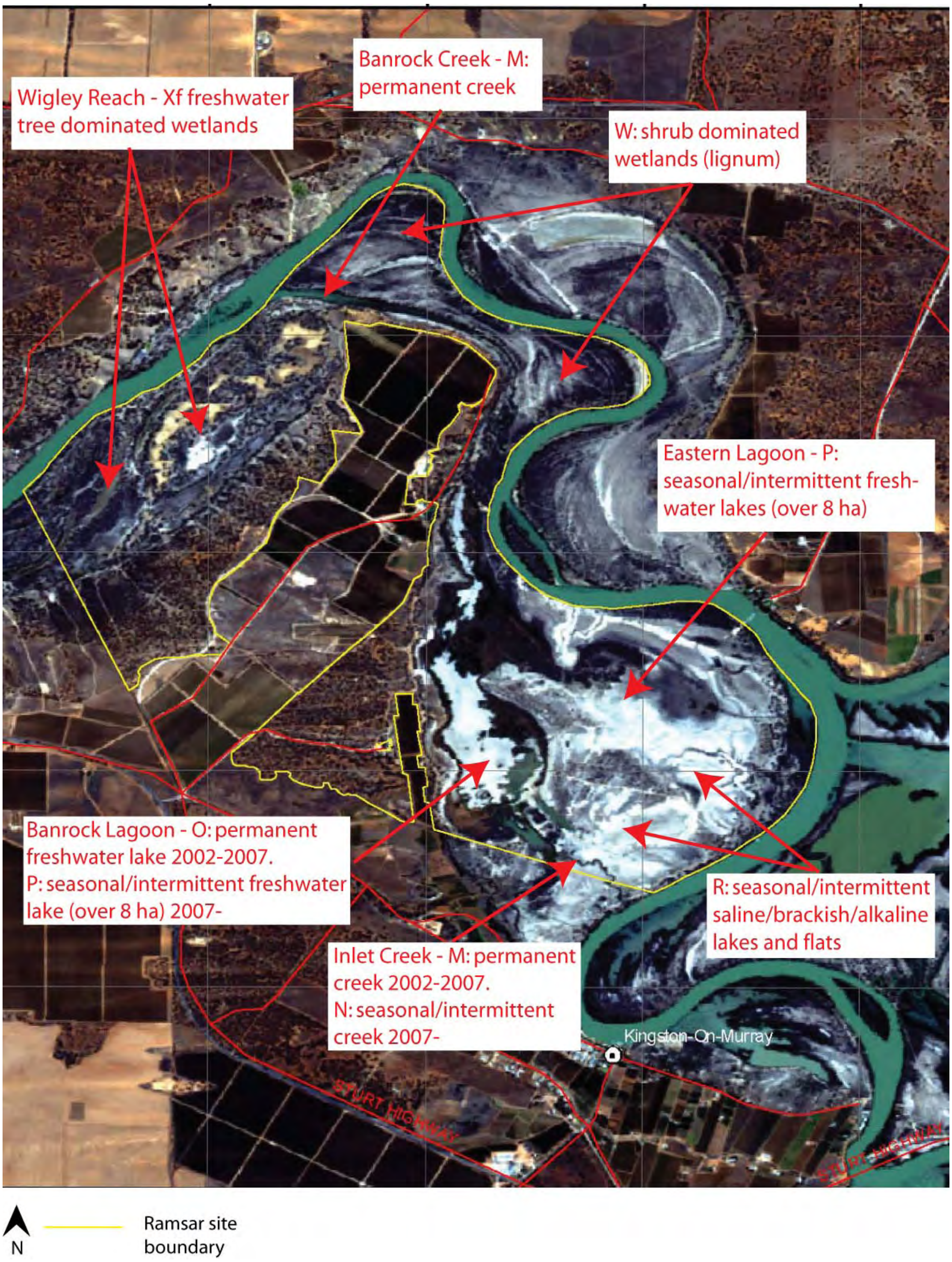


Figure 11: General location of different wetland types, showing change in type since listing where relevant (modified from Figure 3).

Permanent freshwater lakes (over 8 ha) (Type O) and Seasonal/intermittent freshwater lakes (over 8 ha) (Type P) (Figure 12).

Banrock Lagoon at the time of listing was a permanent freshwater lake with a variable water level. This wetland basin is connected to the Eastern Lagoon which is an intermittent freshwater lake. At 8.6 m AHD Banrock Lagoon is filled, covering approximately 100 ha, Eastern Lagoon is filled at 9.2 m AHD and combined the two lagoons cover approximately 251 ha (Gippel 2006).

Figure 12: Banrock Lagoon, permanent freshwater lake. Photograph R. Butcher 2005.

Permanent creeks (Type M) and Seasonal/intermittent creeks (Type N). Since 1925, when Lock 3 was constructed, there has been a 3.7 m hydraulic gradient from the inlet creek (Figure 13) to the outlet on Banrock Creek ensuring these creeks have permanent flow. Manipulation of control structures on the creeks enables these systems to undergo periods of no flow. The inlet creek has been closed every year since 2002. From 2002 to 2006 the inlet creek regulator was closed in May and reopened in September preventing flow for 5 months and enabling a partial drying of Banrock Lagoon. The inlet regulator was closed in January 2007 and reopened again in June 2008 preventing flow for 18 months and enabling complete drying in the channel and Banrock Lagoon.

Figure 13: Inlet creek looking downstream into wetland (left) and upstream to River Murray (right) from causeway. Photographs R. Butcher 2005.

Seasonal/intermittent saline/brackish/alkaline lakes and flats (Type R)
Approximately 83 ha of saline floodplain occurs within the Banrock Station Wetland Complex the majority of which lies on the eastern and south eastern edges of Banrock and Eastern Lagoons (see Figure 14). This wetland type is present due to secondary salinisation processes occurring prior to listing.

Figure 14: Saline floodplain showing Samphire in foreground and dead trees in background (from Kuys and Clarke 2003).

Freshwater, tree-dominated wetlands (Type Xf)
This wetland type includes freshwater swamp forests, seasonally flooded forests and wooded swamps on inorganic soils. Several smaller intermittently flooded wetlands found at Wigley Reach which are occasionally flooded also fall within this wetland type. River Red Gum woodlands are found throughout the site, along the creek lines and also surrounding the main lagoons.

Shrub dominated wetlands (Type W)
This wetland type is found in a number of places throughout the site, with lignum extending into the saline floodplain areas as well into the River Red Gum woodlands as an understorey species. The largest area of lignum is on the floodplain between the River Murray and Banrock Creek.

Original maps of the area show Banrock Lagoon as a lignum swamp, and this is evidenced by large areas of dead stumps on the wetland bed due to permanent inundation. The first complete drying since 1925 occurred in February 2007. During this dry period, lignum began to recolonise the bed of the Banrock Lagoon (Sharley et al. 2009).

3 Critical components and processes

3.1 Identifying critical components and processes

Ecological Character Descriptions 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.

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

- that are important determinants of the sites unique character;
- that are important for supporting the Ramsar or DIWA criteria under which the site was listed (or in this case nominated);
- for which change is reasonably likely to occur over short to medium time scales (<100 years); and
- that will cause significant negative consequences if change occurs.

Ecosystem components are defined by (Ramsar 2005) as the physical, chemical and biological parts of a wetland at both large and small scales (e.g. habitat to genes). Ecosystem processes are the dynamic forces that occur in ecosystems, including processes that occur between organisms (e.g. competition), formative processes (e.g. geomorphology) and interactions with the nonliving environment, that create and influence ecosystems states (e.g. climate).

Climate and geomorphology dictate the type and location of wetlands in the landscape, and together with hydrological regime are the key physical drivers of all other aspects of wetland ecology (Mitsch and Gosselink, 2000). Therefore, climate, geomorphology and hydrology are critical components of all wetland systems. Additional components and processes that can be considered critical to maintaining ecological character will be dependent on the wetlands' type and location, as well as the benefits and services it provides (Hale and Butcher 2008).

Critical components, processes and services for the Banrock Station Wetland Complex have been identified as those which relate to or are linked to the reasons which the site is listed under the Convention (Table 3). This identifies key biotic components and processes that are directly responsible for meeting each criterion and the components and processes which are important in supporting these.

From the descriptions contained in Table 3 and an application of the DEWHA (2008) principles above, the critical components and processes for the Banrock Station Wetland Complex have been identified as:

- Geomorphology (including soils);

- Hydrology;
- Water Quality (salinity, suspended solids);
- Vegetation;
- Birds;
- Amphibians;
- Fish; and
- Invertebrates

The attributes and characteristics of each of these critical components and processes/functions are described in the following sections. Where possible, quantitative information has been included; however, as with many ecological character descriptions, there are significant knowledge gaps (see Section 8). In the absence of direct evidence from within the site, general ecological theory has been used where appropriate.

Each of the descriptions in the following sections contain both a general description of the component and /or processes; as well as a description of the function of that component / process in contributing to the ecological character of the site.

Table 3: Relationship between Ramsar criteria met and critical components, and supporting components, processes/functions at the Banrock Station Wetland Complex.

Ramsar Criteria	Direct Components	Supporting Biotic Components, Processes/functions	Supporting Abiotic Components and Processes/functions
2. Supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	Regent Parrot and Southern Bell Frog	Vegetation communities – River Red Gum and surrounding mallee formations. Littoral vegetation.	Hydrology, water quality.
3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region	Invertebrates, fish, waterbirds	Habitat extent and type, food webs.	Hydrology, geomorphology.
4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions	Waterbirds and fish	Habitat extent and type, food webs.	Hydrology, connectivity, water quality.

3.2 Geomorphology

3.2.1 Geology and geomorphology

Upstream of Overland Corner the River Murray has cut through the Murray Group Limestone creating an extensive floodplain area (5-10 km wide), which narrows to a 1 km wide floodplain within the Mallee Gorge. The floodplain areas contain the highly conductive semi-confined Monomon Formation overlain by the Coonambidgal Formation.

The Murray Group Limestone is 100 m thick with a typical hydraulic conductivity of 1-2 m d^{-1}. The Monomon Formation is pure quartz sand with a hydraulic conductivity of 10 m d^{-1} or greater and a thickness of 10 m. The clays of the Coonambidgal Formation have a hydraulic conductivity of between 0.0001 and 0.04 m d^{-1} and typically have a thickness of 2-5 m. The river and floodplains are discharge areas for the regional groundwater which in general leads to an upward hydraulic gradient from the Murray Group to the Monomon Formation and Coonambidgal Formation (Crosbie et al. 2007).

The wetlands exist as discrete depositional basins and active channels incised into the Coonambidgal Formation ancestral floodplain approximately 5-10 m above sea level. Pliestocene calcrete and alluvium soils cover Tertiary limestone (Morgan Mannum) and sandstone. A significant part of the wetland area is probably comprised of ancient palaeo river channels (Hubbs and Hancock 2000a). The mallee areas of the site rise to 40 - 50 m above the floodplain with the highest point on the site being 62 m above sea level (Constellations Wines Australia 2008a).

3.2.2 Soils

The Banrock Station Wetland Complex lies within the Riverland environmental province, which extends from Renmark to east of Waikerie near the confluence of Burra Creek and the River Murray (Laut et al. 1977). The geology and soils of this region have been described by Laut et al. (1977), Cole (1978), Pressey (1986) and the South Australian River Murray Wetlands Working Party (1989)(all cited in Constellation Wines Australia 2008a) and mapped by DEH (see Figure 15).

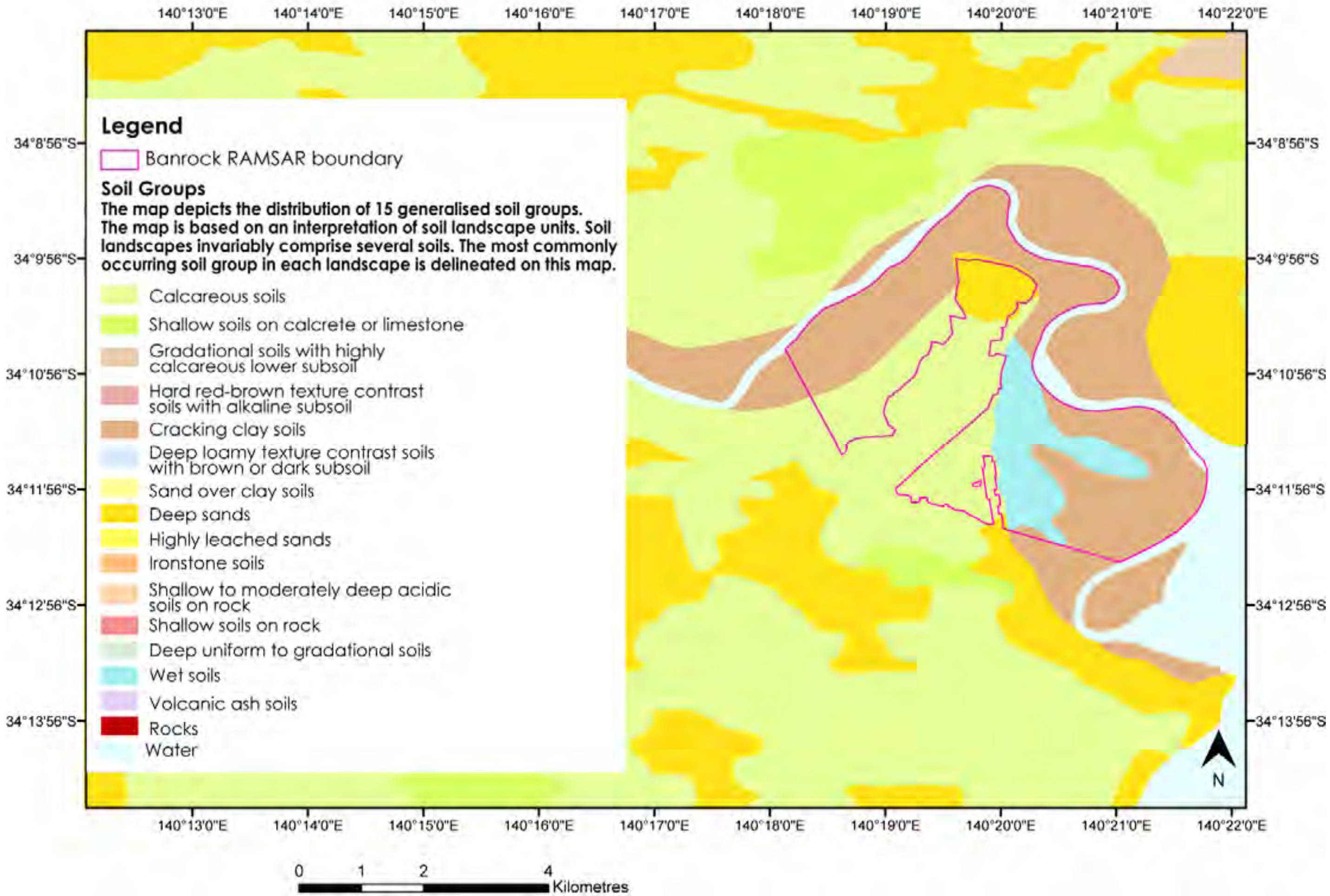


Figure 15: Major soil groups within the Banrock Station Wetland Complex (data from DWLBC (2007).

Figure 15 suggests that the majority of the site is comprised of “cracking clay” and “wet soils” with a small patch of “deep sands”. Laut et al. 1977 cited in Constellation Wines Australia 2008a describes the soils around the wetlands as uniform, fine textured grey, self-mulching clays and the sandy rises in the north-east as dunes of brownish sands. Laut et al. (1977) (cited in Constellation Wines Australia 2008a) also describe red calcareous earths as underlying elevated areas.

A soil texture survey of the vineyard areas and observations of the floodplain surface soils (A. Sharley, Banrock Station, pers. comm.) reveals that the alluvial soils of the floodplains comprise a grey cracking clay base (Coonambidgal Formation) overlying a coarse sand aquifer (Monoman Formation). The surface soils have been shaped by surface water processes including flooding and erosion, thereby creating a surface soil mix of sands, silts and clays of varying portions. Recent aeolian sand deposits have been blown onto the floodplain forming lunettes whose subsequent erosion has resulted in sand dispersion onto floodplain clays. Cliff face erosion has also resulted in sandy deposits over the floodplain soils.

The mallee highland soils comprise aeolian sands mixed with fine carbonates overlying calcareous subsoils in the form of stony marine and aeolian deposits depending on the topography.

Recent work by Crosbie et al. 2007 demonstrated that when the Banrock Lagoon is held full it acts as a recharge site; however, when dry the hydraulic head of water in the River Murray and water tables beneath the surrounding floodplains causes Banrock Lagoon to become a discharge site, although the relative significance of this with regards to the local water balance is not known.

Acid Sulfate Soils (ASS) can develop in anoxic areas where naturally occurring soil bacteria have access to sulfate, iron and organic matter. ASS are soils that either contain sulfuric acid or have the potential to form sulfuric acid if in contact with air. There are three main types of ASS: sulfidic material (containing sulfides), sulfuric material (containing sulfuric acid) and monosulfidic black ooze (containing monosulfides and modified in soil structure to be oozy). Contact with air can occur if the soils are disturbed by human (e.g. dredging, building structures) or animal activities (e.g. burrowing, trampling) or if the soils are dried out. ASS that are oxidised by the air can directly harm natural ecosystems through acidification, deoxygenation, element mobilisation and noxious gas emissions (Sammut and Lines-Kelly, 1996).

During the recent drying of the Banrock Station wetlands (summer 2007/08), Acid Sulfate Soils were uncovered in parts of the wetland bed as the water level fell. Approximately 5 % of the wetland bed had very high acidity levels and were at high risk of Acid Sulfate Soil development (Fitzpatrick et al. unpublished)(see Section 5.4 and 7.2.2 for more details).

Fitzpatrick et al. (unpublished) developed a series of conceptual models for the site. The partial drying of Banrock Lagoon since 1993 to 2006 mimicked, to some degree, the process expected to have occurred pre-regulation, with the build-up of sulfidic material kept in check by oxidation (e.g. burned off) (Fitzpatrick et al. unpublished). This would have occurred mainly on the margins of the lagoon. During rewetting the acidic material was submerged in the water column, being diluted/nuetralised and reforming sulfidic material (Fiztpatrick et al. unpublished). This is illustrated in the conceptual model of Banrock Lagoon for the period 1993-2003 as shown in Figure 16. No data on acidity levels are available for the time of listing.

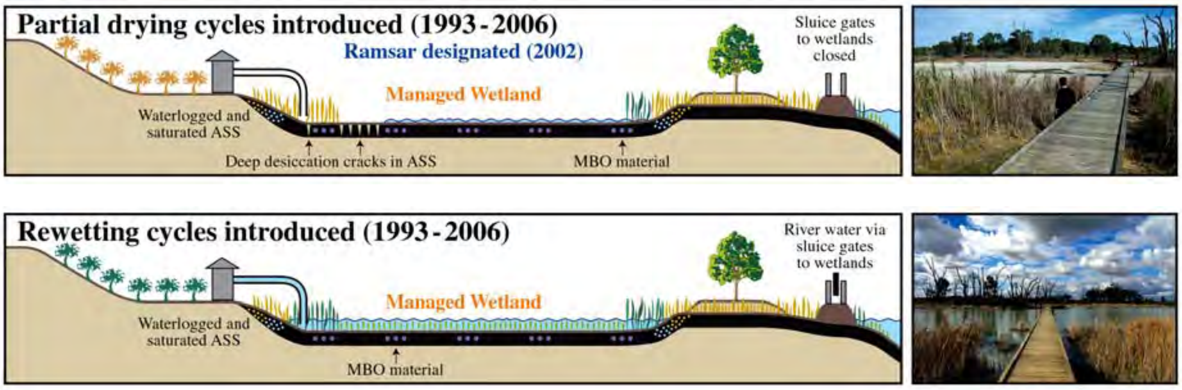


Figure 16: Generalised schematic cross section models for Banrock Lagoon; illustrating the installation of sluice gates to manage the partial drying cycle (upper panel) and the rewetting/ flushing cycle (lower panel) during 1993 to 2006) (From Fitzpatrick et al. unpublished).

3.3 Hydrology

The hydrology of the site at the time of listing is described in the following sections. It should be noted that the hydrological regime of the main wetland area has been modified to a more 'natural' pre-regulation pattern of inundation in 2007. The change in hydrology was in part to save water through reduced evaporative losses as well as to achieve ecological gains. The implications of this change in management are detailed in Section 7.

3.3.1 Surface water

Prior to river regulation Banrock Lagoon was considered intermittent (Gippel 2006; Crosbie et al. 2007). However, surface water hydrology was altered from natural well before the site was listed in 2002. Weir and Lock 3 (Figure 17) were installed on the River Murray in 1925. The inlet creek is located on the upstream pool of Lock 3 and flows into the Banrock Lagoon before flowing out to the River Murray on the downstream pool of Lock 3. The normal regulated river level upstream of Lock 3 is 9.8 m AHD and downstream is approximately 6.1 m AHD (Gippel 2006). A the time of listing the raised water level upstream resulted in the main wetland areas on Banrock Station being permanently inundated, operating as a flow through system (Gippel 2006; Crosbie et al. 2007). This can be clearly seen in the LiDAR elevation map presented in Figure 18. Note the stark difference in the height of the River Murray upstream and downstream of Lock 3.

Figure 17: Weir and Lock 3 on the River Murray adjacent to the Banrock Station Wetland Complex. Photograph Bill Phillips.

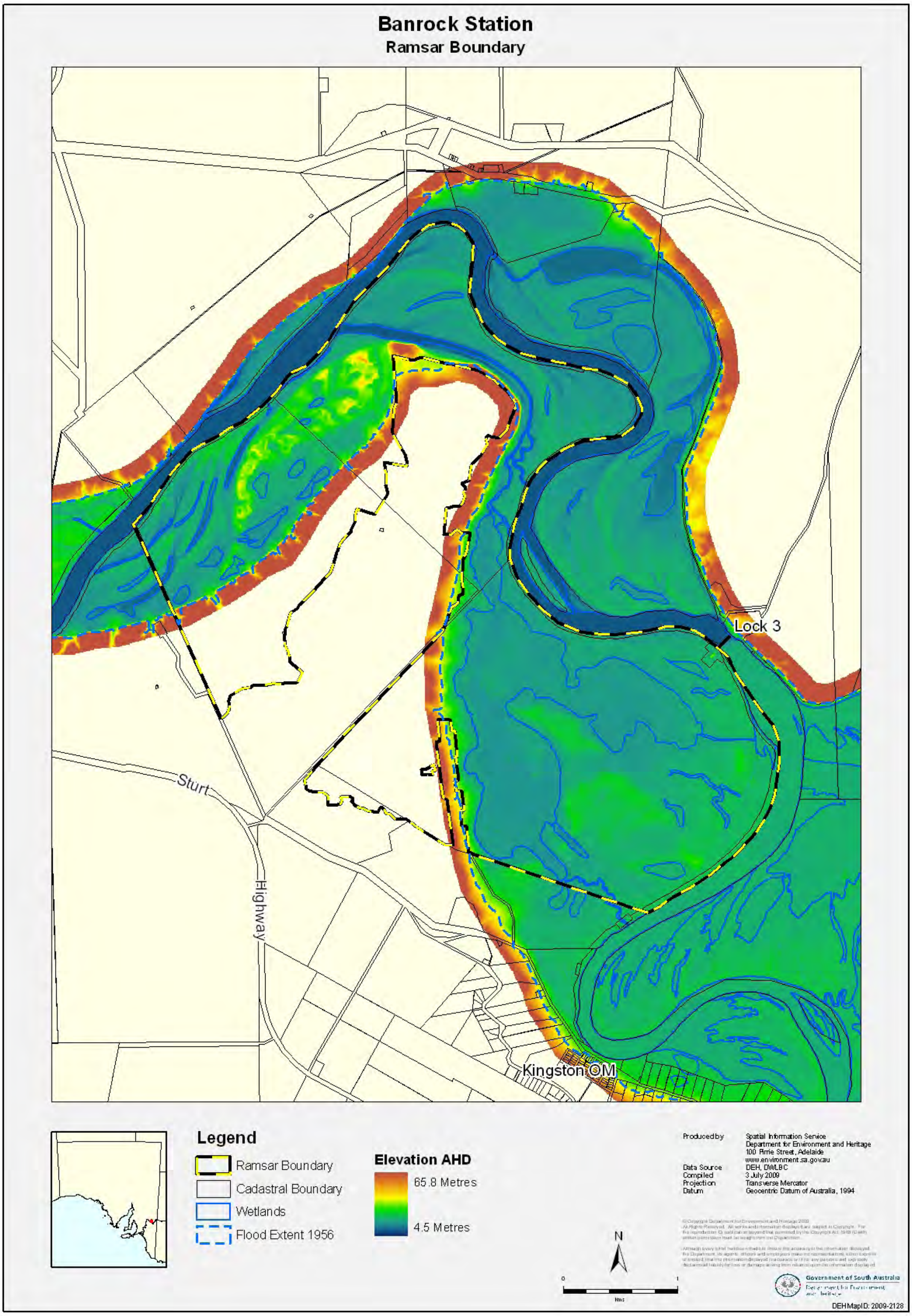


Figure 18: LiDAR image showing elevation of the floodplain and River Murray at the Banrock Station Wetland Complex. Data supplied DEH July 2009.

Crude control structures were installed at the downstream end of Banrock Lagoon and on inlet creek in the 1950s, with the lagoon being managed to maintain a water level of 8.6 m AHD, except when high river flows overtopped the control structures (Gippel 2006). The level of 8.6 m was maintained by a sill level on one of the outlets of the wetland. In 1992 flow control gates were installed on the inlet channel and Banrock Creek which allowed manipulation of water levels to wet and dry the margins of Banrock Lagoon. This management action was taken to enhance productivity and improve habitat diversity in the margins of Banrock Lagoon (Gippel 2006). Rate of inflows and outflows can also be managed.

Bathymetric survey showed the deepest point of the wetland was 7.78 m AHD; however the wetland is mostly dry at 8.2 m AHD. Banrock Lagoon is essentially full at 8.6 m AHD and Eastern Lagoon begins to fill at 8.75 m AHD (Figure 19) (Gippel 2006).

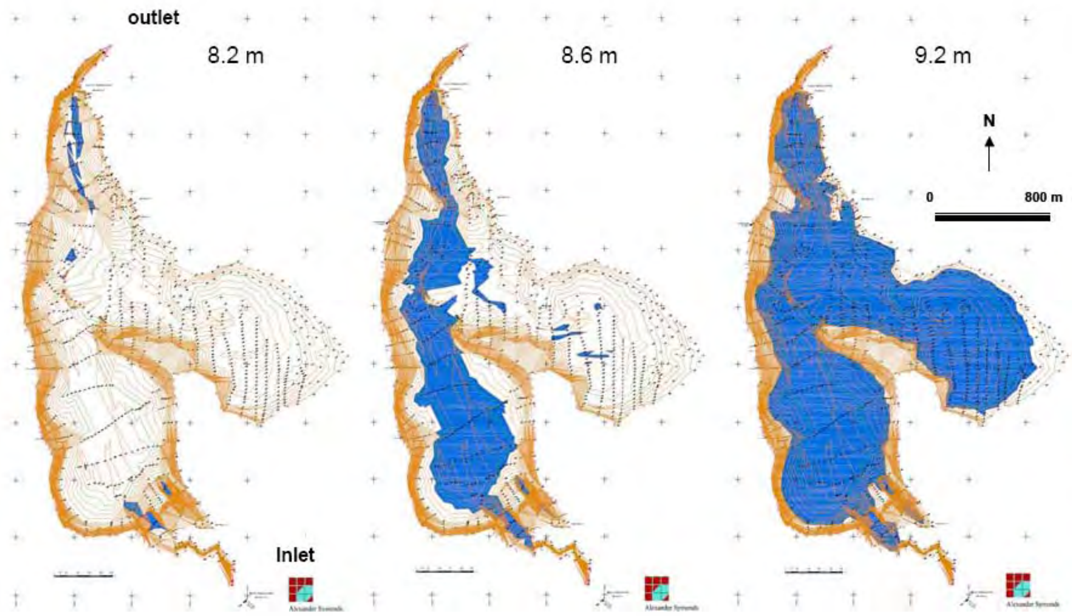


Figure 19: Banrock Lagoon and Eastern Lagoon extent of inundation at three elevations, 8.2 m, 8.6 m and 9.2 m AHD (from Gippel 2006).

The impacts of basin-scale river regulation and the abstraction of water for irrigation were to reduce the frequency of small to medium-sized floods in the lower River Murray. Small floods previously occurred on average every 1 - 2 years. The installation of regulatory structures on the inlet and outlet creeks of Banrock Lagoon has allowed the water regime in Banrock Lagoon to be manipulated to mimic these small-sized floods. Medium or large floods still rely on overbank flows, which begin at approximately 70-75,000ML/day. Medium-sized floods occurred every 2 - 3 years prior to river regulation; now they occur one in every ten years (Sharley and Huggan 1995), a frequency that appears insufficient to sustain the riparian tree communities in both the Mallee Trench and Mallee Gorge geomorphic tracts.

At the time of listing the Banrock Lagoon retained water all year round. Only after the removal of the irrigation pump from the wetland in 2007 was this wetland able to be fully dried (see Section 7).

Banrock Creek had a variable flow regime at the time of listing. During high river flows water moved into Banrock Creek from a number of small inlet creeks downstream of Ball Island. At the downstream confluence with the River Murray, water backs into the creek from the river and remains wet for longer periods than the upstream segments of the creek. Wigley Reach wetlands are intermittently filled River Red Gum dominated wetlands requiring small to medium sized floods to fill. The hydrology of these wetlands has not significantly changed since listing.

3.3.2 Surface water extraction

At the time of listing water was pumped from Banrock Lagoon to irrigate vines in the adjoining vineyard. Water was pumped directly from the Banrock Lagoon via a pump located at the northern end of the wetland (Gippel 2006). Banrock Station's annual allocation was 1610 ML (approximately 6.5 ML/ha) of which 74 % was used in the wettest years and 100 % in the driest years (Gippel 2006).

3.3.3 Groundwater

Crosbie et al. (2007) investigated surface-groundwater interactions at three wetlands along the lower River Murray including Banrock. The position of Lock 3 and significant river level gradient between the up and downstream sides of the lock has resulted in a large groundwater gradient from the upstream side of the lock to the downstream side of the lock (Crosbie et al. 2007), with the groundwater levels on the upstream side being very shallow (1–2 m below ground level). This has resulted in salt accumulation on the floodplain and wetland soils of Banrock Station (Crosbie et al. 2007).

Crosbie et al. (2007) created a conceptual model for Banrock showing salt movement and direction of fluxes (see Figure 20). They suggested that when the inlet and outlet creeks were open and Banrock Lagoon full, the wetland acts in a recharge capacity. The saline floodplain located between the river and Banrock and Eastern Lagoons acts as a groundwater sink. Groundwater flowing from the river and the wetland combine here and groundwater discharges to the surface, bringing dissolved salts and consequently this is an area of high salt storage (Crosbie et al. 2007). This was the situation at the time of listing and represents the benchmark for the ecological character description.

When Banrock Lagoon is dry the hydraulic gradients reverse and the wetland area becomes a discharge feature and it is predicted that it will begin to accumulate salt (Crosbie et al. 2007) (see Section 7 for further discussion on changes to ecological character).

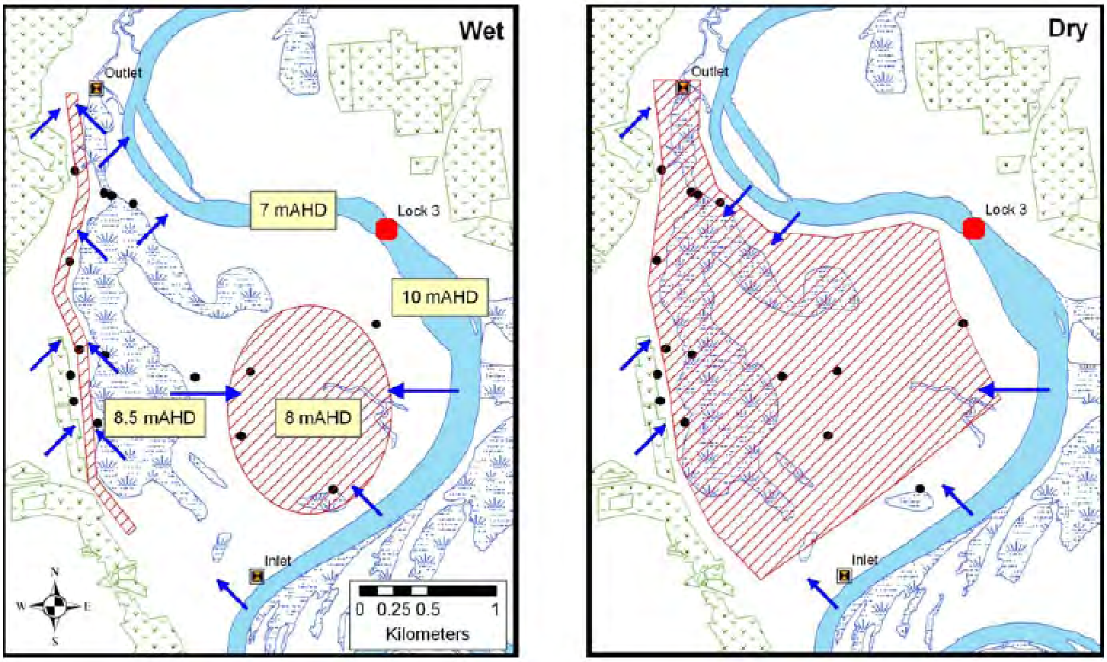


Figure 20: Conceptual model of water and salt movement at the Banrock Station Wetland Complex under wet and dry conditions. Red hatching represents areas that are sinks and therefore accumulating salt and blue arrows represent direction of fluxes (from Crosbie et al. 2007).

A general description of the issue of saline groundwater and increase salinisation of the lower River Murray floodplain is presented in Section 5.1.2. Specific information relating to surface-groundwater interactions at Wigley Reach is not available.

3.4 Water quality

Water quality data is limited to main wetland area, Banrock Lagoon and inlet and Banrock creeks. No water quality data is available for the wetlands of Wigley Reach.

3.4.1 Surface water salinity

Measures of surface water conductivity within Banrock Lagoon are available from the mid 1990s (Olsen 1997) and 1998 – 2000 (Tucker 2003). As other conditions in the wetland (e.g. hydrology) were similar during these periods as in 2002, they can be considered indicative of conditions at the time of listing.

The Banrock Lagoon is a freshwater system and although salinity fluctuates (predominantly reflecting changes in the River Murray source water), the system remained fresh at all times with electrical conductivity typically between 500 and 1000 µS/cm (Olsen 1997; Tucker 2003). The exception to this was in November 1994, when a blocked inlet pipe resulted in isolation of the wetland from the River Murray and the effects of evaporation resulted in concentration of salts in the water body and salinity rose to > 1800 µS/cm (Olsen 1997).

Tucker (2003) speculated that the pattern of salinity in Banrock Station Wetland Complex was linked to hydrology. For the majority of the time, salinity in the main wetland reflects salinity in the River Murray. Conversely, when the wetland is in the process of being filled beyond 8.5 m AHD, the surrounding floodplain becomes inundated and salts stored in surficial sediments are released raising salinity in the wetland. However, within the two-year monitoring period, mean salinity did not exceed 1000 μS/cm.

3.4.2 Nutrients

Information on nutrients within the Banrock Station Wetland Complex at the time of listing is limited to a 20-month monitoring period from November 1994 to June 1996 for the main lagoon (Olsen 1997). During this time, concentrations of dissolved inorganic nitrogen (ammonium and nitrate-nitrite) and phosphorus (orthophosphate) varied considerably.

Ammonium ranged from < 100 μg/L to > 3000 μg/L, with the lowest concentrations during winter and the highest during summer. Olsen (1997) suggested that increased temperatures in summer might have stimulated microbial processes and decomposition in the sediments leading to the release of ammonium.

Nitrate concentrations ranged from less than the detection limit to 7900 μg/L, with lowest concentrations during winter and the highest during summer. Peaks in nitrate were at slightly different times to ammonium, perhaps reflecting the different conditions required for their release from the sediment (nitrate when aerobic condition prevail and ammonium under anaerobic conditions). However, in the absence of measures of sediment or water column dissolved oxygen concentrations this is merely supposition.

Phosphate concentrations ranged from less than the detection limit to over 600 μg/L. Unlike the dissolved inorganic nitrogen, there were few discernable trends in phosphate concentrations. Olsen (1997) suggested that fluctuations in phosphate concentration may be linked to those in the source water rather than internal nutrient cycling.

3.4.3 Turbidity

Turbidity at the Banrock Station Wetland Complex at the time of listing ranged from 50 NTU to over 300 NTU (Olsen 1997; Tucker 2003). At these levels light would be unable to penetrate more than a few centimetres into the water column. Similar to salinity, turbidity often reflects water quality condition in the source water (River Murray). However, during times of filling, turbidity is highest (> 200 NTU) and greater than that in the source water as the clay sediments are disturbed by inflowing water. This then takes some weeks to settle to the 50 – 100 NTU range (Tucker 2003).

In addition the presence of a large adult Common Carp population at the time of listing may have contributed to the disturbance of sediments and thus helped to maintain high turbidity levels.

3.5 Ecological processes

3.5.1 Primary productivity

There is limited information concerning primary productivity in the wetland at the time of listing. Olsen (1997) indicated "blooms" of cyanobacteria in the summers of 1992, 1994 /5 and 1995/6. Although no quantitative data is available for 1992, *Anabaena* > 2000 cells / mL were recorded in December 1994 and January and February 1996 (Olsen 1997).

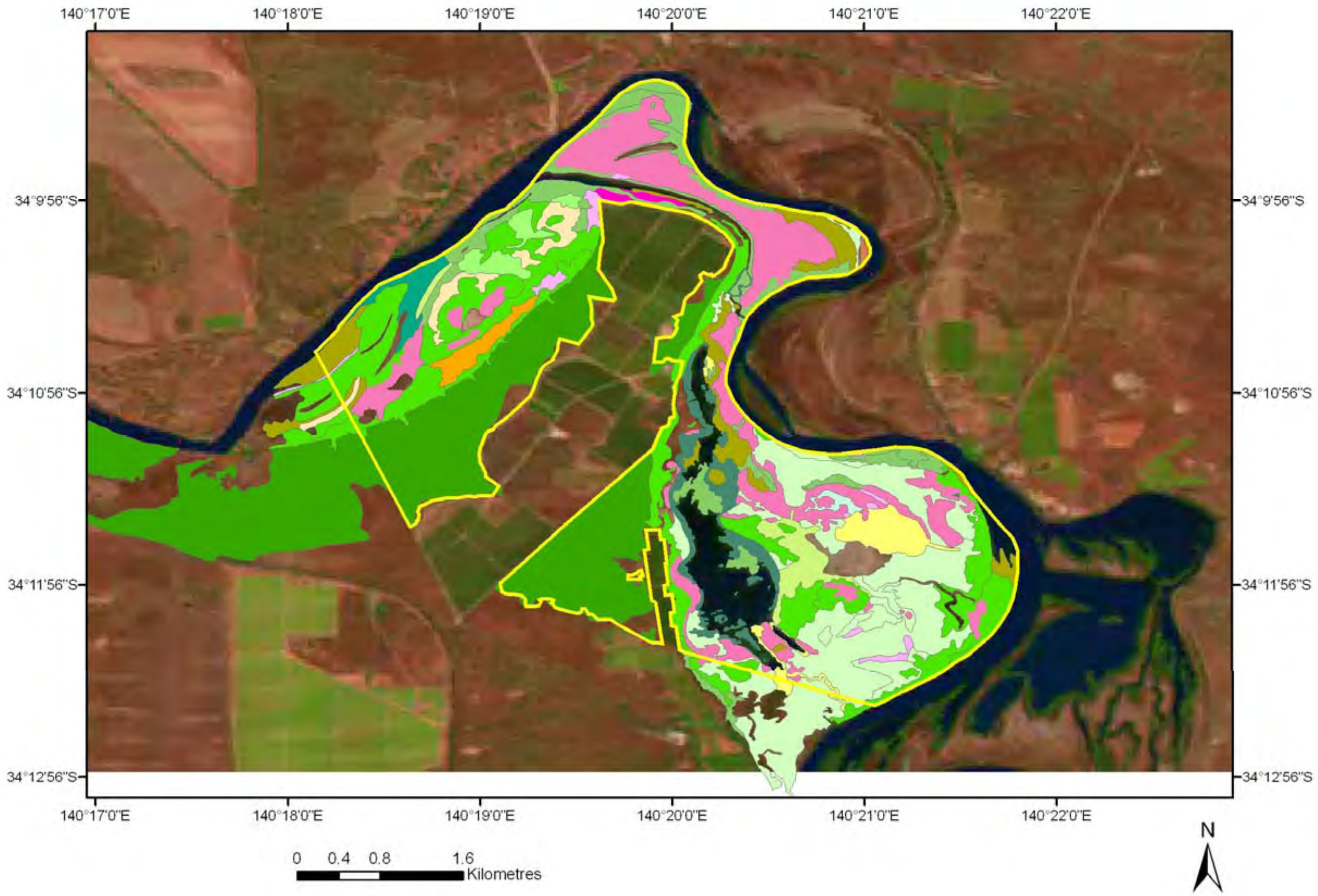
The conditions of warm temperatures, high turbidity and high concentrations of dissolved inorganic nutrients and a high nitrogen to phosphorus ratio would all have contributed to these blooms.

3.6 Vegetation

3.6.1 Vegetation associations- general description

Species records exist for 118 plants and data from the National Vegetation Inventory System (NVIS) shows 16 broad vegetation associations (Figure 21) and seven broad structural forms (Figure 22) within the bounds of the Ramsar site. NVIS data is derived from a compilation of data collected at different scales by different organisations. The data for South Australia covers the period 2001-2004 and as such represents the baseline for the site at the time of listing. Kuys and Clarke (2003) undertook vegetation surveys whilst developing a revegetation plan for Banrock Station. They identified 11 management zones relating to rehabilitation options. The mosaic of vegetation associations seen on site reflect topography, soil salinity and inundation regimes. Flood inundation levels for the site are shown in Figure 23 as predicted by the Floodplain Inundation Model (Overton et al. 2006).

All floodplain vegetation along the River Murray in South Australia is considered to be significantly stressed (Kahrimanis et al. 2001) with the impacts of river regulation exacerbated by ongoing drought. There have been no significant overbank floods since 1996 with 70 % of trees dead, dying or stressed by 2004 (Jensen 2008). The lower River Murray floodplain is underlain by relatively shallow and highly saline groundwater (see Section 5.1.2) with salt and water balances affected by river regulation, local irrigation practices and water extraction (Jensen 2008). A freshwater lens above the saline ground water and soil moisture maintained by rainfall are key elements in maintaining the health of floodplain vegetation. Landuse activities in the catchment including regional vegetation clearance and irrigation activities are causing increased pressure on the saline groundwater, leading to salt movement into the root zone of floodplain trees and subsequent stress and death (Jensen 2008). This 'stressed' condition represents the baseline condition for the key vegetation associations at the Banrock Station Wetland Complex.



140°17'0"E
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34°9'56"S
34°10'56"S
34°11'56"S
34°12'56"S
0 0.4 0.8 1.6
Kilometres
N

Legend

Banrock RAMSAR boundary

dominant species

Acacia stenophylla woodland

Eucalyptus brachycalyx mallee woodland

Eucalyptus camaldulensis var. *camaldulensis* (mixed) woodland

Eucalyptus camaldulensis var. *camaldulensis* forest

Eucalyptus camaldulensis var. *camaldulensis* woodland

Eucalyptus largiflorens woodland

Tecticornia arbuscula shrubland <1m

Tecticornia pergranulata ssp. *pergranulata* (mixed) shrubland <1m

Tecticornia pergranulata ssp. *pergranulata* shrubland <1m

Atriplex rhagodioides shrubland >1m

Maireana brevifolia (mixed) shrubland <1m

Sporobolus virginicus (mixed) grassland

Muehlenbeckia florulenta shrubland >1m

Agrostis avenacea var. *avenacea* (NC) grassland

Phragmites australis grassland

Typha domingensis sedgeland

Figure 21: Vegetation mapping from the National Vegetation Inventory System (NVIS) data showing dominant species within the Banrock Station Wetland Complex (data supplied DEH South Australia 26 March 2009).

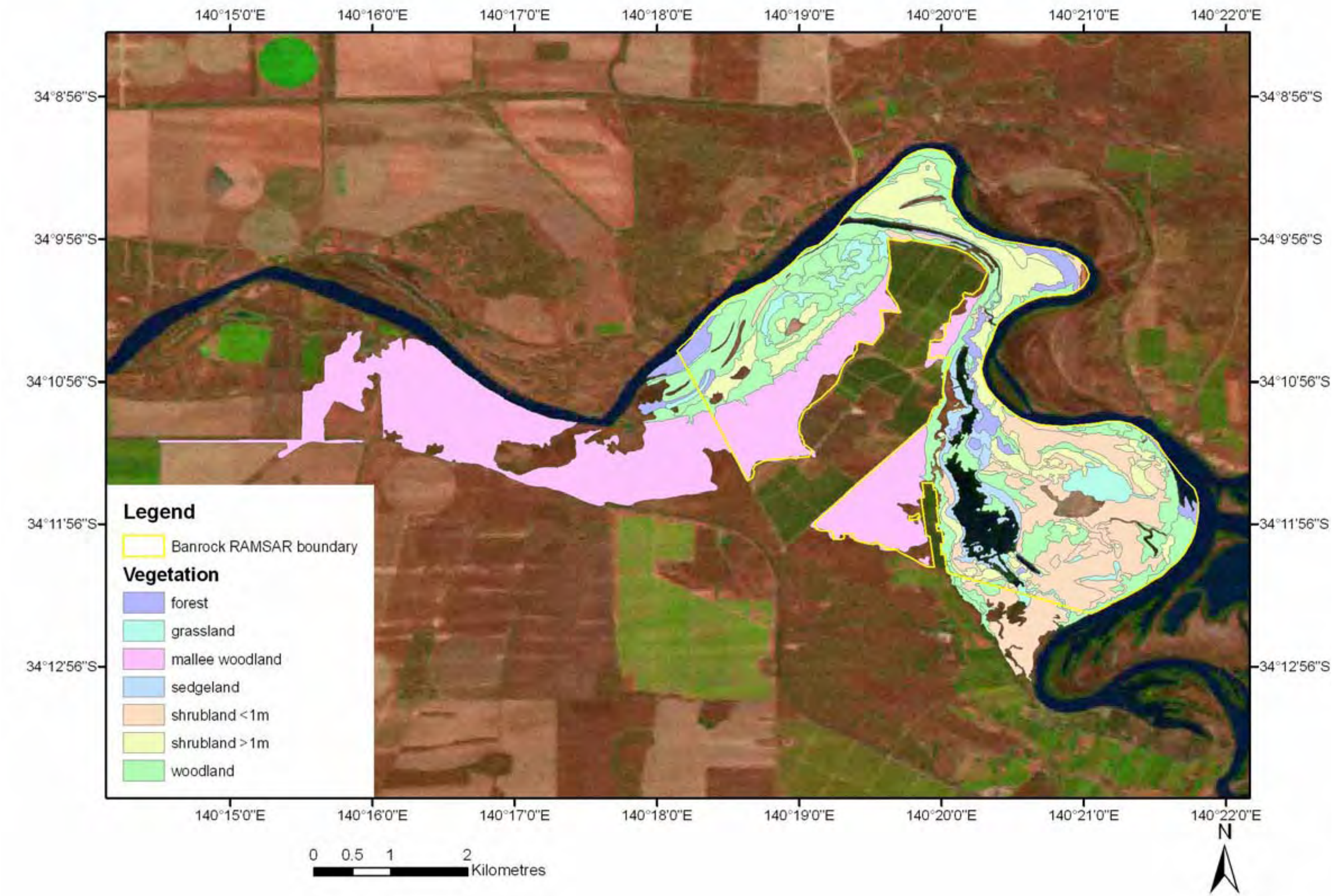

Figure 22: Broad structural forms of vegetation at the Banrock Station Wetland Complex. Data from NVIS supplied by DEH 26 March 2009

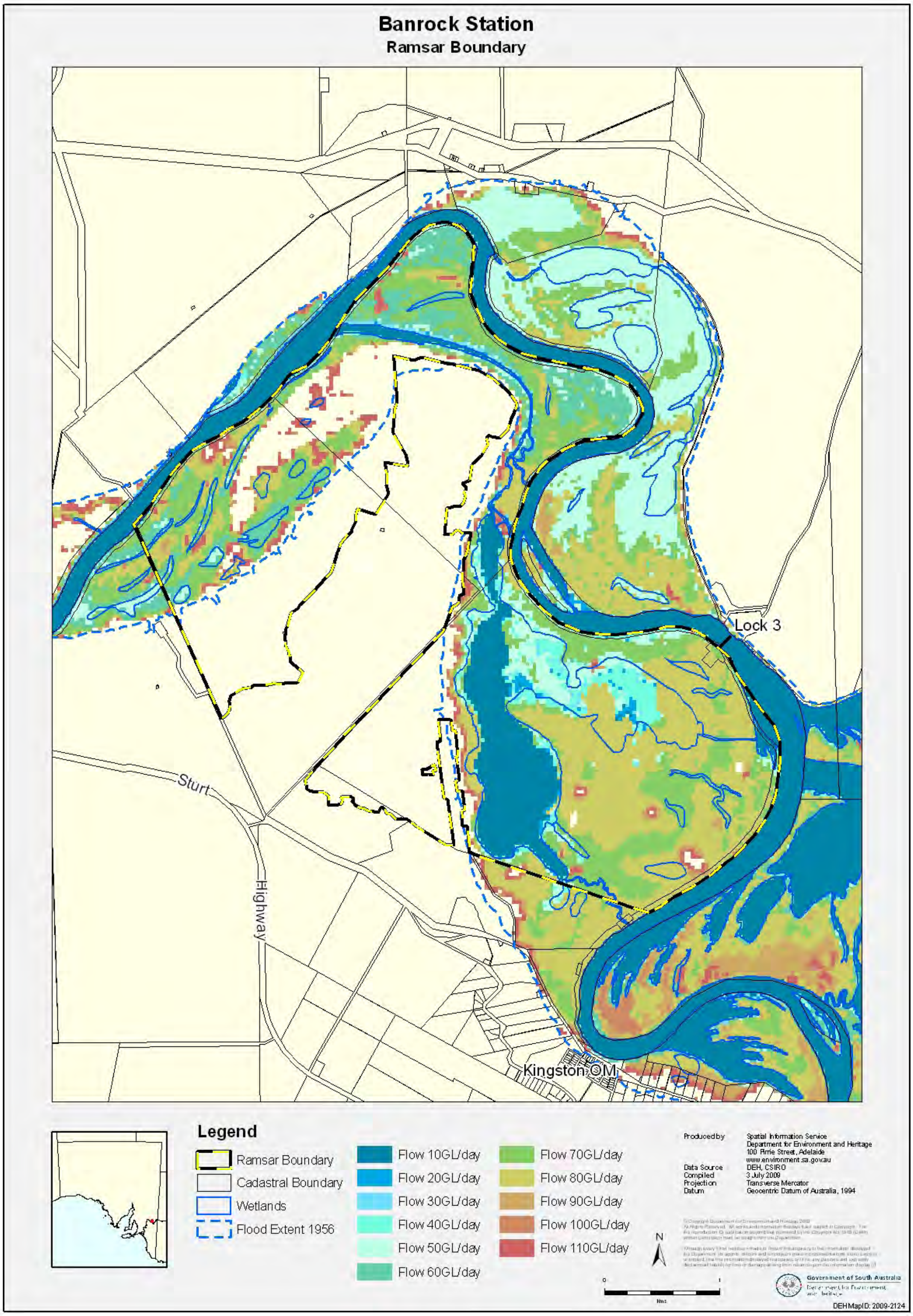

Figure 23: Flood inundation levels for the Banrock Station Wetland Complex

The vegetation associations considered critical to the ecological character of the Banrock Station Wetland Complex are described below and include:

- River Red Gum and Black Box woodlands – support Regent Parrots;
- *Tecticornia*[2] (Samphire) shrublands – while the majority of this vegetation association is present due to salinisation of parts of the floodplain this vegetation association is an important waterbird habitat when flooded;
- Lignum shrublands – important fish and waterbird habitat when flooded
- *Typha* sedgelands and *Phragmites* grasslands – important fish and frog habitat; and
- Aquatic macrophyte herblands – important fish and frog habitat.

<u>River Red Gum (177 ha) and Black Box (222 ha) woodlands</u>
Along the River Murray Corridor of the South Australian Murray Darling Basin River Red Gum (*Eucalyptus camaldulensis*) and Black Box (*E. largiflorens*) woodlands are the dominant vegetation associations. They are often associated with Lignum (*Muehlenbeckia florulenta*) and chenopod *Atriplex* shrublands and/or an understorey of grasses (Kahrimanis et al. 2001). These types of woodlands have high biodiversity values as they support a number of species reliant on hollows, such as the Regent Parrot, and Brushtail Possum.

This vegetation association at the Banrock Station Wetland Complex, as described by Kuys and Clarke (2003), is dominated by open woodland of River Red Gum, Black Box, and River Cooba *(Acacia stenophylla*). The floodplain is subject to occasional flooding and areas of high soil salinity. Understorey species associated here are Samphire (*Tecticornia spp.*), in the more salty floodplain areas, Lignum, Club Rush *(Schoenoplectus sp.*), Bog Rush *(Schoenus sp*.), in wetter edge areas and Spreading Emubush (*Eremophila divaricata*), Spiny Saltbush (*Rhagodia spinescens*), Spiny Flat Sedge (*Cyperus gymnocaulos*) on the drier areas subject to occasional flooding (Kuys and Clarke 2003).

At the time of listing the River Red Gums on the Banrock Station Wetland Complex supported two nesting colonies of the threatened Regent Parrot and as such is a critical component of the ecological character of the site.

Threats to this vegetation association include altered water regimes, increasing salinisation and fragmentation. Further discussion on River Red Gum and Black Box condition are presented in Section 5.1.3 and 7.

<u>*Tecticornia*(Samphire) (223 ha) shrublands</u>
The saline floodplain areas of the site which support the Samphire shrublands are the low lying areas adjacent to the lagoons, with scattered dead trees and Lignum. Samphire is the dominant groundcover (Kuys and Clarke 2003). When flooded this vegetation association provides habitat for waterbirds.

<u>Lignum (*Muehlenbeckia florulenta*) (191 ha) shrublands</u>

[2] In 2007 Samphire genera *Halosarcia*, *Pachycornia*, *Sclerostegia* and *Tegicornia* were incorporated into the genus *Tecticornia*.

Lignum shrublands are poorly mapped in the SA Murray Darling Basin (Kahrimanis et al. 2001) however it is the dominant perennial shrub of the floodplain of the lower River Murray and is also a common understorey species in the River Red Gum and Black Box woodlands. Usually found in low lying poorly drained areas, it is relatively tolerant of high soil salinities. The shrubs can reach up to 3 m in height and have rootstock which reach at least 2 - 3 m deep (Jensen 2008). Functionally Lignum can have a significant affect on the evaporative balance and groundwater levels of floodplain systems (Jensen 2008). Ecologically it provides nesting sites for a number of waterbirds including Ibis and Freckled Duck, and while flooded shelter for Murray Cod and Golden Perch and juveniles of a number of other native fish (Jensen et al. 2006). The relative importance of this habitat in large floods for large bodied native fish species is not known.

Growth and reproductive responses of Lignum to watering at Banrock in 2004-2005 were investigated by Jensen (2008). Significant growth was observed only after direct watering of shrubs with approximately 6 weeks of growth before reverting to a dormant state of no leaves or flowers (Jensen 2008). Plants which were near to seasonal watering (within 20 m) but not actually inundated showed no benefits, essentially remaining dormant. Jensen (2008) suggested that the low transmissivity of the heavy clay soils at the Banrock site prevented soil moisture extending from the wetted area 20-30 m to the monitoring site.

Threats to Lignum shrublands include grazing, altered water regimes and water quality, and increasing salinisation. Lignum is tallest and most vigorous where there is surface or sub-surface soil moisture with low pH and salinity. Lignum shrublands will become dominated by more salt tolerant species as saline ground water reaches the root zones. The loss, reduction of active growth phases or die-back of lignum from the floodplain may lead to increased accumulation of salt stored on the floodplain (Jensen 2008). Further investigations are required to establish if altered water regimes and ongoing drought are seriously affecting recruitment of Lignum (Jensen 2008).

Typha sedgelands (44 ha) and *Phragmites* grasslands (31 ha)

Kahrimanis et al. (2001) stated that whilst they were poorly mapped along the river corridor of the South Australian Murray Darling Basin, and considered rare in the South East of South Australia, Typha and Phragmites sedge and grasslands are poorly conserved. Stands of Typha and Phragmites often form at the transition between the terrestrial and aquatic environments. They provide shelter for invertebrates, fish, frogs and nesting water birds (Kahrimanis et al. 2001). Other emergent species are often associated with these sedge and grasslands. Emergent species recorded at Banrock by Tucker (2003) include, *Bolboschoenus caldwellii*, *Cyperus gymnocaulus*, *Paspalum distichum*, and *Persicaria* spp. Threats include altered water regimes, salinity and grazing.

Aquatic macrophytes - herblands

Neagle (1995) listed the “*Potamogeton pectinatus*, *Myriophllum* spp., *Azolla filiculoides*, and *Lemna disperma* closed herbland (plus other submerged and floating aquatic species)” as a priority 7 ‘poorly’ conserved plant community in South Australia (Neagle 1995; Kahrimanis et al. 2001). Aquatic herblands were not surveyed by Kuys and Clarke (2003), however data from the late 1990s is presented in Tucker (2003) lists the following aquatic species: *Azolla*, *Elatine gratioloides*, *Myriophyllum verrucosum, Triglochin striatum,* and *Vallisneria americana*. Community composition changes were observed in response to partial wetting and drying with the vegetation responding to changes in depth reflecting local topography and period of inundation.

3.6.2 Tree health

The poor regeneration of River Red Gum and Black Box communities as a result of altered water regimes on the floodplains was described as 'disturbing' and the long term survival of these woodlands along the River Murray corridor as 'seriously threatened' (Smith and Smith 1989 cited in Kahrimanis et al. 2001). More recent investigations into River Red Gum health are supporting these early warnings (e.g. MDBC 2003). Survey work in 2002 and 2004 along the River Murray has shown regional declines in tree health occurring over short timeframes (Brett Lane and Associates 2005).

In 2002, 51% of River Red Gum trees surveyed were considered stressed, compared to 75% in 2004 (Brett Lane and Associates 2005, George et al. nd). This regional trend is likely to be reflected in tree health on site at the Banrock Station Wetland Complex. George et al. (nd) examined the association between health and reproductive potential which included a visual assessment of crown condition at the Banrock Station Wetland Complex. They found that across the majority of diameter size classes of both River Red Gum and Black Box were in poor health (Figure 24). This is reflected in tree health data captured by DEH in 2003 (Figure 25) which shows significant areas of poor health and dead trees across the site. The 2003 survey represents the baseline for the site, with approximately 522 ha of live trees (82%) and 116 ha of dead trees (18%) assessed (note the assessment area only went to the 1956 flood level). Of the live trees the majority are classed as unhealthy (approximately 299 ha or 57%).

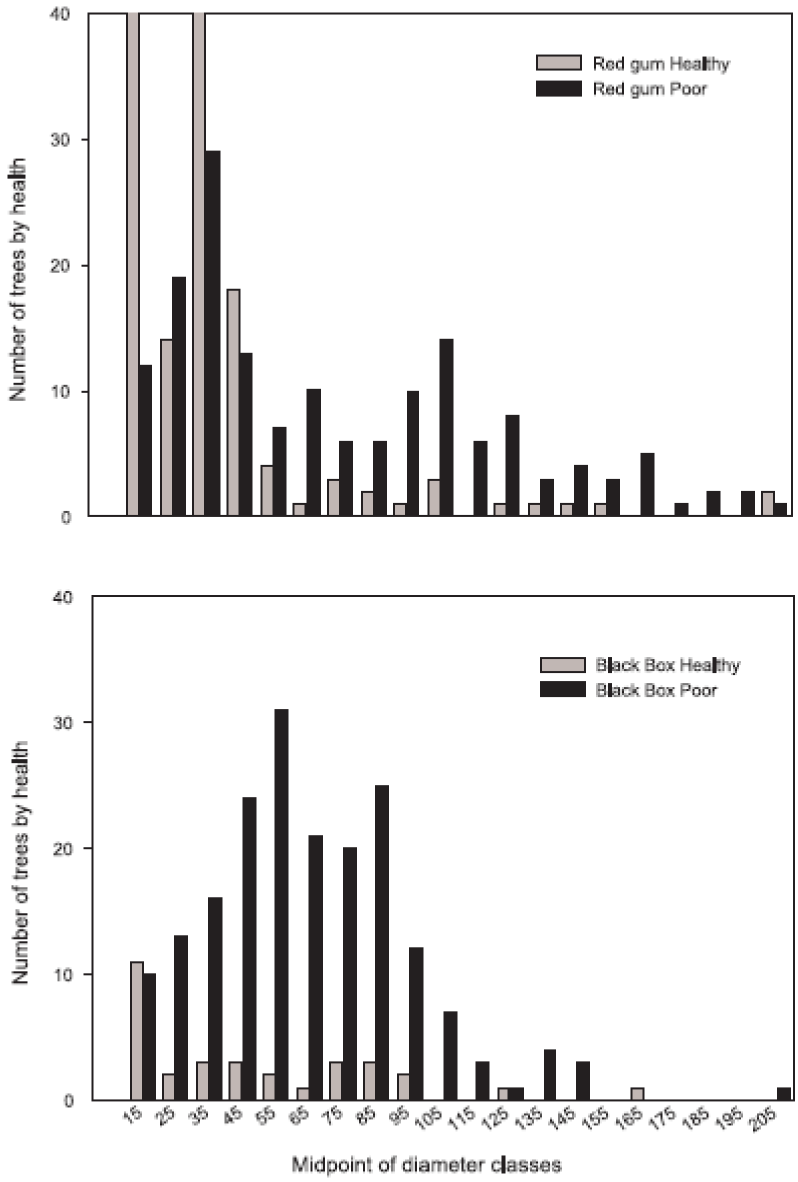

Figure 24: Density of River Red Gum and Black Box trees at Banrock Station Wetland Complex, based on diameter and health classification (from George et al. nd).

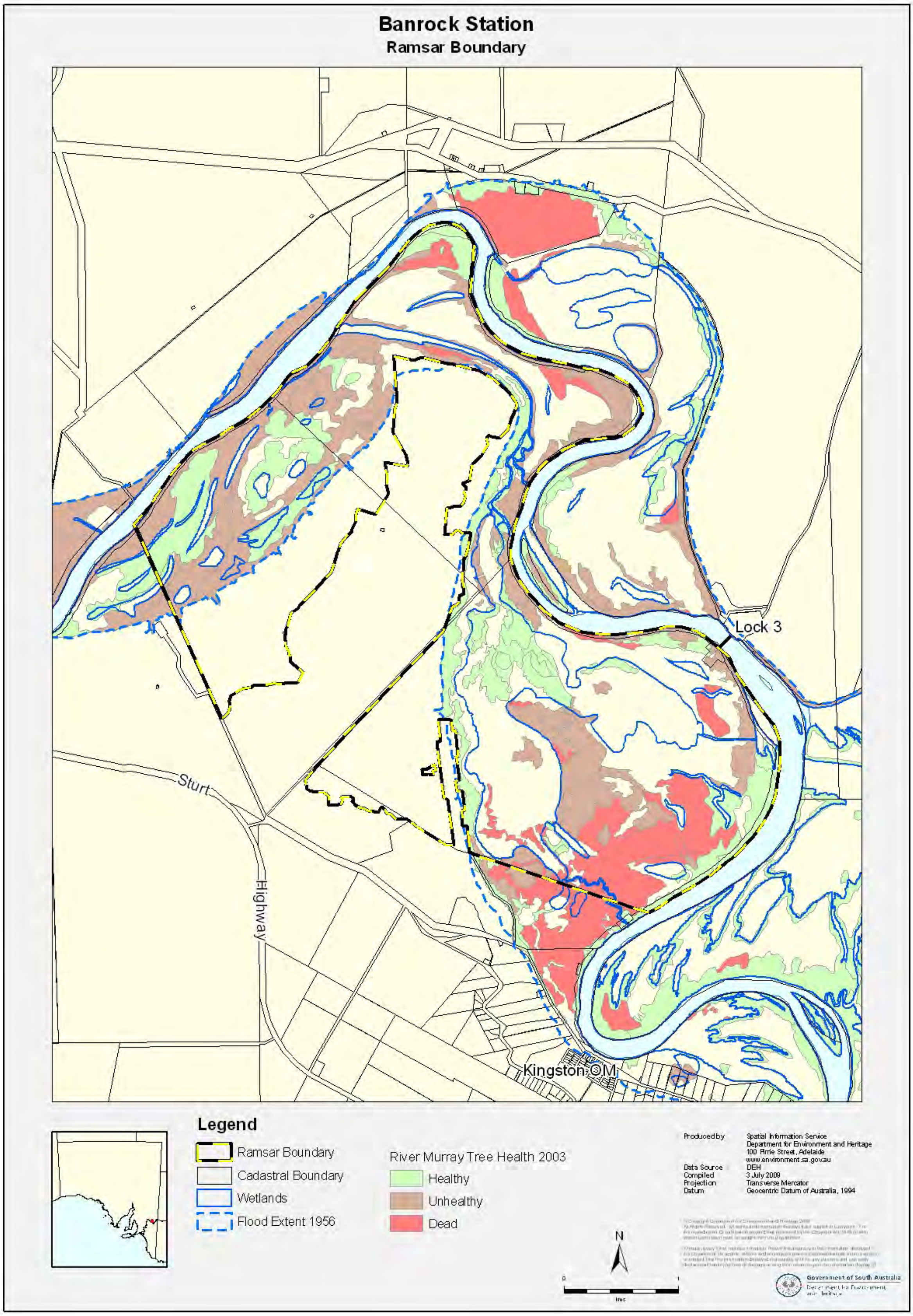

Figure 25: River Murray Tree Health 2003 data for the Banrock Station Wetland Complex. Note the assessment of tree health is only to the 1956 flood level, not the whole site (supplied DEH, July 2009).

George (2004) investigated the stand structure and long term viability of River Red Gum and Black Box woodlands at the Banrock Station Wetland Complex. Her investigations were undertaken in November 2002 and provide a detailed description of tree density and age structure at the time of listing. Overall tree density was calculated as 88 trees per ha with River Red Gum being dominant (60 %) based on density measures (69 trees per ha) and basal area per ha (8.2 m^2 of basal area per ha) (George 2004; George et al. 2005). Across the site localised clumps of small trees of both species can be found, and size distributions suggest episodic recruitment and opportunistic survival (George et al. 2005).

Using tree size as a surrogate measure of age and a number of assumptions regarding longevity of the species, she determined that the viability of the Black Box woodlands at Banrock was questionable. George (2004) estimated that to maintain the River Red Gum population at the 2002 level, 57 % of the extant saplings had to survive. For the Black Box, 100 % of the saplings had to survive. The altered age structure of both species at Banrock suggest that the long term survival of the populations is of concern, particularly Black Box. The elevated sites with Black Box at Banrock were last inundated in the 1973-1975 floods (Jensen 2008). Sapling release, the process of self thinning in cohorts, is believed to be of paramount importance (George et al. 2005) and altered water regimes and increased soil salinisation are serious threats to the long term survival of these woodlands.

3.7 Fauna

3.7.1 Invertebrates

Macroinvertebrate sampling was undertaken to assess response to partial wetting and drying at the Banrock Station Wetland Complex between July 1998 and February 2000(Tucker (2003). This data represents baseline data for aquatic macroinvertebrates for the site. Sampling was inconclusive with regards to changes in richness and community composition in response to altered water regimes. The fauna collected are typical of riverine wetlands and the partial drying was most likely insufficient to result in any significant changes in the macroinvertebrate fauna. Although identification was only to family level (or in some cases tribe), the fauna are typical of permanent wetlands. The taxa would have a high correlation with species found in the main channel, a reflection of the wetland being a flow through system and that taxa from the river will be the main source of colonists.

Fauna were similar to those collected at Loch Luna (under the River Murray Wetland Baseline Survey funded by the SA Murray Darling Basin NRM Board). However, there were fewer taxa recorded at Banrock. Taxa collected at Loch Luna but not recorded at Banrock were five water mite families and a number of Hemipteran families. Continued sampling of macroinvertebrates at Banrock Station Wetland Complex would likely increase the number of taxa recorded. It is possible that difference in sampling between the two locations is reflected in the results.

River Snail - *Notopala*

The River Snail *Notopala sublineata* is listed as endangered in NSW and threatened in Victoria. It is also listed as one of the native species that characterises the endangered ecological community 'Aquatic Ecological Community in the Natural Drainage System of the Lower Murray River Catchment' which is listed under the *NSW Fisheries Management Act 1994*. It was recently unsuccessfully nominated for listing under the EPBC Act (http://www.environment.gov.au/biodiversity/threatened/species/river-snail.html).

This species is no longer able to survive in the main channel of the lower River Murray and is believed confined to a few populations in irrigation pipelines. In 1992 a population was found at Kingston-on-Murray, South Australia (upstream of Banrock) in pipelines that were 50 years old, fully enclosed and 2 m below ground. The current status and the extent of occurrence of the River Snail in irrigation pipelines in the Murray-Darling Basin are not clear as surveys have been limited. Surveys in suitable areas of the lower River Murray in South Australia have failed to find the River Snail in the past (http://www.environment.gov.au/biodiversity/threatened/species/river-snail.html).

A small breeding colony exists at Banrock Station and was relocated from the wetland to the river during the complete drying of the wetland in 2008 (K. Thorn, Banrock Station, pers. comm.). The breeding colony is confined to a PVC tube that enables juvenile snails access from the tube to the wetland. In February 2000, 13 snails were placed in the tube and within 9 months 44 were counted inside the tube, indicating breeding and possible dispersal into the wetland. A small population (<100) continues to live within the tube indicating that the tube habitat is suitable for breeding, however, it is not known whether breeding has occurred outside the tube (A. Sharley, Banrock Station, pers. comm.)

The RIS (2002) listed the River Snail as a significant taxon located at Banrock, and suggested that an introduced population was becoming established. Further data is required to clarify the standing of the population at the Banrock Station Wetland Complex, particularly in light of irrigation pumps being moved from the wetland.

3.7.2 Fish

Native species

Tucker (2003) reported only five species of fish in Banrock (three native and two invasive) from October 1998 – February 2000. Subsequent fish surveys of the Banrock Station Wetland Complex have recorded nine species of native fish and four invasive species (Table 4) (Tucker 2003; Smith and Fleer 2007; Fredberg et al. 2009). The species present are considered 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.

The Ramsar site straddles Lock 3 and provides a natural fish passage around the main channel barrier, allowing migration to occur in high flows.

Whilst formal evaluation of fish passage remains a knowledge gap and a research priority, the current flow control regulators and their management are unlikely to facilitate the bi-directional passage of fish around the Weir – upstream migration is especially unlikely. This is due to the use of flow control boards and the resulting head loss either side of those boards. As a result, native fish passage upstream is hampered, by high water velocities (about 80 cm/s^{-1}) and a waterfall (approximately 1 m) at both the inlet and outlet structures. Downstream passage is possible, however, but all fish that enter and exit the wetland must survive the waterfall at either end. Clearly some do because Banrock Lagoon was re-colonised with small-bodied fish during the last filing event, the relative success of lateral migration is still unknown (B. Smith, SARDI Aquatic Sciences, pers. comm.).

Native fish exhibit a range of migratory behaviour, however all species recorded from the Ramsar site are potamodromous, in that they only migrate within freshwater. The migratory behaviour of some of the species recorded at the site is poorly known. Species characteristics are detailed in Appendix C.

Table 4: Fish species recorded at the Banrock Station Wetland Complex (Smith and Fleer 2007; Fredberg et al. 2009).

Common name	Scientific name
Small bodied natives	
Australian smelt	*Retropinna semoni*
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*
Carp gudgeons	*Hypseleotris spp*
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*
Flat-headed Gudgeon	*Philypnodon grandiceps*
Murray River Rainbowfish	*Melanotaenia fluviatilis*
Bony Herring	*Nematalosa erebi*
Large bodied natives – juveniles only	
Freshwater Catfish	*Tandanus tandanus*
Golden Perch (Callop)	*Macquaria ambigua*
Invasive species	
Common Carp	*Cyprinus carpio*
Eastern Gambusia	*Gambusia holbrooki*
Goldfish	*Carrasius auratus*
Redfin Perch	*Perca fluviatilis*

The native fish community is comprised principally of small-bodied species (< 250 mm at maturity). Adult large-bodied native species (> 250 mm total length, at maturity) are absent. During the 2008 filling, some juvenile Golden Perch and one juvenile Freshwater Catfish was sampled in the wetland's connecting channels (Fredberg et al. 2009). As the wetland is shallow, large-bodied native riverine species such as Murray Cod and Silver Perch have not been recorded (Smith and Fleer 2007).

<u>Invasive species</u>
Invasive fish species recorded at the Banrock Station Wetland Complex include Common Carp, Goldfish (*Carrasius auratus*), and Eastern Gambusia (*Gambusia holbrooki*). Common Carp have been historically abundant (75 %

by number and a larger but uncalculated proportion of the biomass; Smith and Fleer 2007). Redfin Perch (*Perca fluviatilis*) was not found by Fredberg et al. (2009) although the species is common throughout the Riverland region and previously recorded at the site by Smith and Fleer (2007). It is possible that the fish community at the Banrock Station Wetland Complex degraded after listing due to a greater dominance by Common Carp, caused by raised water levels in spring for irrigation which promotes Common Carp spawning and recruitment (B. Smith, SARDI Aquatic Sciences, pers. comm.). Banrock wetland was one of a number of wetlands sampled during the River Murray Baseline Surveys that was considered to be a Common Carp recruitment 'hot spot' (B. Smith, SARDI Aquatic Sciences, pers. comm.). Carp control is considered a key management issue for the wetland.

3.7.3 Amphibians

Eight of the ten species of frogs found in the region have been recorded from Banrock Station Wetland Complex, including Peron's Tree Frog (*Litoria peronii*), Southern Bell Frog (*Litoria raniformis*), Eastern Banjo Frog (*Limnodynastes dumerlii*), Barking Marsh Frog (*Limnodynastes fletcheri*), Spotted Grass Frog (*Limnodynastes tasmaniensis*), Common Froglet (*Crinia signifera*), Eastern Sign-bearing Froglet (*Crinia parinsignifera*), and the Mallee Spadefoot (*Neobatrachus pictus*).

The Southern Bell Frog (also called the Growling Grass Frog) is listed under the EPBC Act 1999, the IUCN Red List, and is considered vulnerable in South Australia. The species occurs across the southeastern States, and whilst it can be locally common, it is in decline in many areas of its range. Adults are typically found near water or in wet areas in woodlands, shrubland or open and disturbed areas, but prefer still waters. Tadpoles hide amongst vegetation in the shallower edges of wetlands. They will occupy both permanent and temporary wetland habitats, actively moving onto recently flooded areas and using permanent wetlands as refuges in dry periods (DEC 2005). Plant species often recorded at sites where Southern Bell Frogs persist include *Typha* spp., *Phragmites australis*, and *Baumea arthrophylla* among others (DEH 2007). However they have also been recorded associated with Lignum shrublands, River Red Gum and Black Box woodlands (DEC 2005). Refuge habitat could include soil cracks in dry wetland beds, fallen timber, debris and dense vegetation on low frequently inundated floodplains DEC 2005).

Adult frogs have a varied diet and will eat terrestrial invertebrates, small reptiles, other frogs and even small fish. They are sit-and-wait predators, and predominantly nocturnal (DEC 2005). Breeding typically occurs in November and March (DEC 2005) following rises in water levels, from rain events or flooding. The main threats include habitat loss and fragmentation, especially reduced inundation of floodplains providing a range of wetland types. Loss of floodplain connectivity affects movement, breeding opportunities and can displace animals from their natural environment (DEC 2005). Disturbance to the riparian zone through grazing and removal of woody debris affects the adults and loss of aquatic vegetation the tadpoles. Altered water regimes alter the seasonality of flooding and as such can also remove triggers for breeding (DEC 2005). Salinity, potential predation by fish and pollution are all thought to impact on the tadpoles (DEC 2005).

3.7.4 Waterbirds

Australian waterbirds are highly mobile, exhibiting opportunistic behaviour and occurrence (Jaensch 2002) with habitat resources and availability driving waterbird abundances. The movements of waterbirds are considered to be largely unpredictable and complex with the nomadic nature of many Australian waterbirds believed to have evolved in response to Australia's variable climate (Kingsford and Norman 2002). The most predictable movements are seen in those species which migrate annually to the Northern Hemisphere and/or New Zealand.

Only wetland associated birds are included in the ecological character description of the Banrock Station Wetland Complex. Terrestrial birds recorded in adjacent landscapes are not discussed in detail. A broad definition of "wetland associated" has been adopted. Wetland associated in this context is defined as birds that are associated with habitats and vegetation that are considered to require periods of inundation. Wetland dependency may only apply to certain life stages for some species.

Birds from the Banrock Station Wetland Complex have been placed into the following broad groupings:

Waterbirds

- Waterfowl (Anatidae, Anseranatidae) – ducks, swans, and geese are typically grouped as waterfowl. These feed on both plant and animal material, and require freshwater for drinking.
- Grebes (Podicipedidae) – diving waterbirds which feed mainly on animals including fish and use both fresh and saline wetlands.
- Pelicans (Pelecanidae), Cormorants (Phalacrocoracidae), Darters (Anhingidae) – piscivore waterbirds (fish eating) although they will also eat invertebrates such as crabs, prawns, crayfish. They typically feed in water > 1 m.
- Herons and Egrets (Ardeidae), Ibis and Spoonbills (Threskiornithidae) – these forage in the shallows feeding on fish and invertebrates.
- Crakes, Rails, Coots, Water Hens (Rallidae) – forage in the shallows and amongst inundated vegetation feeding on both plant and animals.
- Shorebirds (Scolopacidae, Recurvirostridae, Charadriidae) – forage in the shallows and on exposed mud banks for benthic invertebrates.
- Gulls, Terns (Laridae) – feed mainly on animals both in the shallows and in water > 1 m, with the gulls considered omnivorous scavengers.

Non waterbirds:

- Hawks and Eagles (Accipitridae) – raptors that eat fish and/or waterbirds and/or nest in wetlands.
- Wetland associated birds – includes species that utilise wetland habitat/vegetation for at least part of their life cycle (e.g. Clamorous Reed Warbler, Sacred Kingfisher).

Waterbirds exhibit a range of feeding strategies, which ultimately affect how they use wetlands. As a result of these different physiological and morphological characteristics, different species are able to use the same areas by feeding on different resources (Kingsford and Norman 2002). Bill shape and size is often related to diet, and closely related species can use different habitats but eat the same or different prey. Diet requirements affect the behaviour and patterns of habitat use; for example, it is typical to see herbivorous species feeding for extended periods, as their food is harder to digest.

The range of wetland types found at the Banrock Station Wetland Complex supports species typical of inland floodplain wetlands. A total of 61 wetland associated bird species have been recorded within the site (Table 5; Appendix D and E). These include species which are resident throughout the year, as well as transient species such as migratory shorebirds that use the Banrock wetlands intermittently. Included in the list are several migratory species that are listed under international agreements CAMBA (9), JAMBA (8) and ROKAMBA (5) as well as an additional 26 Australian species that are listed as migratory or marine under the *Environmental Biodiversity and Conservation Act 1999* (EPBC).

Table 5: Wetland dependent birds recorded within the Banrock Station Wetland Complex.

Waterbird group	Typical feeding and foraging information	Number of species
Waterfowl	Shallow or deeper open water foragers. Vegetarian (Black Swan) or omnivorous with diet including leaves, seeds and invertebrates.	13
Grebes	Deeper open waters feeding mainly on fish.	3
Pelicans, Cormorants, Darters	Deeper open waters feeding mainly on fish.	6
Heron, Ibis, Egrets	Shallow water or mudflats. Feeding mainly on animals (fish and invertebrates).	11
Crakes, Rails, Water Hens, Coots	Coots in open water; others in shallow water within range of cover. Omnivores.	7
Shorebirds	Shallow water mudflats and beach foreshore. Feeding mainly on animals (invertebrates and fish).	11
Gulls, Terns	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats.	4
Hawks, Eagles	Shallow or deeper open water on fish and occasionally waterbirds and carrion.	2
Wetland associated	Wetland vegetation dependant	4
Total		**61**

Waterbird breeding

At the time of listing four species of waterbird had been recorded breeding at the site: Australian Shelduck (*Tadorna tadornoides*), Australian Wood Duck (*Chenonetta jubata*), Black Swan (*Cygnus atratus*), and Grey Teal (*Anas gracilis*) (Birds Australia 2009). In 2008 Musk Duck (*Biziura lobata*) were observed breeding on site (Banrock Station unpublished). Musk Duck are listed as rare in South Australia.

Regent Parrots

Regent Parrots nest in hollows in mature and dead River Red Gums, foraging up to 12 km from the nest trees. The birds prefer to use flight corridors of native vegetation between their nesting colonies along the River Murray to their preferred feeding areas, large areas of intact mallee woodlands (DEH 2006) (Figure 26). Details of the recorded population of Regent Parrots at Banrock Station are provided in Section 4.3.5.

Figure 26: Regent Parrot (*Polytelis anthopeplus*) in Mallee. Photograph supplied Banrock Station.

4 Ecosystem services and benefits

4.1 Overview of benefits and services

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

The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) defines four main categories of ecosystem services:

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

The ecosystem benefits and services of the Banrock Station Wetland Complex are outlined in Table 6 .

Table 6: Ecosystem services and benefits provided by the Banrock Station Wetland Complex at the time of listing.

Category	Description
Provisioning services - products obtained from the ecosystem such as food, fuel and fresh water.	
Irrigation	At the time of listing the wetlands provided irrigation water for Banrock Station Vineyard.
Regulating services - benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation.	
Maintenance of hydrological regimes	Permanent inundation of the main wetlands contributes to maintaining surface-groundwater balances at the local scale, although the relative importance is not well understood. Connectivity between a river channel and its floodplain ensures that flood peaks are reduced at the local scale.
Carbon sequestration	Data deficient but plausible. The vegetation in the lagoons, the floodplains and mallee woodland sequester carbon and thus potentially play a role in reducing greenhouse gasses
Cultural services - benefits people obtain through spiritual enrichment, recreation, education and aesthetics.	
Recreation and tourism	Regionally important tourism destination with up to 100,000 visitors annually many of whom experience the eco-tourism accredited trails through the mallee woodland, floodplain and main lagoon. Prior to 1993 the wetland was used extensively by the local community for recreational purposes including 4WD clubs, horse hunting trials, fundraising picnics, waterfowl hunting and yabbying.

Category	Description
Cultural heritage and identity	A number of culturally significant features occur on site including scar trees, middens, hearths, various artefacts. There is evidence of tool making, camping, plant/seed processing, hunting and utilization of the natural resources of the area over extended time periods. The site is also important for European heritage, for example the South Australian Police hold an annual service on site in recognition of the first South Australian Policemen killed on active duty.
Science and education	The Banrock Station Wetland Complex provides extensive educational opportunities with the central principle of sustainable management and wise use showcased.
	The site has been used for a number of research investigations including carp removal studies, seed bank resilience, groundwater surface water interactions, and ecological response to a restored hydrological regime, among others.
Supporting services - 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.	
Hydrological processes	The hydrological regime supports a number of floodplain wetland habitats. Wetting and drying of the wetland has been shown to have some influence on local groundwater levels and stress to riparian vegetation.
Physical habitat	Supports a range of wetland habitats representative of the lower River Murray floodplain.
Ecological connectivity	Potentially provides a migratory pathway around Lock 3 for native fish species, and the ability for aquatic species to move between the river and the floodplain/wetlands to meet their life cycle needs. The presence of control structures may act as a limiting factor on this service. Despite this, downstream small native fish migration was observed at the site during 2008 (K. Thorn, Banrock Station, pers. comm.), however the relative success of such movements are not known.
Nutrient cycling	Data deficient but plausible.
Biodiversity	Supports a range of species typical of lowland River Murray floodplain wetlands and mallee shrublands.
Threatened wetland species, habitats, and ecosystems	Supports the nationally listed species, Regent Parrot and Southern Bell Frog, the latter being considered globally endangered (IUCN 2009).

4.2 Conceptual component and character models

Documenting the ecological character of a site has moved beyond just describing a list of components (usually species), but rather the intention is to understand the intricacies of the interactions between the components, processes and benefits and services, and how the unique combination of interactions gives each site its character.

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. It therefore becomes necessary to step back and look at the bigger picture, to identify the critical components, processes, and ecosystem services (see preceding sections) and the basic rules that science tells us links these together.

For most wetlands the ecological signature of a wetland, as reflected in its biotic components, is determined by the abiotic drivers of climate, geomorphology and hydrology. The critical components, processes and services combined provide the unique biodiversity value of the site, its ecological services and its ecological signature.

The use of conceptual models in natural resource management is becoming more prevalent (e.g. Davis and Brock 2008; Scholz and Fee 2008; Price and Gawne 2009). Conceptual models can be used for a number of purposes including (Price and Gawne 2009):

- Synthesis of knowledge and to identify knowledge gaps.
- Identification of key links between drivers, stressors, and system responses.
- Understanding of how the processes, threats and system dynamics differ between wetland types.
- Facilitate in the selection and justification of indicators.
- Interpretation of monitoring data (specific to different wetland types) and identification of acceptable levels of change.
- Education and communications tools.

Price and Gawne (2009) illustrate how four different types of conceptual models are being used to develop an understanding of wetland ecosystems (Figure 27).

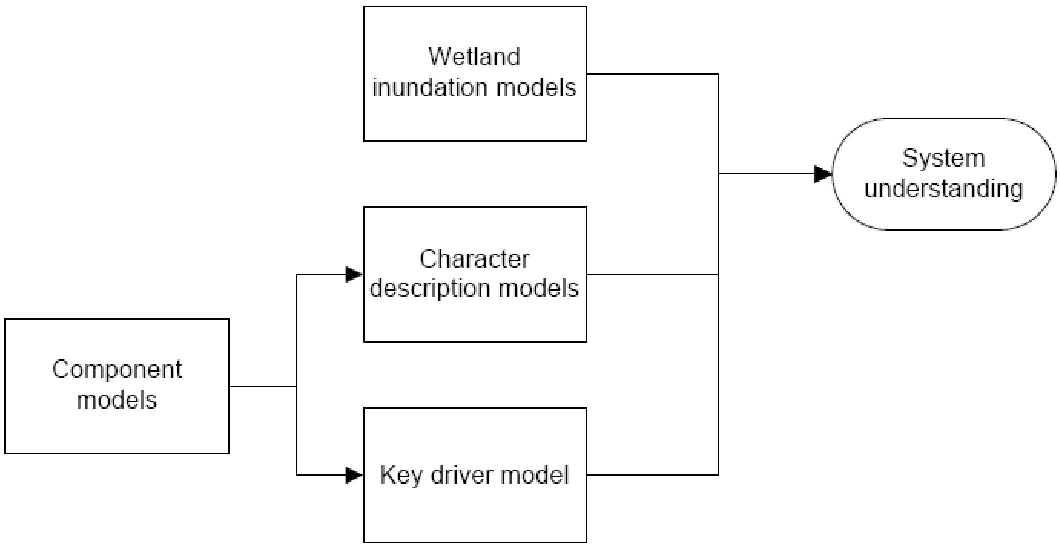

Figure 27: The relationship between the four types of conceptual model used in wetland management (from Price and Gawne 2009). Component models can be used to illustrate individual components, processes and services. Key driver models can equate to stressor models.

Component and character models are frequently used in ecological character descriptions to help illustrate the key elements of the ecological character of the site. Key driver or stressor models are recommended for use in the determination of limits of acceptable change (Davis and Brock 2008) and the identification of indicators for inclusion in monitoring programs.

Wetland character description models have been developed by a number of agencies including the QLD EPA, Murray Darling Basin Authority, and South Australian DWLBC for the majority of wetland types found in the south eastern States. Character models for two of the major wetland types found at Banrock are presented below (Figure 28 and Figure 29). These are based on models presented in Price and Gawne (2009) and modified to reflect the specific characteristics of Banrock Lagoon and wetlands found at Wigley Reach. An overarching conceptual model of how the system works (including relationship between the listing criteria and critical components, process and services) is presented in section 4.5 below.

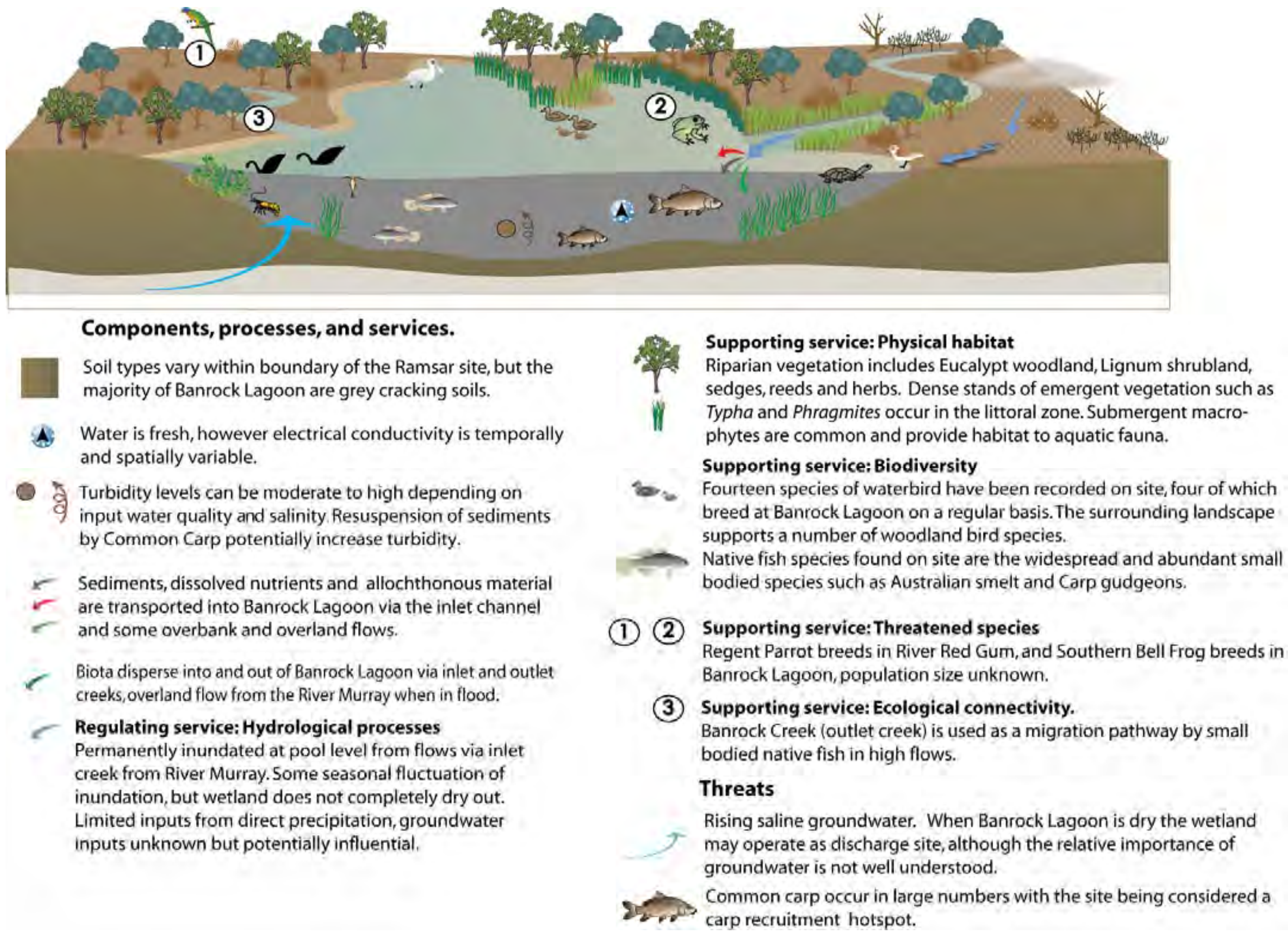

Figure 28: Conceptual model of Banrock Lagoon (Ramsar wetland type O) at listing, showing critical components, processes, services and services. Modified from base map kindly supplied by MDFRC – Commonly wet floodplain lake (Price and Gawne 2009).

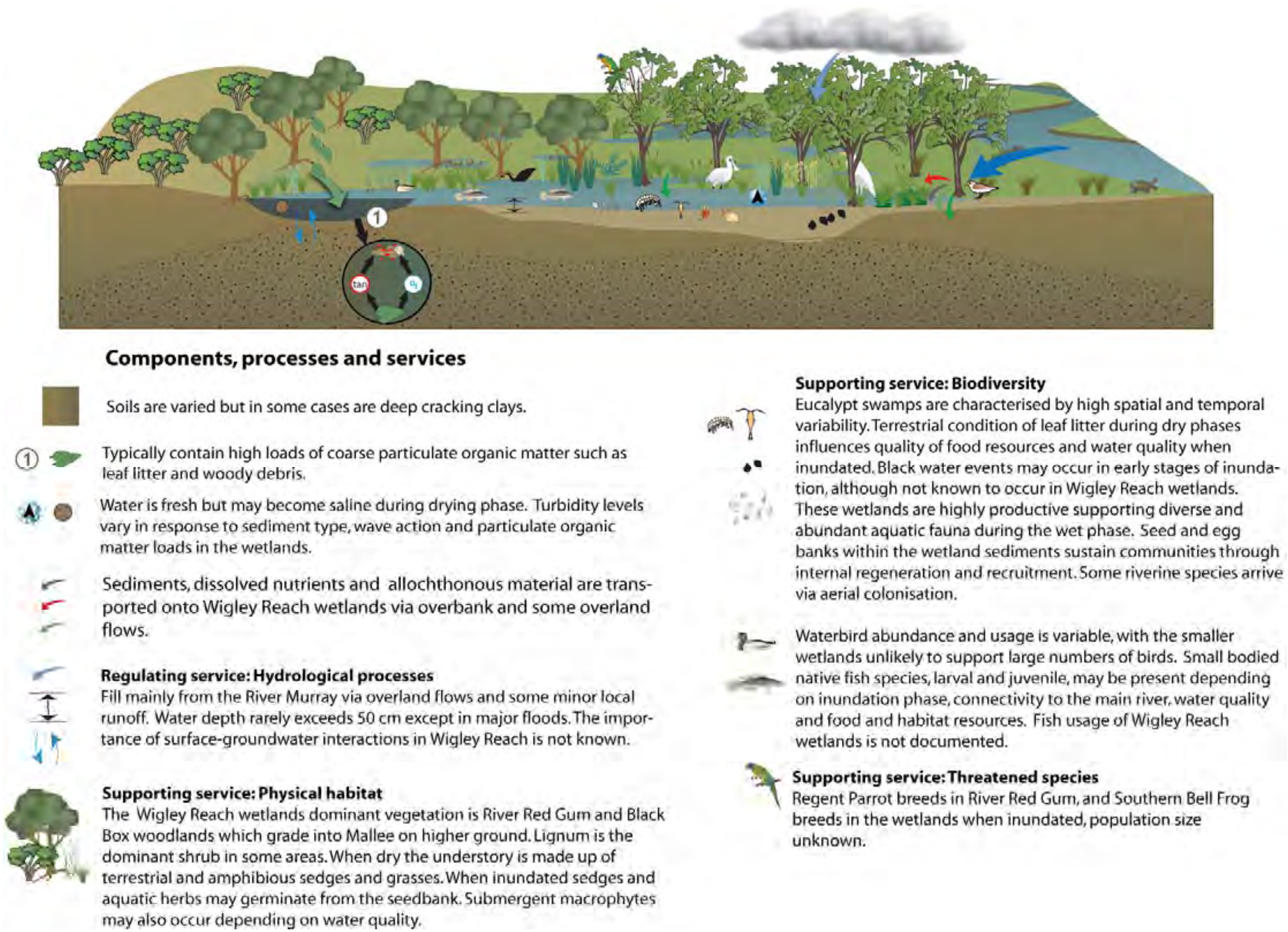

Figure 29: Conceptual model of Wigley Reach River Red Gum/Eucalypt dominated wetlands (Ramsar wetland type Xf). Critical components, process, services and threats are shown. Modified from base map kindly supplied by MDFRC – Eucalypt swamp (Price and Gawne 2009).

4.3 Identifying critical services and benefits

The critical ecosystem services and benefits of the Banrock Station Wetland Complex have been identified using the same criteria for selecting critical components and processes (DEWHA 2008):

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

An assessment of the services of the site against each of the above criterion is presented in Table 7. This identified five ecological services critical to the character of the site (those which met all 4 of the above criteria), which are described in greater detail below.

Table 7: Assessment of identified ecosystem services and benefits against the DEWHA (2008) criteria for identifying services critical to the ecological character of the site. A service is considered critical if it meets all four criteria. An x indicates the service meets the DEWHA criteria shown above. The numerals relate to the Ramsar criteria for which the site was listed.

Category and service/benefit	DEWHA criteria			
	1	2	3	4
Provisioning services				
Irrigation			X	
Regulating services				
Maintenance of hydrological regimes		3,4	X	X
Carbon sequestration				
Cultural services				
Recreation and tourism	X		X	X
Cultural heritage and identity	X			
Science and educational	X			
Supporting services				
Hydrological processes	X	2,3,4	X	X
Physical habitat	X	2,3,4	X	X
Ecological connectivity		4	X	X
Nutrient cycling			X	
Biodiversity	X	3	X	X
Threatened wetland species, habitats, and ecosystems	X	2	X	X

4.3.1 Hydrological processes

Banrock Station Wetland Complex is a floodplain wetland complex with the main wetland areas being Banrock Lagoon and Eastern Lagoon. At listing Banrock Lagoon was a permanent wetland which could have its water levels manipulated through the operation of control structures on both inlet and outlet creeks. The most significant affect of wetting and drying of the wetland is the affect on riparian vegetation. See Sections 3.3 and 5.1 for further discussions on this service. Keeping Banrock Lagoon full may influence the local water balance and interactions between surface and groundwater, although the relative importance of this service is not well documented.

4.3.2 Physical habitat - supports a range of wetland habitats typical of the lower River Murray floodplain

The wetlands found at the Banrock Station Wetland Complex are representative of floodplain wetlands found along the lower River Murray. As illustrated in section 4.2 the hydrological variability and complex vegetation associations present at the site provide a wide range of physical habitat for biota. Banrock Station Wetland Complex straddles the boundary of the Mallee Trench and Mallee Gorge geomorphic tracts encompassing both a broad and narrower floodplain (Wigley Reach).

4.3.3 Biodiversity - supports waterbird breeding

The species preferences and breeding requirements of the five species of waterbird which have been recorded breeding at the site are detailed in Table 8.

Table 8: Habitat preferences and breeding requirements for waterbirds recorded breeding at the Banrock Station Wetland Complex.

Species/Common name	Breeding requirements
Australian Shelduck, *Tadorna tadornoides*	Breeding begins in June/July in tree hollows and on the ground with down used to line the nest. Occurs on shallow fresh/brackish lakes, lagoons and marshes with short grasslands with scattered trees surrounding. Eggs take up to 33 days to hatch and fledging occurs at 3.5 months.
Australian Wood Duck, *Chenonetta jubata*	Breeding is variable across Australia, depending on rainfall and available grass for grazing. Will nest in tree hollows with down covering eggs, not always near water. Recorded breeding all year round. Prefer lightly wooded country near water. Will utilise both permanent and temporary wetlands as long as abundant grazing is nearby. Eggs take up to 28 days to hatch and fledging occurs at 3 months.
Black Swan, *Cygnus atratus*	Prefer large lakes and lagoons, with shallow, permanent fresh or brackish water. Nest in colonies. Nest mound built in open water, on an island, or in swamp vegetation. Breeding events have been recorded all year, but typically timed to coincide with highest water levels. Requires minimum water depth of 30 – 50 cm. until cygnets are independent. Eggs take up to 40 days to hatch. First flight 20 – 25 weeks.
Grey Teal, *Anas gracilis*	Commonly nest in a tree hollow or on the ground or in swamp vegetation with considerable lining of down. Prefers shallower waters but will utilise permanent or temporary water bodies. Breeding is irregular and may occur all year. Eggs take up to 26 days to hatch. Ducklings leave the nest soon after hatching by dropping to the ground/water. First flight at approximately 8 weeks.
Purple Swamphen, *Porphyrio porphyrio*	Recorded breeding all year round with timing of laying correlated with rainfall, temperature increase and photoperiod. Usually in reeds

Species/Common name	Breeding requirements
	in swamps, dams, usually in water but occasionally on isolated tussock up to about 180m from the water. Nest is beaten down reeds or rushes about 20cm thick. Multiple females can lay in the one nest. Each bird can lay 3–6 eggs. A communal nest may contain up to 12 eggs. The incubation period is between 25-27 days. Both sexes capable of breeding in the first year.

4.3.4 Supports threatened species, habitats and ecosystems

The Banrock Station Wetland Complex supports two threatened species, the Regent Parrot (*Polytelis anthopeplus monarchoides*) and the Southern Bell Frog (*Litoria raniformis*). The ecological requirements of each species is summarised in Table 9.

Table 9: Summary of ecological requirements for threatened species occurring at the Banrock Station Wetland Complex.

Regent Parrot (*Polytelis anthopeplus monarchoides*)	
Maintenance of taxa	Require vegetated flight paths from nesting trees to feeding grounds in mallee vegetation. Require River Red Gum community and mallee woodland.
Regeneration and reproduction	Requires hollow bearing trees of River Red Gum typically close to water. Hollows can be in dead or live trees. Requires food source in nearby mallee communities.
Southern Bell Frog (*Litoria raniformis*)	
Maintenance of taxa	Adults prefer still waters, with tadpoles hiding amongst vegetation. Adults are typically found in close proximity to water or wet areas in woodlands, shrublands or open disturbed areas.
Regeneration and reproduction	Inundation is a cue for breeding events. Eggs are typically laid in large fluid clusters or floating rafts in the littoral zone amongst vegetation in permanent wetlands. Tadpoles can live for 12-15 months with metamorphosis occurring in summer and autumn.

The size of the Southern Bell Frog population at the site is not known. A monitoring program was commenced in 2008, however there are too few data points on which to establish the size of the resident population as yet.

The Regent Parrot colony at the Banrock Station Wetland Complex has been monitored bi-annually since 2003/2004 as part of the 'Regent Parrot Population Monitoring' project delivered by the SA Department for Environment and Heritage. The project monitors a total of ten representative and spatially distinct Regent Parrot colonies within the South Australian distribution of this species (C. Crossing, DEH Berri, pers. comm.).

The main Regent Parrot colony at the Banrock Station Wetland Complex covers an area of approximately 30 hectares. The site is described as 'a River Red Gum forest/woodland with live trees along the inside edge of a large bend in the river'. All nest trees detected in the most recent survey in 2008 were located within 120 m of the Murray River (C. Crossing, DEH Berri, pers. comm.).

Regent Parrot surveys are undertaken every two years, with the data for the main colony at Banrock summarised in Table 10.

Table 10: Summary of nesting trees and nests for Regent Parrots at Banrock Bend colony and regional totals (Data supplied by DEH, Berri).

Banrock Bend monitoring site	2004	2006	2008
Nest Trees at Banrock	36	36	22
Total nests across population range	156	152	134
Proportion of nest trees at Banrock	23 %	23.7 %	16.2 %
Regional decline in nest trees			14.1 %
Decline in nest trees at Banrock			39 %
Nests at Banrock	37	38	25
Total nests across population range	175	165	155
Proportion of nests at Banrock	21.2 %	23 %	16.2 %
Regional decline in nests			11.4 %
Decline in nests at Banrock			32.4 %

The data suggest the proportion of the breeding population found at the main colony at Banrock remained reasonably stable during 2004 and 2006, with a decline in the number of nests detected in the last survey. The most recent figure of 25 nests would suggest approximately 50 breeding adults utilised the colony site in 2008. This colony is the second largest (in terms of total nests) of the ten colonies monitored under the program (C. Crossing, DEH Berri, pers. comm.).

The decrease in number of total nest at Banrock needs to be considered in light of regional population trends. Data collected by DEH has shown that there has been a decrease in total nests from 175 in 2004 to 155 nests in 2008, representing an 11.4 % decline in the population. DEH has largely attributed the decline to changes at three sites upstream of the Banrock colony suggesting they may be related to nesting tree health and/or reduced access to foraging grounds (C. Treilibs, DEH Berri, pers. comm.). As yet the reasons for the declines have not been clearly established, however further investigations are planned for the near future (C. Treilibs, DEH Berri, pers. comm.). The major threats to this species are the loss of mallee woodland within 20 km of the Murray River and vegetated corridors between nesting trees and foraging grounds.

A second smaller colony of the parrots was located at the downstream end of Banrock Creek at the junction with the River Murray in 2003/2004. At that time 11 nests in 11 nest trees were detected at this site, indicating approximately 22 adult birds utilised the area for breeding at that time, however more recent data are not available for this smaller colony.

4.4 Non ecological services and benefits

There are no criteria for listing a Wetland of International Importance that relate to cultural and economic services; however Banrock Station Wetland Complex has significant non ecological services and benefits. The site is culturally significant to both indigenous and non-indigenous communities, it has high value as a demonstration site for the concept of ‘wise use’ and provides significant recreational, tourism, educational and scientific research services and benefits. Several of these non ecological services and benefits are considered critical elements which contribute to the significance of the site as a wetland of international importance. Banrock Station Wetland Complex was one of three wetlands to win the Ramsar and Evian Award in 2002 for the best examples of the “wise use” principle in wetlands. A brief description of these services and benefits are presented below. Further detail can be found in the Ramsar Management Plan for the site.

4.4.1 Recreation and Tourism

The Banrock Station Wetland Complex is used extensively for recreation and tourism and showcases the principles of wise use for wetlands. The visitor education and wine tasting centre allows for awareness raising about the wetland ecosystem from a prominent location overlooking the site.

The Wine and Wetland Centre provides information panels describing the importance of the wetland, its rehabilitation and the overall ethos for the integrated management of the grape growing areas, the mallee ‘buffer’ zone and the core wetland ecosystem. The visitor information and wine tasting centre has up to 100,000 visitors annually.

The Wine and Wetland Centre also stresses issues such as water and electricity conservation practices through its recycling and solar energy generation infrastructure. Interpretive boards, a comprehensive field guide and a number of boardwalks and walking trails allows visitors to enjoy the wetland and environs whilst gaining information on wetland ecology, rehabilitation activities being undertaken, the history of the Station and the operation of the vineyard.

4.4.2 Indigenous values

The rich diversity and abundance of flora and fauna that was likely to have been present prior to European settlement of the lower River Murray would have provided a bountiful supply of natural resources for Indigenous Peoples. Banrock Station appears, from artefacts collected on surveys and historical accounts, to have been used and occupied by Indigenous Peoples for a diverse range of natural resources.

In one survey prior to the construction of boardwalks at Banrock Station, Hubbs and Hancock (2000a) found 216 lithic artefacts, nine hearths and identified a scatter of artefacts across the survey area. Four areas were described as significant archaeological sites. In a second survey (Hubbs and Hancock 2000b), found 157 lithic artefacts, 2 hearths, one fireplace and identified scatters of artefacts were found. Noted in the surveys were numerous culturally-modified (scar) trees, grinding stones, stone tool scatters, midden materials and in-situ hearth features. The size of the scars on the trees suggests that they were used for making shields or coolamons rather than canoes. Canoe sized scars have been found elsewhere on the Banrock Station property suggesting that the Indigenous Peoples used the trees for multiple purposes (Hubbs and Hancock 2000a and b).

It is highly likely that Indigenous Peoples used and occupied the area that is now Banrock Station. There is evidence of tool making, camping, plant/seed processing, hunting and utilization of the natural resources of the area over extended time periods. It is also likely that a quarry site was situated nearby. The range of different stone tools and other artefacts suggested to Hubbs and Hancock (2000a) that Indigenous Peoples at the site undertook multiple tasks and natural resources strategies. They state that ethnographic accounts, archaeological evidence and the close proximity to the Overland Corner Police Station Ration Depot, infer that large numbers of Indigenous Peoples would have congregated in the general area. Hubbs and Hancock (2000a) consider that the exposed surface artefacts represent only a small percentage of the unexposed cultural materials beneath the soil surface. The Principal Investigators believe that much remains to be investigated at the Banrock Station site with regard to cultural values (Hubbs and Hancock (2000b).

Tindale (n.d.) suggests that the Banrock Station area lies within the past boundary areas of the Erawirum and Nawait Aboriginal groups. If this is correct, it may be possible that the site was a significant area for trade and that use and access rights to different sections of the river affected the daily lifestyles of the Indigenous Peoples living in the area (Hubbs and Hancock, 2000a). Today, the Riverland Heritage Committee oversees the management of cultural heritage in the region.

Modern day Indigenous Peoples have been involved in the management of the Banrock Station site through activities such as cultural surveys prior to construction or other works, contribution to interpretative signage on boardwalks and entertainment (didgeridoo, dance, and stories) provided to Banrock Station hosted functions and guests.

There are a number of risks to the artefacts on site including disturbance by tourists, vehicles and construction of structures such as boardwalks.

4.4.3 Education

In 2001 a boardwalk walking trail was opened enabling tourists to walk out onto the wetland and enter bird hides to observe the wildlife. This opportunity to educate the community on the value of wetlands is a great achievement for the site (Constellation Wines Australia 2008a).

The Banrock Station Wetland Complex offers an ‘education experience’ for its visitors; both in terms of the wise use of a wetland, but also in terms of the rehabilitation of a wetland and its adjoining habitats, and for sustainable agricultural practices(Constellation Wines Australia 2008a).

This ‘education experience’ starts with the Wine and Wetland Centre which is designed to capture the imagination and interest of those that come to the site. This is done through the design of the building, and its location overlooking the floodplain wetland, mallee woodland buffer zone and the vines. Information panels within the Centre are designed to inform visitors and encourage them to take one of the walks available which will provide them with more detailed information about the site and its integrated management regime (Constellation Wines Australia 2008a).

Banrock Station offers four self-guided walks around the wetland; one of 2 kilometres, 4.5 kilometres and one of 8 kilometres around the Banrock Lagoon, with an additional 1 km section across the wetland bed when it is dry. They provide the visitors with an insight into the historical management of the site, the degradation that resulted from earlier less sustainable practices, and the rehabilitation which sees the site as it is today. Along the walking trails there are regular information boards describing aspects of the landscape, history or current management of the site which are 'interpreted' in the Walking Trail Guide. Along each trail there are also strategically placed Story Centres and Information Shelters which also provide detailed information about the site (Constellation Wines Australia 2008a).

4.5 How the system works

An overarching conceptual model which illustrates the critical components, processes and services and the criteria met for the Banrock Station Wetland Complex is shown in Figure 30. Whilst the site is representative of lower River Murray floodplain wetlands, the cultural and social services provided are central to the importance of this wetland. The site is managed using the wise use principles providing an important regional asset which showcases sustainable wetland management principles and provides an excellent recreation and educational experience. In addition it is a significant site at which research into floodplain ecosystems is routinely undertaken, contributing significant advances to our scientific understanding of how floodplain wetlands function.

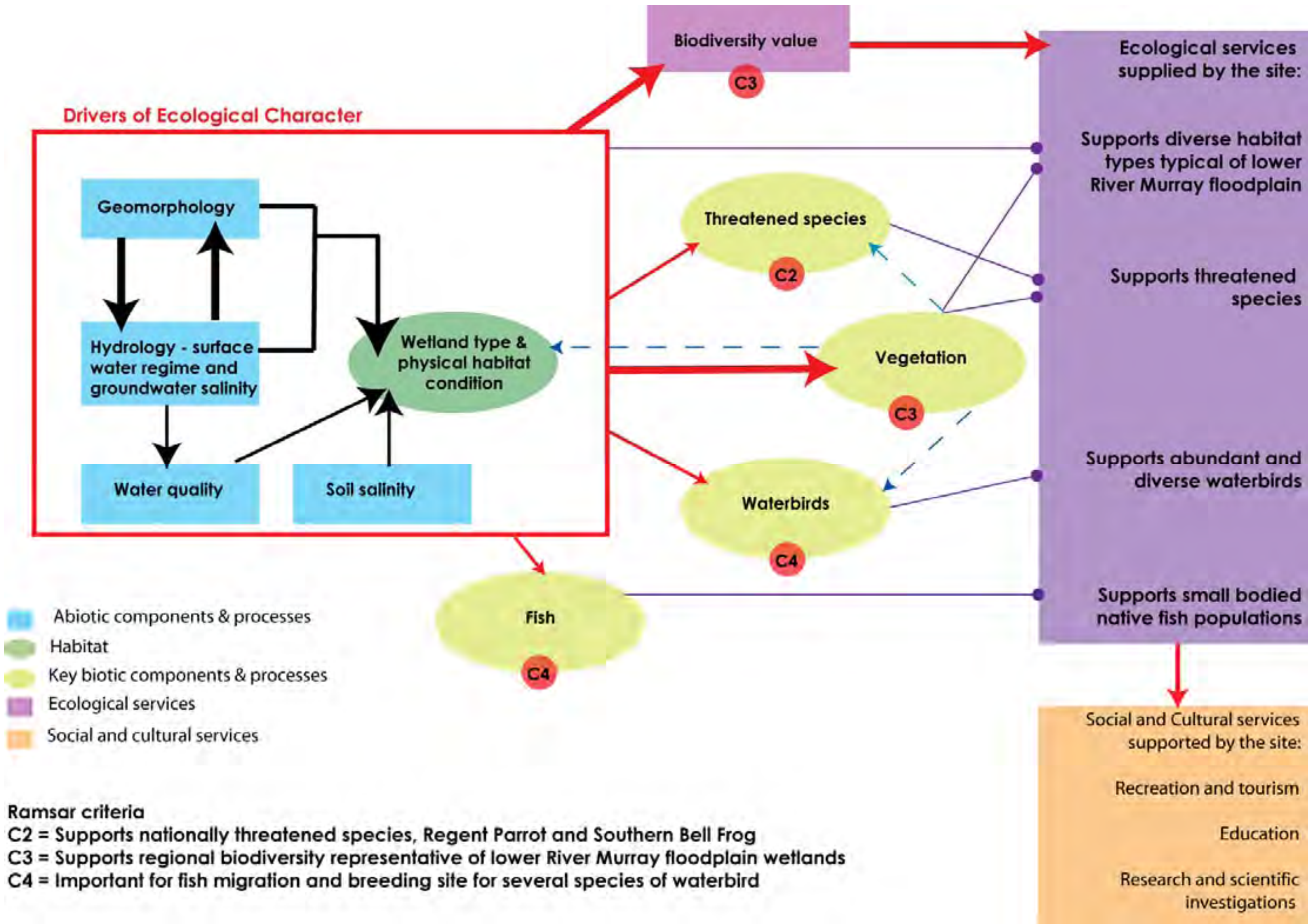

Figure 30: Conceptual model of ecological character of the Banrock Station Wetland Complex.

5 Threats to the ecological character of the Banrock Station Wetland Complex

Wetlands are one of the most threatened ecosystems, potentially at risk from a number of threats, which are often interrelated, and operating at multiple temporal and spatial scales. For example, vegetation patterns can be modified as a result of changed hydrology and rising saline groundwater, land clearing and grazing pressure (individually or in combination), the effects of which may be a legacy of past practices (decades) or current activities. In addition, changes in land use and associated activities increase the risk of invasion by weeds, introduced predators such as foxes pose risks to wetland fauna, while uncontrolled access for recreation increases the risks to wetland vegetation (e.g. via introduction of weeds or pathogens, or by physical damage) (Butcher et al. 2008).

The South Australia Wetland Strategy (DEH and DWLBC 2003) identifies the major threats and management issues to wetlands in South Australia as:

- Destruction of wetlands – conversion to alternative uses;
- Changes to water regimes;
- Introduced plant and animal species;
- Pollution impacts;
- Inappropriate land use practices;
- Salinity; and
- Over exploitation of wetland resources.

Water management (e.g. river regulation) and use is the most significant ongoing threat to wetlands of the Murray-Darling Basin (DEH and DWLBC 2003).

While there are many potential threats that may impact on the habitat and biodiversity values of the Banrock Station Wetland Complex, many of them are controlled under current management arrangements for the site. The main threats to the ecological character of the Banrock Station Wetland Complex are climate change, water management and use, invasive species and to a lesser extent human disturbance. In the following sections each is briefly described along with the more minor threats to the site. The IUCN-CMP (2006) threat classification has been adopted to describe the threats to the ecological character of the site, as recommended in DEWHA (2008).

A summary stressor model of the major threats, stressors and ecological effects each have on the components, processes and services of the site is presented in Figure 31. These threats have the potential to influence, or are currently affecting, the ecological character of the site. More specific stressor models are presented in the following sections describing each threat.

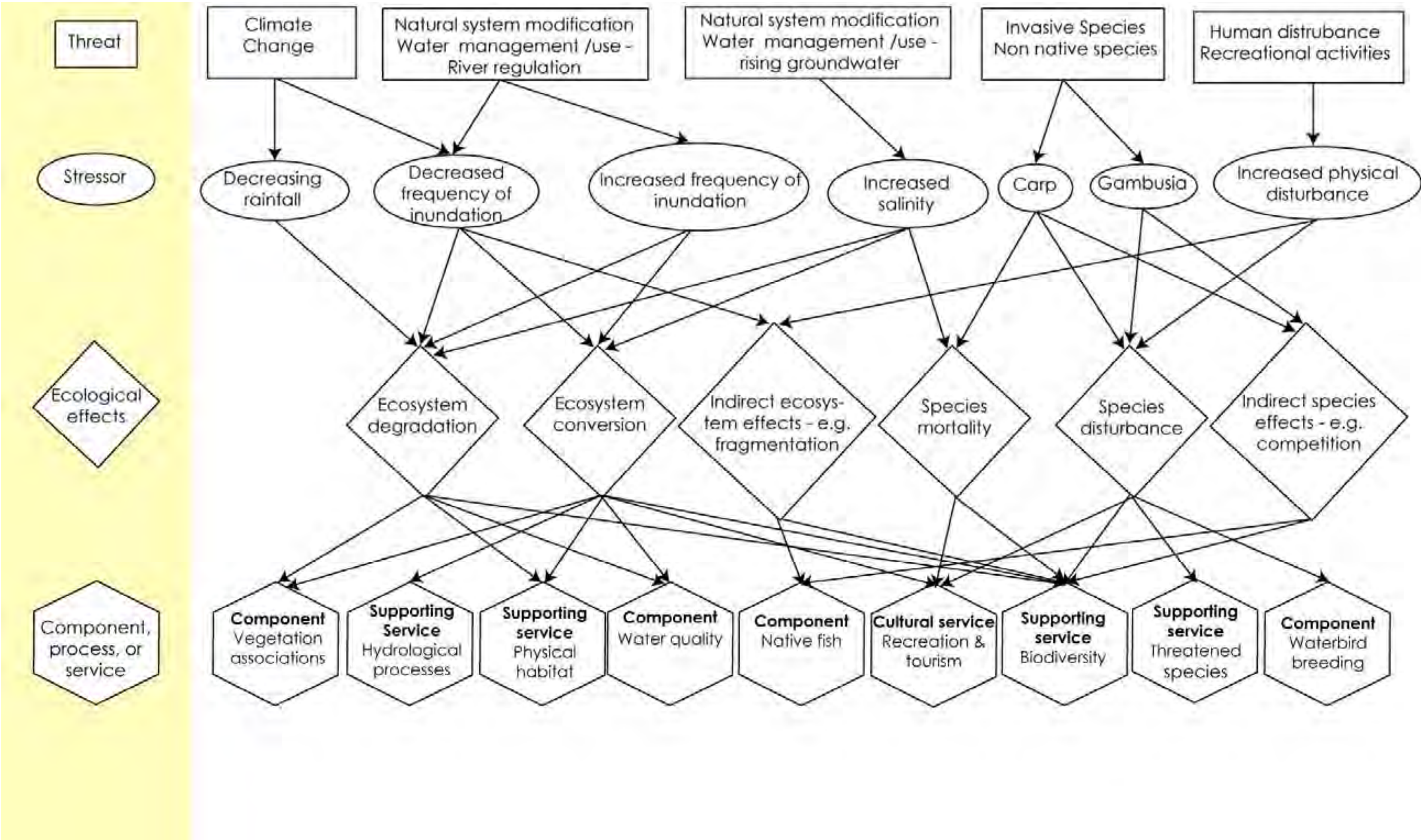

Figure 31: Major stressor model for the Banrock Station Wetland Complex at listing. Note that not all threats and ecological effects are shown, only those considered to have the potential to change the ecological character of the site.

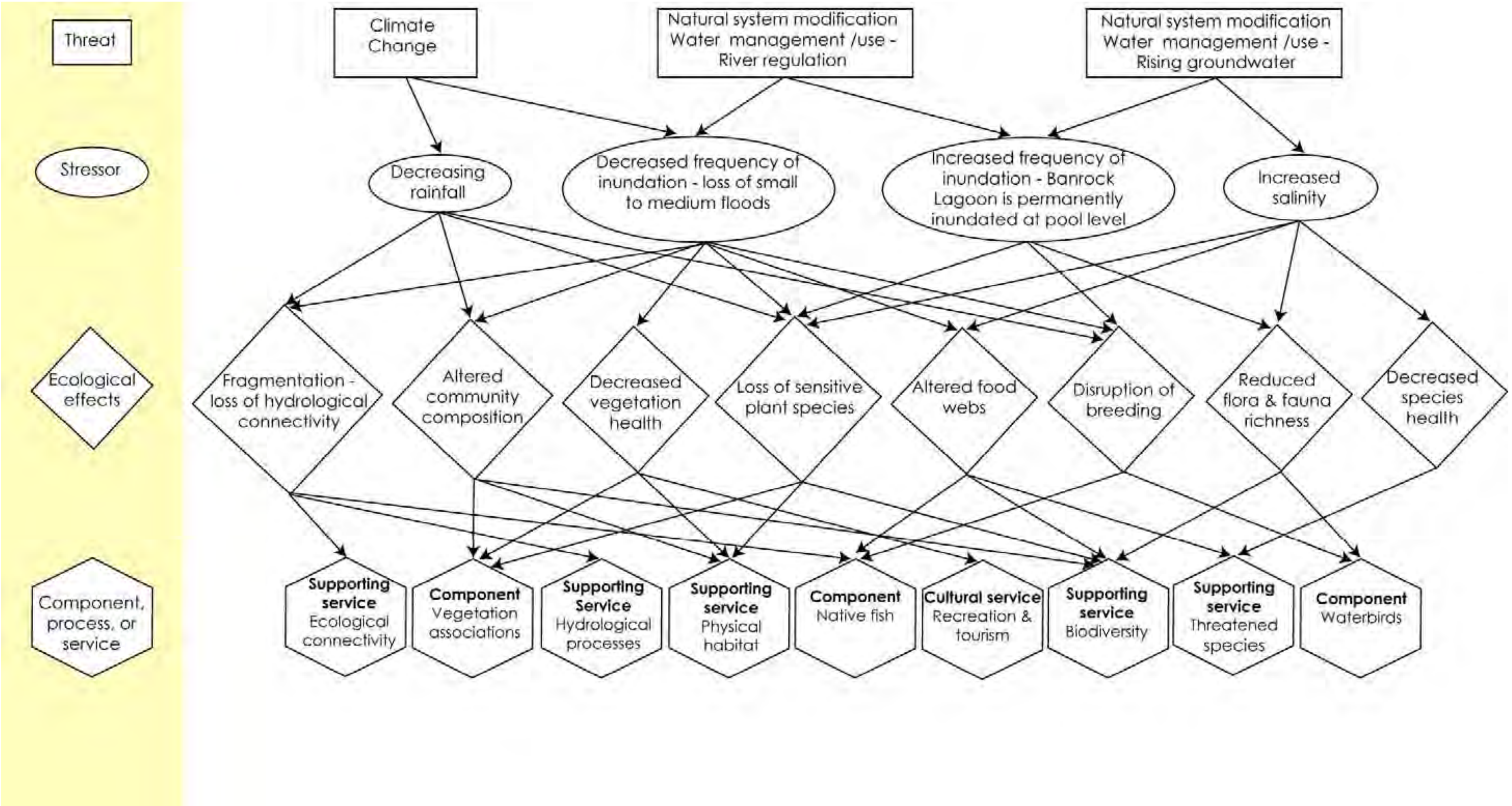

Figure 32: Stressor model of natural system modification – water management and use. Illustrates ecological effects and components, processes and services affected at time of listing.

5.1 Natural system modification - Water management/use

The major ecological affects and the components, processes and services affected by water management and use at the time of listing are shown in Figure 32 above. Note that climate change, decreasing rainfall exacerbates the stressors associated with water management at both the local and catchment scale.

5.1.1 Loss of small to moderate floods

Water regime is considered the key driver of wetland ecosystems and determines the ecological signature of a wetland. Altered water regimes are considered the single most damaging impact on wetland and floodplain ecosystems (Bunn and Arthington 2002). Disruption of the hydrological integrity of a system such as the River Murray can affect several attributes as described by Bunn and Arthington (2002) including:

- Physical and geomorphic processes,
- The timing, duration and extent of floodplain inundation,
- Habitat availability at both local and landscape scales,
- Biological and ecological processes for riverine and floodplain flora and fauna (e.g. breeding, migration, recruitment, metabolism, competition),
- Water quality and the cycling of nutrients and energy,
- Resilience to invasive flora and fauna species.

Wetlands along the lower River Murray have had their natural hydrological regimes significantly altered by river regulation (Walker and Thoms 1993). Wetlands with low elevations have had a significant increase in water permanency, and wetlands at higher elevations are dry more often. Frequency, timing, and duration of floods have all been altered.

As Banrock Station floodplain straddle Lock 3 the affect of river regulation has increased permanency in Banrock Lagoon, with the main wetland area operating as a flow-through system permanently connected to the weir pool upstream of Lock 3. In the Mallee Gorge area of the site the wetlands are less frequently inundated. Small to medium sized floods onto Wigley Reach have been reduced in frequency due to water storages and water diversions upstream, thus reducing flushing of the site. Under non-flood conditions water flows though the system but at a slower rate.

5.1.2 Rising groundwater – salinisation of the floodplain

Salinity has long been recognised as a key threat to the condition of aquatic ecosystems (e.g. MDBC 1999; Hart et al. 2003; Nielson et al. 2003) but despite this the impacts from secondary salinisation is still relatively poorly understood in wetland ecosystems (Jin and Schreiber 2005; Jolly et al. 2008).

The South Australian Wetland Strategy identified the management of salinity levels in wetlands along the River Murray as a significant natural resource management issue (DEH and DLWBC 2003). Protection of the floodplain from salinity impacts is a major goal of natural resource management in South Australia (e.g. SA River Murray Salinity Strategy, River Murray Water Allocation Plan, SA Murray-Darling Basin Integrated Natural Resource Management Plan)(Jolly et al. 2008).

Fluctuations in salinity due to wetland filling and drying patterns are normal, and wetland flora and fauna can tolerate salinity to various degrees. In general prolonged increases in surface water salinity beyond 1500 mS/cm leads to decreases in abundance, species richness and alters community composition of plants and animals in wetlands (Nielson et al. 2003).

Over 100,000 million tonnes of salt is contained within the Murray Basin (Evans and Kellett, 1989 cited Crosbie et al. 2007). The geological setting of the River Murray in the study area is such that groundwater moves towards the river, causing the River Murray to be a gaining river in South Australia with the floodplain considered adapted to cope with salt (Crosbie et al. 2007). Salinity problems in the lower River Murray result from rising groundwater due to changed landuse and management (e.g. irrigation, land clearing, floodplain disposal of drainage water), river regulation and rising in-stream salinity levels (i.e. salt exported from upstream catchments) (Croucher et al. 2005).

Regional groundwater is not only highly saline, but it is also anoxic and reduced (Jolly et al. 2008). Discharge of saline groundwater to the floodplain leads to soil salinisation and flooding is required to flush the salts from the root zone of floodplain vegetation. River regulation has significantly altered the natural pattern of flooding thus reducing the flushing rates as well as causing an increase in the elevation of the water table below the floodplains. Combined, these two processes have led to an increase in the rate of salinisation and a decrease in leaching of salt due to flooding (Crosbie et al. 2007). It is estimated that between 30 – 50 % of the lower River Murray floodplain will be impacted by salinisation in the next 50 years (Jolly et al. 2008).

The salt storage potential of sediments at the Banrock Station Wetland Complex was investigated by Crosbie et al. (2007). The results suggested that while conductivity (and hence salt storage potential) of sediments in the wetland floor were low, the floodplain to the east of the wetland had a high salt storage and conductance potential (Figure 33). Crosbie et al. (2007) concluded that this, coupled with the fact that Banrock and Eastern Lagoons may become a groundwater discharge zone in the prolonged absence of surface water, has serious repercussions for the management of the site. They predicted that if the wetland were to remain disconnected for long periods from the river it would become salinised. The timeframe over which this would occur is a knowledge gap.

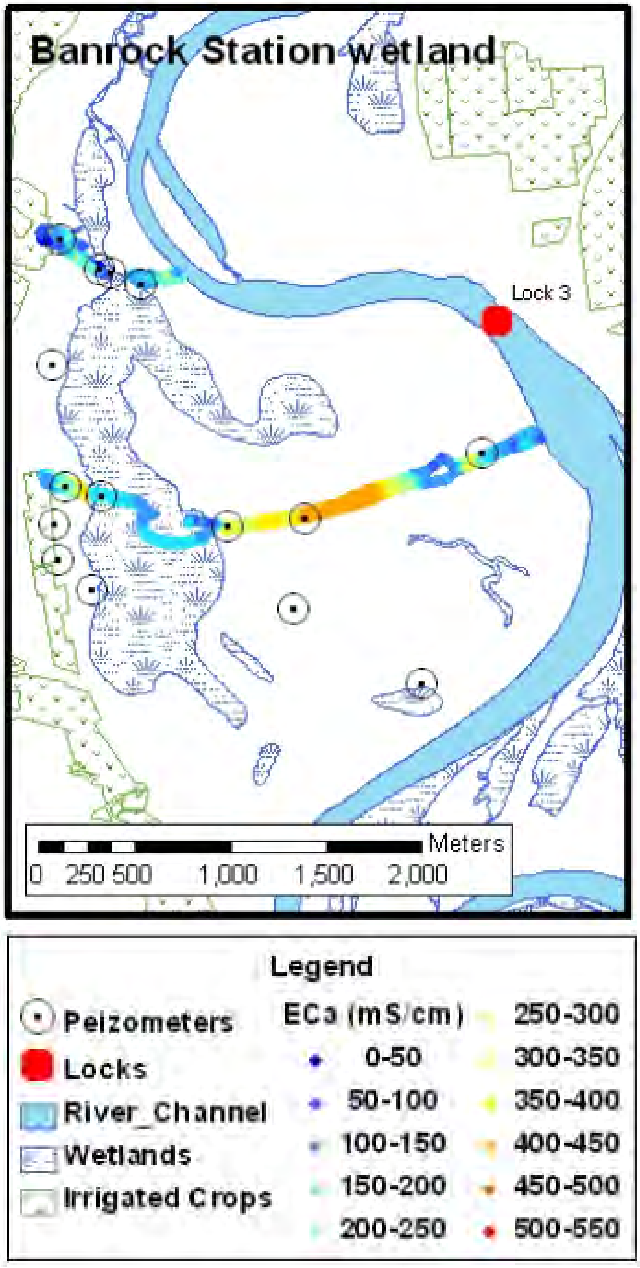

Figure 33: EM31 survey for the Banrock Station Wetland Complex (from Crosbie et al. 2007).

5.1.3 River Red Gum and Black Box – Saline groundwater stress

River Red Gum and Black Box woodlands are characteristic of the lower River Murray floodplain. River Red Gum rely on overbank flooding every 2 - 3 years to replenish the freshwater lenses that buffer the root zones against saline groundwater (Jensen et al. 2008). Dry conditions for two or more years can lead to stress in River Red Gum (Roberts and Marston 2000) as trees that are further than 15 m from fresh surface water will draw on groundwater from their root zones and are therefore susceptible to stress when the groundwater is saline (> 20,000 EC)(Jensen et al. 2008).

Black Box can tolerate longer periods of dry than River Red Gum, relying on soil moisture for periods of up to 10 years, but are also prone to stress when saline groundwater is 2 - 4 m below the surface (Sharley and Huggan 1995). As Black Box lies higher on the floodplain larger floods (> 100,000 ML/day) are required to reduce stress in Black Box communities (Jensen et al. 2008).

As much of the wetland and floodplain area of the Ramsar site has a water table shallower than 2 m (Figure 34) and moderately high soil salinity affected by highly saline seepage (Figure 35) the River Red Gum and Black Box woodlands are highly susceptible to stress.

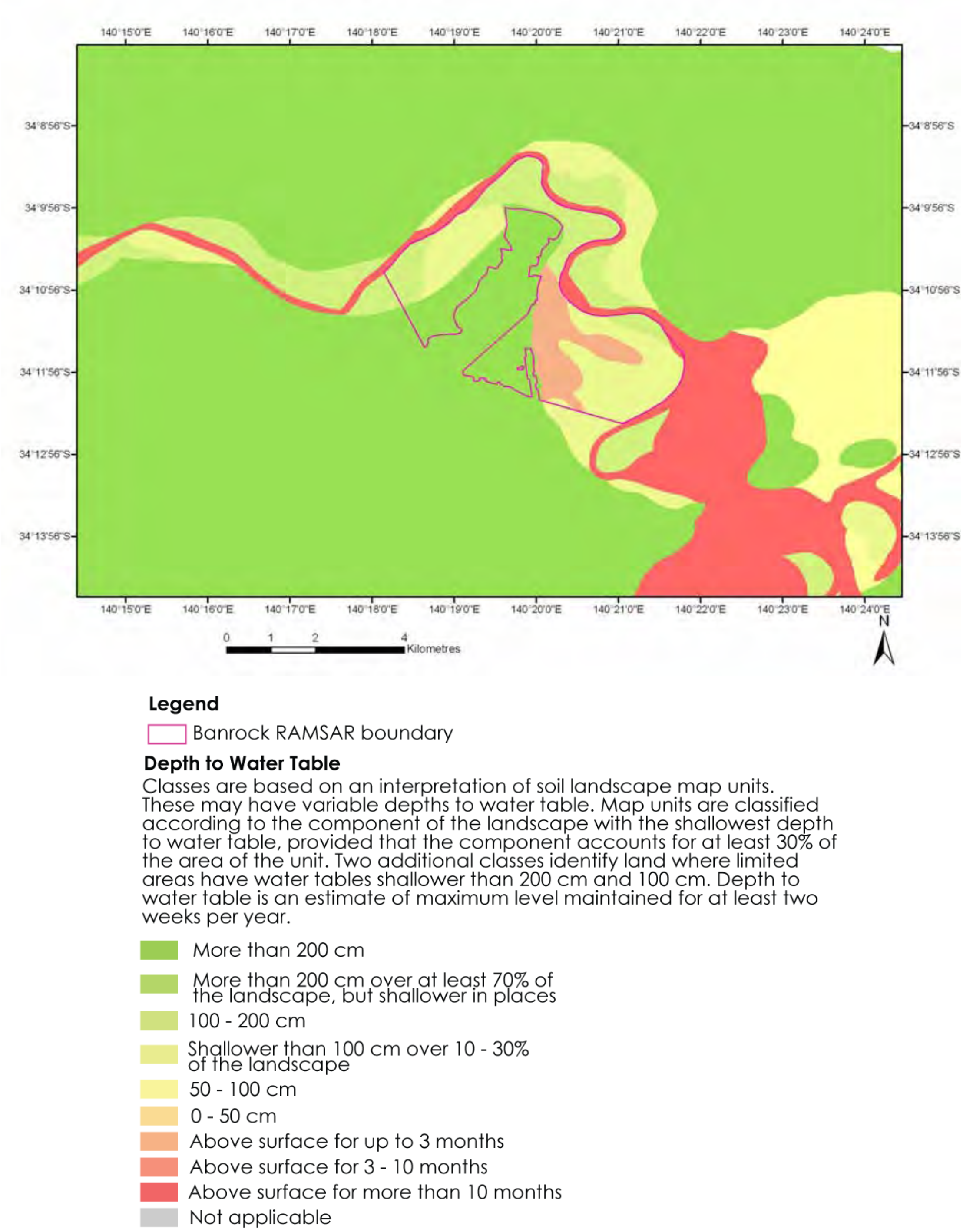

Figure 34: Depth to water table at the Banrock Station Wetland Complex. Data supplied by DEH March 2009.

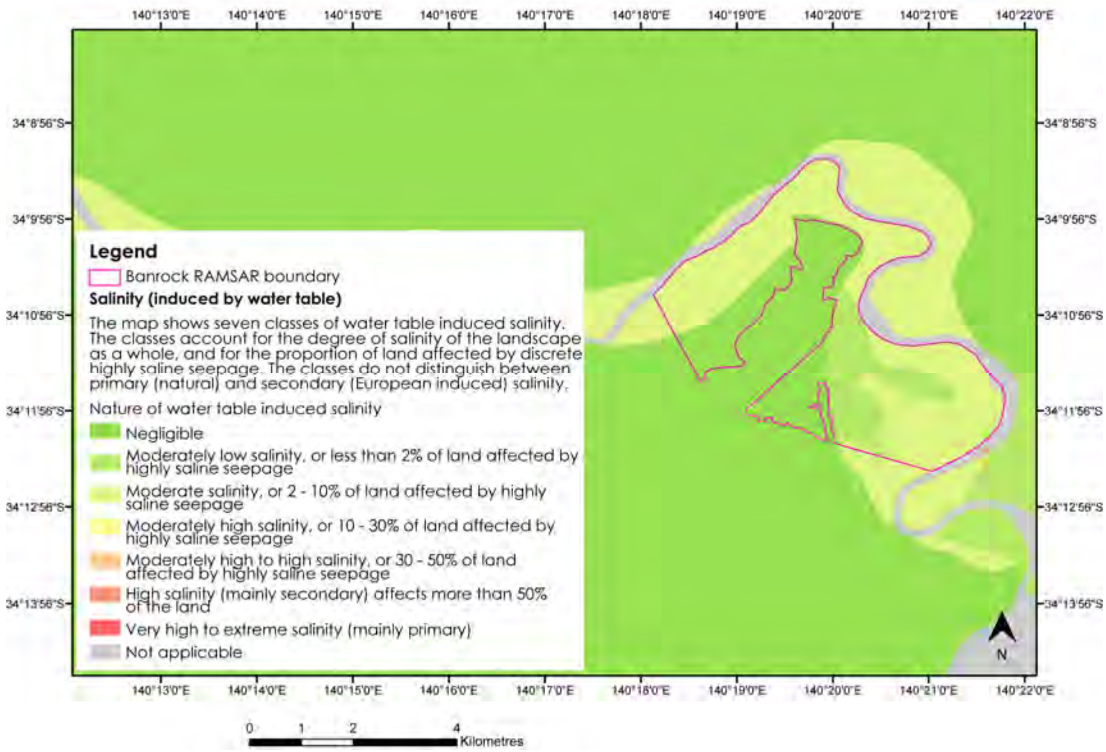

Figure 35: Salinity (induced by water table) for the Banrock Station Wetland Complex. Data supplied by DEH March 2009.

5.2 Invasive species

5.2.1 Non native fish species

Sixty tonnes of Common Carp were removed from the Banrock Station Wetland Complex in 1994 when the wetland was dried. Common Carp returned to the wetland as juveniles and underwent spawning and recruitment each year (Smith and Fleer 2007). Management of the water regime prior to the pumps being relocated from the main wetland may have favoured recruitment by lowering water levels in winter and raising them in spring. This water regime promoted floodplain grasses and vegetation to establish during winter months thus providing spawning and nursery habitat for Common Carp in spring (Smith and Fleer 2007).

One of the management objectives of returning to a more natural wetting and drying regime was to undertake further Common Carp removal. Complete drying of the wetland in 2007 resulted in over 4,000 Common Carp perishing in Banrock Lagoon. Carp screens on the inlet and outlet creek combined with complete drying of the wetland bed will significantly reduce adult Common Carp numbers within the system.

During the refilling of the wetlands between June and December 2008, SARDI Aquatic Sciences operated two cages to trap adult Common Carp attempting to reenter the wetland (Figure 36). The vast majority of fish were collected from the Banrock Creek outlet cage, indicating that Common Carp preferred to move into the wetland against the flow. More than 5000

Common Carp tried to enter the wetland via Banrock Creek compared to four Common Carp via the inlet creek (Sharley et al. 2009).

There has been relatively little research on the ecological impacts of Common Carp on wetland ecology although the main impacts are believed to be associated with increased turbidity, damage to aquatic plants, reduced abundance and diversity of macroinvertebrates and native fish species. These impacts are largely due to the Common Carp's mode of feeding called 'mumbling', which disturbs and re-suspends the sediment of the wetland.

Figure 36: Carp cage and dead Common Carp removed from Banrock Creek. Photograph supplied Banrock Station.

Eastern Gambusia and Goldfish were also recorded attempting to enter Banrock Station Wetland Complex, with Goldfish occurring in large numbers (Fredberg et al. 2009). Redfin, common in other wetlands in the region, were not recorded attempting to enter the Banrock Station Wetland Complex during refilling (Fredberg et al. 2009). It has been postulated that Eastern Gambusia prey on frog eggs and tadpoles of the Southern Bell Frog, however direct relationships between declines in frogs and presence of the fish have not been conclusively established.

A summary of the ecological affects of non native fish on the character of Banrock wetlands is shown in Figure 37.

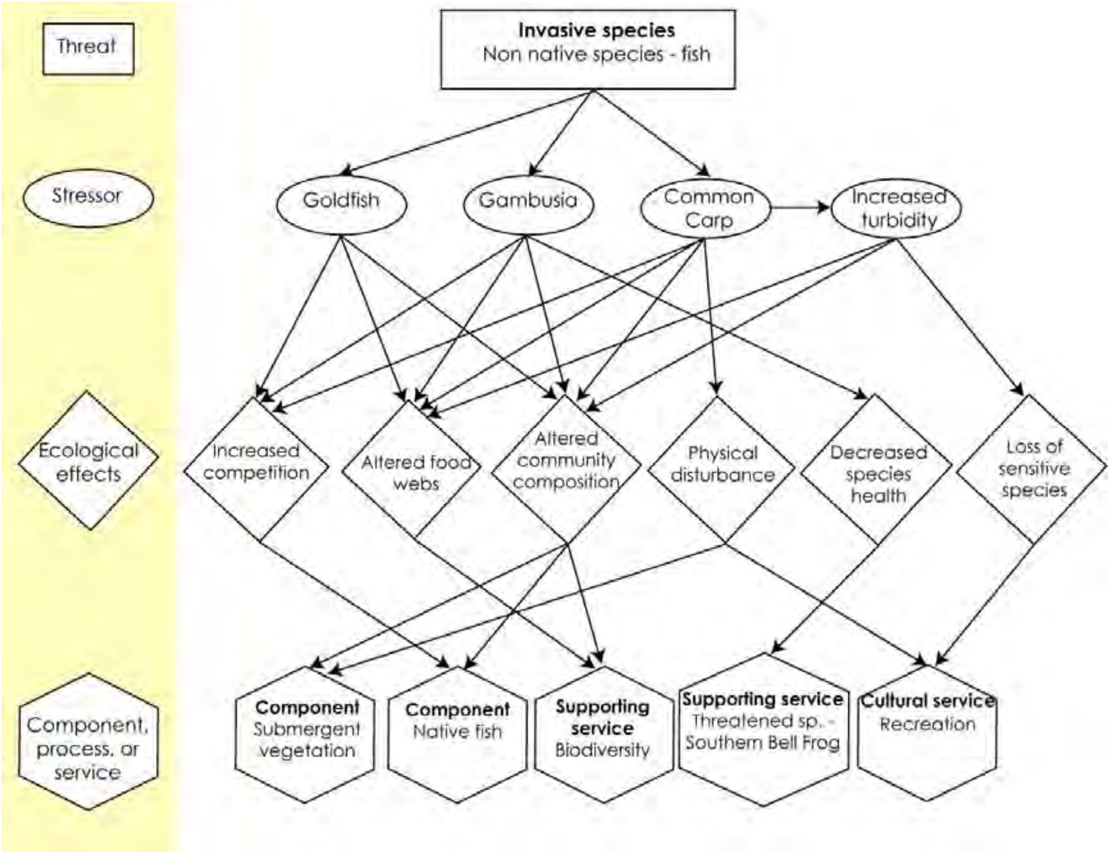

Figure 37: Stressor model of non native fish species on the ecological character of Banrock Station Wetland Complex.

5.2.2 Terrestrial feral pest control

Feral pest species can affect wetland flora and fauna via increased competition, grazing and predation, and altered habitat availability. With the release of the Rabbit Calicivirus Disease in Australia in 1996 the rabbit population on the Banrock Station Wetland Complex was decimated. With the marked reduction in grazing pressure, many ground cover, shrub and tree species were regenerating at the time of listing, and a revegetation program was initiated in May 1999. A feral-proof fence was constructed in 2005 to protect approximately 85% of the Ramsar site. An ongoing feral pest program (baiting, trapping, fumigation and shooting) for feral cats, foxes, rabbits and hares aims to eradicate feral pests within the fenced area and remains a part of the management regime for the site.

5.2.3 Weeds

A number of invasive introduced plants (weeds) exist on the site. Weeds of the wetland margin include *Aster* species, Spiny Rush (*Juncus acutus*), Noogoora Burr (*Xanthium occidentale*), and thistles (including *Onopordum acanthium*). Other weeds which exist on the site in small infestations are Boneseed (*Chrysanthemoides monilifera ssp. Monilifera*), African Boxthorn (*Lycium ferocissimum*), Gazania (*Gazania linearis*) and Salvation Jane (*Echium plantagineum*). These weeds have been prioritised according to threat posed and extent of infestation, and control of priority species is underway (K. Thorn, Banrock Station, pers. comm.).

5.3 Pollution - Acid sulphate soil development

Acid Sulfate Soils (ASS) are benign when submerged underwater because they are not exposed to oxygen and thus they remain subaqueous and sulfidic in nature. Potential issues with sulfuric acid generation occur if ASS come into contact with oxygen in air through processes such as disturbance or wetland drawdown. When oxygen reaches the ASS, oxidation occurs generating sulfuric acid and pH in the soils and soil water may drop to 4 or below depending on the rate of acid generation.

Some soils have a strong capacity to self-deacidify and in these cases pore water pH can remain close to neutral and there is minimal risk of a significant drop in pH in adjacent water bodies. Sulfuric material with pH < 5 poses significant risk to adjacent water bodies. The likelihood of a pH drop in the water depends on the rate of transfer of the acid from the soil where it is made to the water and the capacity of the water to then neutralize the acid that enters it. The greatest risk of the acid and metal salts being transported to the surface water of a wetland or into the groundwater occurs upon rewetting of parched ASS. Rewetting may occur through rainfall, wind-driven water movement, increasing water levels from surface or groundwater inflows or seepage of groundwater.

The movement of ASS oxidation products (e.g. acid and salts) can be horizontal or vertical and can enter either the surface water or the groundwater or both. The rate of transfer is highly dependent on soil type. Clay soils tend to have better self-deacidifying properties and tighter water retention whereas sandy soils have poor capacity to self-deacidify and high rates of infiltration. If enough acid is transported to the surface water to cause the pH to drop to below 5, there is likely to be a fish kill because fish cannot tolerate low pH. Such a drop in pH is likely to affect other aerobic organisms and if sustained can cause a shift in Ecological Character.

As well as generating acid, the oxidation of ASS can generate metal and metalloid salts. The make up of these salts will differ depending on the soil types and metal distribution but they may be harmful to the wetland if they contain elements such as arsenic or aluminium. Aluminium, in particular, is harmful to fish if it is transported to the water column. Different metals become available at different pH with most not being bioavailable until the pH drops to below 4. The exception is arsenic, which is bioavailable across the whole pH range (Stauber et al. 2008). Other environmental harm can occur from ASS exposure and rewetting such as deoxygenation of the water column (particularly from disturbance of Monosulfidic black ooze) and physical changes to water holding capacity of wetland soils through ripening of ASS.

The three main types of ASS: sulfidic, sulfuric and monosulfidic black ooze materials are found at Banrock Station. River regulation is likely to have enhanced the formation of these ASS compared to the pre-European water regime. Conversion of the wetland from intermittent to permanent has meant that the ASS that have formed have not been “burnt-off” by frequent drying cycles to the same extent as pre regulation. Thus the ASS is deeper and more widespread than if would have been if it had remained intermittent.

The increased rates of sedimentation that are likely to have occurred in the wetland since river regulation would also enhance formation of ASS.

Available data indicate that at the time of listing ASS were not considered a major threat on site. However with management of the site returning the system to an intermittent water regime ASS may become a concern in the future (see section 7.2.2).

5.4 Human disturbance - recreation and tourism

Whilst the site is recognised as having important recreation and tourism values, these activities can potentially impact on the ecological character of the site. Visitor impacts have not been assessed with regard to impacts on the wetland, rather planning was undertaken to minimise impacts, including Advanced Eco-tourism Certification obtained in 2003.

In designing the walking trails, care was taken to ensure they are set back from the waters' edge to minimise disturbance of the wildlife. To allow visitors to experience the wetland environment and view bird life, boardwalks have been installed in two locations. The positioning of the boardwalks was done to minimise disturbance of the bird life in particular, with the areas of narrowest open water chosen for the boardwalks (Constellation Wines Australia 2008a).

Along the walking trails there are five bird hides set back from the edge of the plant/water interface which allow visitors to observe the wetland and wildlife at closer quarters with minimal disturbance. This, combined with the set-back distance for the walking trail, ensures that visitor use of the site is closely regulated, and that foot traffic is restricted to those areas of least sensitivity. Approximately 20,000 people walk the trails each year.

In deciding the route of the walking trails, and the location of board walks, information shelters and story centres, consultations was held with the local indigenous community, and areas of cultural significance were avoided (Constellation Wines Australia 2008a).

5.5 Agriculture and aquaculture - vineyard operations

The existing horticultural and conservation activities in the viticulture area on Banrock Station and on neighbouring properties are not considered to be having significant impacts on the wetland, although impacts on groundwater from irrigation practices is a possibility. Soil-moisture monitoring and efficient irrigation technology are in place in the Banrock Station Vineyards in order to minimise irrigation impacts and water usage. The most pronounced impact was pumping of water from the wetland for irrigation purposes. In 2007 the pumps were relocated to the river and no longer extract water from the wetland system. Vehicle access tracks may provide a small threat from increased runoff containing sediments after rainfall events; however this is not considered a major threat to the system.

5.6 Climate change

Wetlands are highly susceptible to climate change impacts as they are at the interface between aquatic and terrestrial ecosystems, being subject to direct impacts as well as climate change being a compounding factor for other environmental stresses such as salinisation (Jin 2008). The potential range of climate change impacts which could affect the Banrock Station Wetland Complex are summarised in Table 11.

Table 11: Potential direct and indirect impacts from climate change which could affect floodplain wetlands of the lower River Murray. Modified from http://www.climatechange.gov.au/impacts/biodiversity.html Note not all climate impacts are shown.

Potential direct physical and ecosystem effects	Potential secondary and indirect impacts
Increases in temperature	
• Southward species migration • Changes in range of weeds, other invasive species and pests and diseases • Species migration to higher altitudes • Changes in phenology (life-cycle events - flowering, egg-laying, migration) • Changes in distribution and abundance of species • Changes in metabolism (photosynthesis, respiration, growth and tissue composition) in plants • Species loss • Increased frequency and intensity of wild fires • Genetic changes in species to new climatic conditions	• Mismatching of life-cycle interactions between species (predator-prey; plant-herbivore; pathogen-host; pollinators-flowering plants) leading to species declines and extinctions • Changes in competitive interactions among species, and the structure and composition of communities and ecosystems • Increased occurrence of eutrophication of streams, lakes, wetlands and estuaries • Reduced capacity for recovery of natural areas following wild fire and other disturbance regimes.
Altered rainfall and runoff patterns (local increases/decreases)	
• Altered river flow and changes to sediment and nutrient dynamics • Altered lowland flood risk • Loss of wetlands and associated biodiversity • Loss of migratory birds dependent on wetlands and streams • Disruption to stream, estuarine, wetland food webs due to reduced supply of nutrients • Drying of ecosystems leading to loss of species and changes in community composition • Invasion of woody shrubs into drying landscapes	• Increased incidence of eutrophication of streams, lakes and estuaries • Changes in species distribution and ecosystem composition.

Wetland ecosystems are influenced by altered average conditions, variability and extremes. Increases in temperature and decreases in rainfall will contribute to declines in water quantity and quality deteriorating average wetland conditions (Jin 2008). Altered hydrological regimes caused by increasing climate variability, in combination with elevated temperature may result in a substantial increase in the strength of seasonality in some regions. Model simulations (Jin 2008) showed that deterioration in condition and increased seasonal variability could lead to reduced wetland resilience.

The latest climate projection models for South Australia suggest that by 2030 it is likely that average summer temperatures in the vicinity of Banrock Station will increase 0.6 to 1.0°, and there will be a tendency towards lower rainfall across the year of -5 to -2 % (using 50th percentiles)(Figure 38 and Figure 39).

Site specific impacts from climate change could include reduced capacity to support Regent Parrot feeding habitat. It has been proposed that reduced winter rainfall reduces the availability of mallee groundcovers and fruiting which is the parrot's main food source (A. Sharley, Banrock Station, pers. comm.).

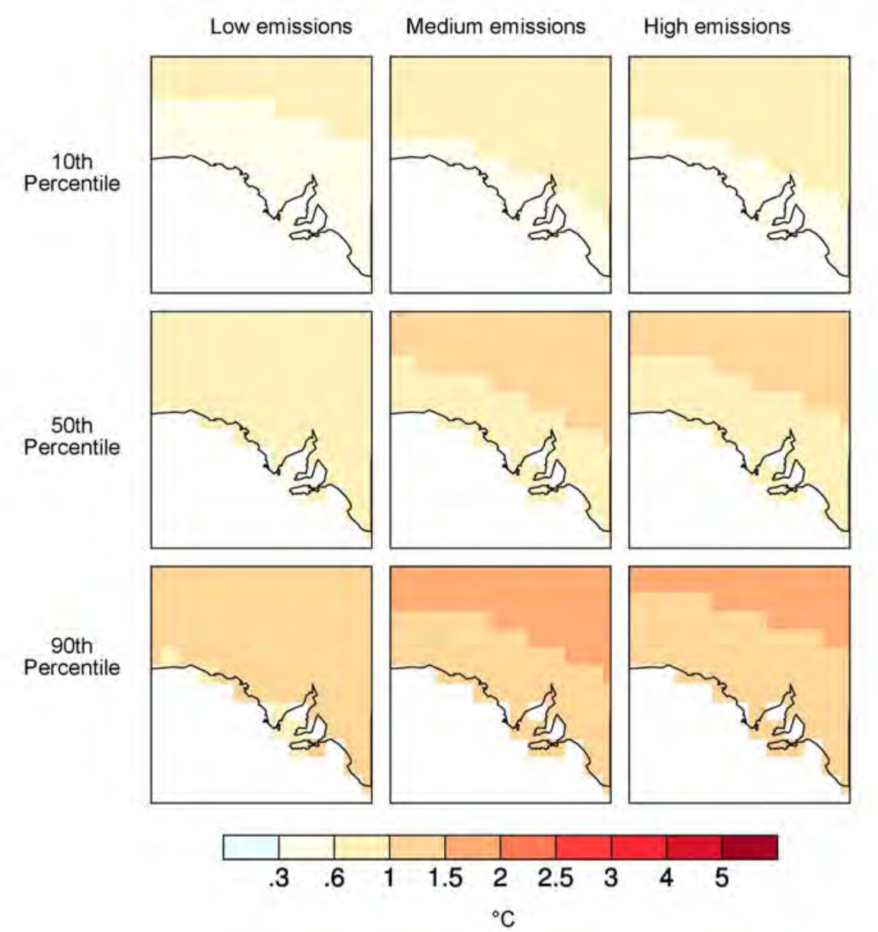

Figure 38: Summer temperature change to 2030 for South Australia (CSIRO 2007; http://www.climatechangeinaustralia.gov.au/satemp1.php)

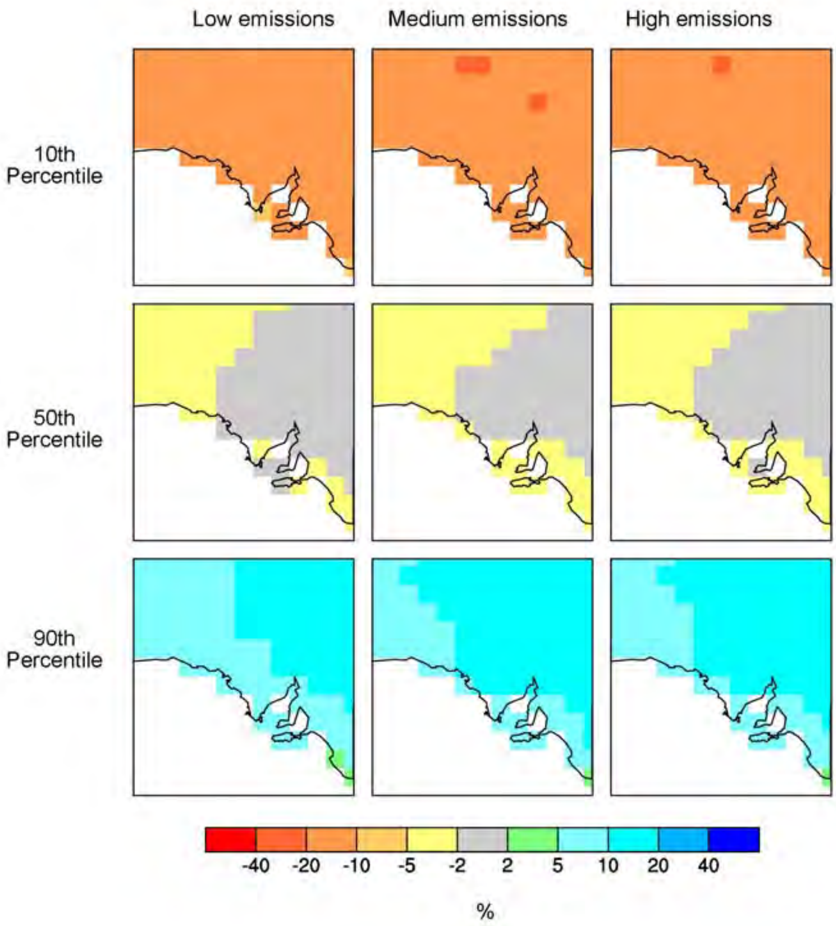

Figure 39: Summer rainfall change by 2030 for South Australia (CSIRO 2007; http://www.climatechangeinaustralia.gov.au/satemp1.php)

5.7 Summary of threats

The threats considered in the previous sections have been summarised in Table 12. In line with the DEWHA (2008) framework a full risk assessment is to be part of the site management plan.

Table 12: Summary of the main threats to the Banrock Station Wetland Complex. Certain = known to occur at the site or has occurred in the past. Medium = not known from the site but occurs at similar sites. Low = theoretically possible, but not recorded at this or similar sites.

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, and/or service	Likelihood	Timing of threat
Natural system modification. Water management/ use – river regulation	• Permanent flow through wetland • Loss of small to medium floods • Altered ecological connectivity • Loss of habitat diversity • Facilitation of invasive species • Stressed riparian vegetation	Certain	Immediate
Natural system modification. Water management/	• Increased soil and water salinity • Stressed riparian vegetation	Certain	Immediate

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, and/or service	Likelihood	Timing of threat
use – Rising saline groundwater	• Changed species composition • Decreased diversity		
Invasive species – non native species	• Competition with native fish • Predation of Southern Bell Frog tadpoles • Water quality issues • Predation of turtles at all life stages • Predation on ground-nesting birds	Certain	Immediate – medium term (5 years)
Pollution. Acid sulphate soil development	• Deoxygenation of water column • Decreased pH to levels harmful to biota	Medium	Medium to long term (5 years to decades)
Human Disturbance. Recreation and tourism – vehicle impacts	• Compaction of soils • Loss of vegetation • Potential erosion issues • Disturbance during bird breeding events	Medium	Immediate – long term
Human Disturbance. Recreation and tourism – visitor impacts	• Compaction of soils • Loss of vegetation	Medium	Immediate – long term
Natural system modification. Water management/ use Vineyard operations - pumping	• Extraction of water required permanent inundation – see above for associated potential impacts	Certain, past	From listing until 2006
Agriculture and aquaculture. Vineyard operations – vehicle tracks	• Compaction of soils • Loss of vegetation • Potential erosion issues	Medium	Immediate – long term
Agriculture and aquaculture. Vineyard operations – irrigation drainage	• Increased recharge into wetlands • Increased riparian soil salinity	Low	Immediate – long term
Climate change – temperature rise and reduced rainfall	• Altered water regime, less water available • Altered seasonality of flooding • Reduced wetland condition and resilience • Changes in range and life cycle of biota, including threatened and invasive species	Medium	Medium to long term (5 years to decades)

6 Limits of acceptable change

6.1 The concept

In the context of describing ecological character limits of acceptable change is (Phillips 2006):

> "*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".*

Limits of acceptable change (LAC) and the natural variability in the parameters for which limits are set are inextricably linked. Setting limits that take into consideration natural variability is an important, but complex concept. As indicated in the previous sections wetlands are complex systems across space and time, therefore defining natural variability and determining what constitutes a trend away from or beyond "natural" is not a simple process (Hale and Butcher 2008).

An important distinction is the difference between setting LAC of ecological character and setting management triggers. Management triggers provide an early indication of change in a component, process or service which may ultimately lead to an irreversible change in ecological character. Management triggers need to be able to detect change with sufficient time to allow management actions to be implemented to prevent permanent change in ecological character.

DEWHA recently provided the following advice regarding setting LAC and management triggers (DEWHA May 2009 unpublished):

- LAC should be set for the ecological character of the site at the time of listing, not for the impact of activities that existed at the time of listing. If a wetland was already on a degradation trajectory at the time of listing, then the LAC may already have been exceeded. If this proves to be the case then the LAC still needs to be set at this exceeded level. It will then be a consideration for State/Territory and Australian governments.
- If a wetland has degraded since listing, but has since re-stabilised, then the LAC for the new stabilised wetland should be added to the ECD.
- LAC only should be put into the ECD. LAC reflect what could change the ecological character of the site at the time of listing (and are therefore set in a point in time), whereas management plans (which use management triggers) will be updated over time.

- Management triggers are more appropriate for the purpose of a management plan as they directly relate to an associated action.
- Where possible, it is advisable that values are given for LAC instead of 'not enough information'. If the value is based on an educated guess rather than exact science, this should be noted.
- The ECD needs to make a distinction on what basis the LAC was set.

Setting LAC 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 median conditions.

In order to detect if the LAC are being met monitoring against these limits needs to occur. As such it is neither practical nor desirable to set limits for every component and process within a wetland system (Hale and Butcher 2008).

Accordingly, components and processes for which LAC can be established are those:

- For which there is adequate information to form a baseline against which change can be measured;
- For which there is sufficient information to characterise natural variability;
- That support the critical components and services of the site;
- That can be managed (directly or indirectly); and
- That can be monitored.

There are a number of critical components and services within the Banrock Station Wetland Complex that do not meet these criteria, in particular the first two. For example the data for the Regent Parrot is insufficient to determine quantitative LAC as there are records for only three sampling times. Where data limitations exist qualitative LAC will be set. This will typically be for biota and processes which require long term data sets to establish ranges of natural variation.

Abiotic components are often easier to monitor and change can be detected in the short term (within 1 or 2 years) (although perhaps not with geomorphology). However, as the focus is on LAC and not management triggers per se, parameters such as water quality are not included here as LAC.

Limits of acceptable change are set for the primary responses to the abiotic components and processes: physical / biological habitat (wetland type, vegetation associations) extent and condition. The focus is on the identified critical components and services. Limits are set against baseline data and the habitat requirements or tolerances of key fauna where known (Hale and Butcher 2008).

6.2 LAC for the Banrock Station Wetland Complex

Using the approach described above, LAC and interim LAC have been set for the Banrock Station Wetland Complex (Table 13). Where there is limited quantitative data on which to set limits, general principles have been applied and qualitative limits have been recommended. These will require careful review with increased information gained from future monitoring and consultation with staff. Three of the LAC set at time of listing have been exceeded due to the changed water management practices on site. Refined LAC are presented in Table 14. Further LAC may need to be detailed in light of ongoing changes associated with the new watering regime.

Table 13: Limits of acceptable change for the Banrock Station Wetland Complex for critical components and services at time of listing

Component, process, service	Baseline and supporting evidence	Limit of Acceptable Change	Comments/ LAC exceeded
Hydrological processes – Banrock and Eastern Lagoons – at listing	Permanently inundated wetlands with water levels managed to promote littoral vegetation responses. The permanent inundation regime may contribute to maintaining local water balance between surface and groundwater however the relative importance of this is not known.	Maintenance of Banrock Lagoon as permanently inundated, allowing for seasonal fluctuations of inflows from the River Murray. Depth 8.5 – 8.8 m AHD. Frequency of inundation - alternating years of stable and fluctuating levels. No complete drying of wetland bed. Maintain Eastern Lagoon as drier site with inundation for 3-6 months during managed spring flood to 9.3 m AHD in Banrock and Eastern Lagoons.	LAC is based on expert opinion and published literature (Gippel 2006, Crosbie et al. 2007; Constellation Wines Australia 2008a). This LAC has been exceeded – see Table 14
Hydrological processes – Wigley Reach floodplain	Wigley Reach supports a range of intermittent River Red Gum dominated wetlands. Loss of small to medium floods has reduced the frequency of inundation in this part of the site. Under natural conditions the floodplain would have been flooded once in 3–4 years, but the area is now watered only once in about 12 years (George et al. 2005). George (2003) suggested that positive growth of RRG and Black Box rely on moderate river flows (40,000-80,000 ML/day) coupled with average rainfall (250 – 300 mm/year), with active growth interrupted with saturated conditions occurring when flows exceed 80,000 ML/day	LAC is based on watering requirements to sustain dominate vegetation association. In wet years (rainfall greater than 300 mm) peak flows of 30, 000 ML/day, in dry years (rainfall 250 - 300 mm) peak flows of 40, 000 – 80, 000 ML/day. Frequency of inundation 1 in 4 years. Duration 4 – 7 months. Magnitude as above. Maximum interval without inundation 5 years.	At listing the natural cycle of flooding was already altered, with the LAC being set for the flooding regime for maintaining mature River Red Gum dominated wetlands. This LAC has been exceeded. Current onsite water management does not affect this LAC, so a new LAC has not been set.
River Red Gum woodlands	Approximately 177 ha, with mature trees declining and juveniles increasing at time of listing.	No more than 10% loss of extent of live trees from baseline of 177 ha of River Red Gum.	The area of healthy River Red Gums and Black Box trees is believed to have declined significantly since listing in 2002. Data from 2009 indicate further decline in the extent of live

Component, process, service	Baseline and supporting evidence	Limit of Acceptable Change	Comments/ LAC exceeded
	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.		trees and tree health (K. Thorn, Banrock Station, pers. comm.); however there is insufficient data across the whole site to inform whether there has been sufficient loss of extent of live River Red Gum to indicate a possible change in ecological character. At this point in time it is believed the LAC has not been triggered, however this needs further investigation. Declines are believed to be in line with regional trends, or potentially less.
Black Box woodlands	Approximately 222 ha.	No more than 20% of loss of extent of live trees from baseline of 222 ha.	A lack of monitoring data on Black Box communities means it is not possible to establish if this LAC has been exceeded since listing. This remains a knowledge gap. The LAC is based on expert opinion.
Samphire shrubland	Approximately 223 ha.	Increase in extent – no more than 5 % increase in 5 year period from baseline of 223 ha.	Increases in Samphire shrubland is taken as indication of increased salinisation of the floodplain. Percentage change is based on expert opinion.
Supports threatened species – Regent Parrot	Approximately 100 adult birds (Constellation Wines Australia 2008a). Data collected by DEH suggest the breeding population on site at Banrock constituted 21 % of the regional population at the time of listing. Nesting trees on site contributed to 23 % of habitat used by the regional population (2003/2004 data). Note that there is no count data pre the time the site was listed and therefore the baseline is set on a single sampling event.	No greater than 10% decline in number of breeding pairs over three consecutive seasons. Unless there is evidence that decline in breeding species is caused by changes outside the boundary of the site, and an on-site rate of decline does not exceed the regional trend.	Further monitoring is required to establish trends and causative factors affecting declines on site. Declines in numbers of breeding pairs from 2002 to 2008 reflect regional declines and are not attributed to on site change and therefore this LAC has not been exceeded.
Supports threatened species	Population estimates are not available, only records of calls and sightings of frogs. Frogs appear to be present and breeding in most	No loss of breeding population, males not heard for two consecutive years and no confirmation of breeding	Based on opinion of Steering Committee.

Component, process, service	Baseline and supporting evidence	Limit of Acceptable Change	Comments/ LAC exceeded
- Southern Bell Frog	years (Banrock unpublished data; Constellation Wines Australia 2008a).	every two years (i.e. tadpoles observed).	
Biodiversity - Supports waterbird breeding	Five species of waterbird commonly breed on site: Black Swan, Australian Wood Duck, Australian Shelduck, Grey Teal, and Purple Swamphen. Musk Duck have also been recorded breeding on site.	Annual breeding in 3 of the 5 species which commonly breed on site. Unless there is evidence that decline in breeding species is caused by changes outside the boundary of the site.	Based on opinion of Steering Committee.
Biodiversity – supports native fish	Supports up to 9 species of native fish, with small bodied species being the most common.	7 of 9 recorded native species with multiple size classes indicative of a healthy population.	Based on expert opinion.

Table 14: Limits of acceptable change for the Banrock Station Wetland Complex for critical components and services affected by changed water management practices (2007 – current).

Component, process, service	Baseline and supporting evidence	Limit of Acceptable Change	Comments
Hydrological processes – Banrock and Eastern Lagoons – current management	Introduction of a wetting and drying regime was considered beneficial to the wetlands on site as this would return the hydrological regime to a near natural state. Desired wetting and drying regime is Banrock Lagoon wet for 18 months (can fluctuate water levels) then dried for 6 months. During wet phase increase height to wet Eastern Lagoon for approximately 3 month period.	Banrock Lagoon not > 9 months without flow-through phase (8.5m AHD). Banrock and Eastern Lagoon not > 24 months without inundation to 9.2 AHD.	Based on current management plan for the Banrock Station Wetland Complex (see Constellation Wines Australia 2008a) and advice from K. Thorn, Banrock Station.
Biodiversity – supports native	Whilst condition of native fish population is unknown, it is assumed that reduced	Common Carp comprise > 20 % by number or > 50 % by biomass of fishes	This is a LAC set in response to new water management practices, this more typical of a

fish	numbers and biomass of Common Carp will improve habitat and condition of native fish community.	in Banrock wetland.	management trigger but is included here as Common Carp management is a major factor in improving the condition of Banrock wetlands.

7 Changes in ecological character

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 DEWHA 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.

7.1 Drying and refilling the Banrock Station Wetland Complex – current ecological character

Banrock Station Wetland Complex has undergone a significant change in water regime over the period 2007-2009.

At the time of listing this wetland system was a permanent flow through system with a fluctuating water level. In January 2007 the regulators were closed at the inlet creek as part of a plan to reduce evaporation losses and to simulate a natural drying cycle with the aim to improve the long term health of the wetland. Under the guidance of the Ramsar Management Plan the wetland was due to refill in late August 2007. However, ongoing drought conditions in the Murray Darling Basin led the South Australian Government to close 29 River Murray wetlands including Banrock Station wetland to reduce water losses through evaporation (Constellation Wines Australia 2008a).

In June 2008 the Banrock Lagoon was refilled after being dry for 18 months. The riparian River Red Gum community surrounding Banrock and Eastern Lagoons had not been inundated for a period of 30 months (Sharley et al. 2009). In 2007 an assessment of the health of River Red Gum on site (Sharley et al. 2009) indicated that:

- 5 -10 % of trees around Banrock Lagoon received a stressed to severely stressed rating which equates to < 75 % canopy cover remaining
- 60 - 80 % of trees around Eastern Lagoon received a stressed to severely stressed rating, with these trees not being inundated for almost 3 years.

Six deep test wells were installed in and around Banrock and Eastern Lagoons to determine the availability of fresh groundwater to sustain the riparian vegetation. Results indicated a flushed freshwater zones existed in a small area of Banrock Lagoon closest to the river and that in all other areas a thin film of freshwater (<15, 000 EC) only millimetres thick was underlain by highly saline groundwater within 2 m of the surface. This put most River Red Gums at risk of moisture and salt stress to their root zones (Sharley et al. 2009).

In May 2008 an environmental water allocation of 617 ML was granted by the Murray Darling Basin Commission's Living Murray Program. Banrock Station purchased an additional 215 ML for the refilling of the wetland. Refilling commenced in June 2008 in Banrock Lagoon to coincide with lowest period of evaporation losses, thus maximising the volume of water available to recharge the soil.

7.2 Changes to components, processes and services in response to drying and wetting

7.2.1 Geomorphology

No changes to geomorphology have been recorded.

7.2.2 Soils

Application of the Acid Sulfate Risk Decision Support Framework to the Banrock Station wetlands showed that:

- 5 % of the wetland is at high risk of acidification
- 20 % of the wetland is at medium risk of acidification
- 55 % of the wetland is at low risk of acidification
- 20 % of the wetland is not at risk of acidification.

Constellation Wines Australia (2008b) suggested that these results indicate that it is likely that the wetland will be able to buffer the amount of acid produced across a small area, particularly if operating as a flow through system.

Fitzpatrick et al. (unpublished) assessed ASS across two transects of the dry Banrock Lagoon in 2008 and found that the actual and potential acidity within Banrock Lagoon was substantial and spatially extensive. Sulfuric, sulfidic and monosulfidic materials were observed, with monosulfide formation potential being considered as high across all sample sites (see Table 15).

Table 15: Summary of acid sulfate soil types in Banrock Lagoon (from Fitzpatrick et al. unpublished).

Type of ASS	No. profiles (sites) containing ASS type (total sites = 8)	% of sites
Sulfuric	2	25
Hypersulfidic	5	63
Hyposulfidic ($S_{CR} \geq 0.10\%$)	0	0
Monosulfidic (observed)	1	13
Monosulfidic (potential)	8	100
Hyposulfidic ($S_{CR} < 0.10\%$)	0	0
Other acidic (pH_w &/or pH_{age}) 4 – 5.5	1	13
Other soil materials	0	0

Whilst Banrock Lagoon was completely dried (2007-2008) the formation of sulfuric material (pH < 4 to depths of 50 cm) and deepening of desiccation cracks (> 50 cm) occurred. Acid dissolution of the layer silicate soil minerals could cause the release of metals and the formation of sulfate-rich salt efflorescences in and near soil surfaces (Fitzpatrick et al. unpublished). Areas with MBO continued to dry out, also causing desiccation cracks to develop in areas of the lagoon with fine textured material (Fitzpatrick et al. unpublished). On rewetting of the wetland these materials are expected to become diluted and mobilised, sulfidic material will reform, and metal salts will bioaccumulated or accumulate in the sediments (Fitzpatrick et al. unpublished). These processes are illustrated in the conceptual models presented in Figure 40 and Figure 41.

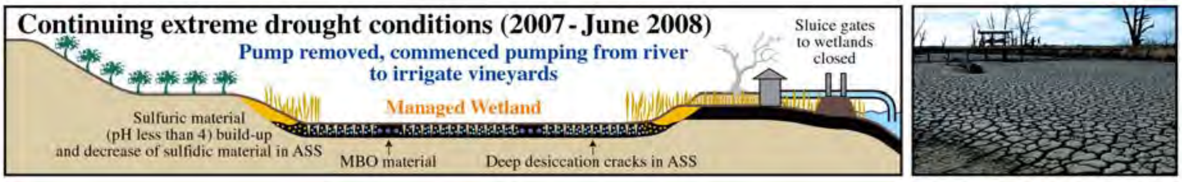

Figure 40: Generic conceptual model for the Banrock Lagoon illustrating the formation of: (i) sulfuric material (pH <4) by oxidation of sulfides in sulfidic material on the edges of the wetland, (ii) sulfate-rich salt efflorescences and (iii) deep desiccation cracks; due to continued lowering of water levels under persistent extreme drought conditions during 2007 – 2008 (from Fitzpatrick et al. unpublished).

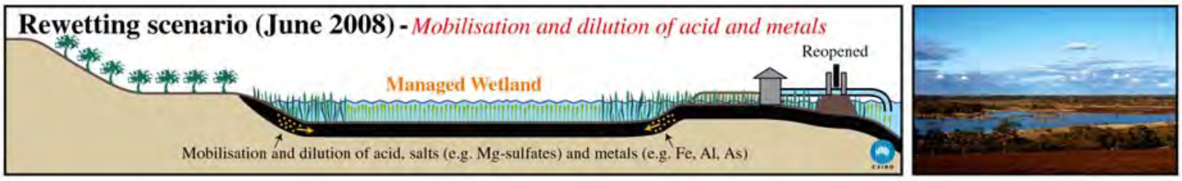

Figure 41: Generic conceptual model for the Banrock Lagoon showing the complete re-wetting of the whole wetland in June 2008 with inundation of sulfuric materials, which occur on the edges of the wetland (from Fitzpatrick et al. unpublished).

7.2.3 Hydrology

The hydrological regime determines the ecological signature of a wetland. The hydrology of Banrock Lagoon has undergone a significant shift from permanent (albeit fluctuating) inundation to an intermittent pattern of inundation. Positive ecological responses have been observed after the initial drying and rewetting, however the availability of water allocations for continuing the desired wetting and drying regime is uncertain and it is unclear if there will be permanent changes in the other key components, processes and services from successive managed dry phases.

7.2.4 Water quality

Salinity levels initially increased on rewetting in 2008 until inflows were sufficient to dilute the salts being released from the sediments. Water column salinity rose to 1,000 EC before dropping to 500 EC and then varying over the filing stage. For most of the refill period salinity was 500 – 700 EC, within 200 EC units of the water in the river. Return flows to the River Murray were estimated to be carrying a maximum of 4 tonne of salt per day, causing a rise in river salinity by between 2 and 15 EC units depending on river flows (Sharley et al. 2009).

No data are available on nutrients or primary production (chlorophyll-a).

Turbidity remained at approximately 40 NTU, similar to river water, until November, but gradually gained colour from tannins. It then cleared over the course of a couple of weeks <6 NTU and colour also receded (Sharley et al. 2009).

7.2.5 Vegetation

In the immediate area of the wetland, improvements in all major vegetation associations described in Section 3.6 except the *Tecticornia* (Samphire) shrublands showed positive responses to the refilling. There was substantial increase in cover of several of the emergent sedges and grasses including *Typha, Prhagmites, Bolboschoenus caldwellii, Persicaria decipiens* and *Schoenoplectus vlaidus*. Submergent aquatic herb growth was substantial with *Myriophyllum verruosum* and *Vallisneria americana* covering 80 % of the open water areas of Banrock Lagoon. Lignum was observed to be recolonising areas that it inhabited prior to regulation (Sharley et al. 2009).

The refilling of the wetland complex has shown a significant improvement in the health of the stressed River Red Gums around Banrock and Eastern Lagoons. At Banrock Lagoon nearly 90 % of the stressed trees have recovered fully (healthy canopies) and around the Eastern Lagoon 20-30 % have responded (Sharley et al. 2009).

This represents a significant improvement in the health of the River Red Gum communities in particular.

7.2.6 Fauna

All major groups of fauna showed immediate response to the refilling of the wetland. Notable gains were the reduction of Common Carp entering the wetland through a caging exercise undertaken by SARDI Aquatic Sciences, increased waterbird abundances and breeding events, including Musk Duck, and frog breeding. Available fish habitat dramatically increased to 80 % cover of submerged vegetation. Continued monitoring will be required to establish if there are sustained changes to communities and populations, however these can be considered positive changes to the ecological character of the site.

7.2.7 Hydrological processes – habitat type change and surface water groundwater interactions at the local scale

The hydrological processes on site have changed since listing. Crosbie et al. (2007) suggested that the wetland groundwater-surface water interactions at the Banrock Station Wetland Complex are directly influenced by the inundation state of Banrock Lagoon.

Prior to refilling groundwater levels at four test wells indicated that salinity exceeded 20,000 EC within 3 m of the surface and at one site levels exceeded 40,000 EC within 1.2 m of the surface. Monitoring of piezometers around Banrock Lagoon indicated good connectivity between surface and groundwater and that on refilling Banrock Lagoon switched from a discharge zone to a recharge zone (Crosbie et al. 2007; Sharley et al. 2009). Six months after refilling the surface layers of the groundwater showed a decrease of approximately 5000 EC at all sites (Sharley et al. 2009).

The long term implications of this change are unclear, however the extended dry period of the wetland bed (18 months) and surrounding riparian zone (30 months) indicates that sustained dry periods pose a significant threat to the condition of the site and will need to be carefully monitored. It is unclear if repeated wetting and drying will ultimately be beneficial as the resilience of the wetland ecosystem to multiple stress events (extended dry) is not known.

Because the natural baseline of inundation for the Banrock and Eastern Lagoons was every year or every second year, it would be advisable to consider a shorter dry phase, whilst also providing for natural flooding processes to trigger breeding and regeneration.

7.2.8 Physical habitat- supports a range of wetland habitats typical of the lower River Murray floodplain

Since flow regulation commenced in the lower River Murray, wetlands connected to the river with low sill levels have typically been permanently inundated.

This service was provided at the time of listing and continues to be provided by the site, however the main wetland type has changed. This is considered to constitute a positive change in ecological character, even though there has been a loss of a wetland type (Ramsar wetland type O).

7.2.9 Ecological connectivity – potentially provides migratory pathway for small bodied native fish

Banrock Station Wetland Complex, due to its position in regards to Lock 3, may provide a migratory pathway around Lock 3 in high flows and may be important for small bodied native fish. Data is limited and whilst not currently considered a critical service it is worth mentioning.

Lateral movement patterns of small bodied native fish were opportunistically investigated during the filling of Banrock wetland over the period June – October 2008. Movement with flows (i.e. via the inlet creek) and against flows (i.e. via the outlet creek) were investigated. Water temperature was continuously recorded at both the inlet and outlet creeks (Fredberg et al. 2009). The most abundant species captured were the Australian Smelt, Carp Gudgeons, and Unspecked Hardyhead constituting 89 % of the catch. Movement into the floodplain wetland corresponded with rising water temperature. Fredberg et al. (2009) found that the peak migration of small bodied native fish species moving onto the Banrock floodplain overlapped with that of Common Carp. Ecological connectivity is currently hampered by the 1 m waterfalls discussed in section 3.7.2. However in high flows the wetland system does provide a downstream migratory pathway around Lock 3. Proposed installation of fishways will enhance this ecosystem service.

The data obtained on the movement of small bodied native fish at the time of refilling in 2008 suggests the site provides a migratory pathway for native fish. Control structures were installed in 1992 and as such no significant change to connectivity has occurred since listing, however the relative success and importance of this service has not been established.

7.2.10 Supports biodiversity – waterbirds breeding

All four waterbird species which were recorded as breeding on site at the time of listing were recorded breeding in the months following refilling of the wetland in 2008. Also the Musk Duck *Biziura lobata*, was recorded breeding on site for the first time following the refilling of the wetland in 2008.

This service was provided at the time of listing and continues to be provided by the site.

7.2.11 Supports threatened wetland species, habitats and ecosystems

As discussed in Section 4.3.5 there has been a regional decline in Regent Parrots, with a substantial decline in 2008 in nesting trees and nests recorded at Banrock. It is not known if the on site decline is linked to the decline in River Red Gum condition on site or decline in condition of the mallee woodland understory which is a critical food source. Below average winter/spring rainfall in 2008 may be the main cause.

The endangered Southern Bell Frog was recorded four months after refilling indicating the species is still present after the extended dry period. The presence of Southern Bell Frog tadpoles was confirmed, including some near maturity, indicating that a successful breeding event occurred at the site; however population estimates on site remain a knowledge gap.

This service was provided at the time of listing and continues to be provided by the site.

7.3 Summary statement

The current condition as documented above represents a positive change in ecological character for the Banrock Station Wetland Complex. This wetland system can now be considered predominantly intermittent, instead of a mixture of permanent and intermittent freshwater and saline wetland floodplain complex.

Regardless of this change in hydrological regime, the wetland complex continues to support the services which meet criteria 2, 3, and 4 under the Ramsar Convention.

Continued wetting and drying of the main wetlands, shifting the hydrology of the system from a permanent flow through system to an intermittent freshwater wetland system, will ultimately induce further ecological responses/change. Timing of wetting and drying will require careful monitoring to ensure the benefits continue to be positive with no loss of any of the critical components, processes and services. In particular riparian vegetation health, production of acid sulphate soils and rising salinity are key threats that require monitoring.

8 Knowledge gaps

Scientists and natural resource managers have requirements for knowledge and a desire to fully understand complex wetland systems. There is much still to be learned about the interactions between components and processes in this and other wetlands.

While it is tempting to produce an infinite list of research and monitoring needs for this wetland system, 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 (Hale and Butcher 2008).

As Banrock is an actively managed wetland there is considerable data available with regards to many of the key components and services which the site provides. The key knowledge gaps that have been identified will ensure this site continues to be managed in a sustainable manner and further promote the concept of wise use of wetlands.

Past Banrock Station Manager Tony Sharley, Banrock Station Ranger Ecologist and key stakeholders were consulted to identify knowledge gaps. The knowledge gaps identified that are required to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met are outlined in Table 16, together with a brief description of the action required to address these gaps.

Table 16: Summary of knowledge gaps for key components and services relevant to the maintenance of the ecological character of the Banrock Station Wetland Complex.

Component/Service	Knowledge Gap	Recommended Action
Geomorphology	None identified	
Soils - Potential ASS	Understanding of implications of changed hydrological regime on rates and amounts of PASS development is not known. Potential for release of metals or metal salts from soil to surface or groundwater	Undertake detailed risk assessment. Work being undertaken by CSIRO may remove the need for this action.
Hydrology	Surface water-groundwater trends, and local water balance.	Long term monitoring of groundwater trends in response to repeated wetting and drying.
Water Quality	The relationship between organic matter breakdown and buffering of acidity caused by ASS.	Partnership research with CSIRO during 2-3 consecutive years.
Vegetation communities	The fate of declining Black Box Tree communities, in particular in the area east of the Banrock Lagoon, and strategies to protect them. The role and value of mallee ecosystems as feeding sites for Regent Parrots.	Partnership research through post-graduate studies. Coordination of investigations into declining tree health as per work undertaken at the Riverland Ramsar site – i.e. using same methods of assessment. Partnership studies with DEH Endangered Species Program.
Threatened species	Population size for Southern Bell Frog and on site variability. Relationship between tree health on site and breeding colony size of Regent Parrots. Size of total Regent Parrot breeding population on site, including secondary colony recorded in 2004.	Continued monitoring in response to wetting and drying regime.
Waterbirds	The role of the wetland as habitat for cryptic bird species such as crakes and rails, and their distribution and abundance. The frequency of moulting events and the species involved.	Partnership research with Birds Australia, post-graduate students. Monitoring by Banrock Station staff.

Component/Service	Knowledge Gap	Recommended Action
Fish	Use of wetland for nursery and spawning site for small bodied native fish. Presence of Freshwater Catfish at the site. Evaluation of the importance of Banrock wetland as a pathway for the dispersal of fishes around Weir 3. Identify which species can successfully negotiate the current flow control regulators, both in an upstream and downstream direction. Required modifications to control regulators which will better accommodate the passage requirements of small-bodied native fishes. Gambusia population, response to wetting and drying, and impact on native species	Continued monitoring in response to wetting and drying regime. More detailed surveys in deeper water around the connecting channels. Monitoring associated with this will also allow evaluations of temporal variation in the relative abundances of alien versus native fishes. Investigate the appropriateness of the design requirements described in Mallen-Cooper (2001).
Invertebrates and food web	Baseline information on *Notopala* population on site. Impact of wetting and drying regime on *Notopala*. Baseline survey of all invertebrate taxa to species level to determine any key indicators.	Assessment of irrigation pipes and establishment of risk to population. Partnership study with research institutions.

9 Monitoring

As a signatory to the Ramsar Convention, Australia has made a commitment to protect the ecological character of its Wetlands of International Importance. Under Part 3 of the *Environment Protection and Biodiversity Conservation Act 1999* a person must not take an action that has, will have or is likely to have a significant adverse impact on the ecological character of a declared Ramsar wetland. While there is no explicit requirement for monitoring the site, in order to ascertain if the ecological character of the wetland site is being protected a monitoring program is required.

A comprehensive monitoring program is not required as part of the ecological character description, only a guide to the broad areas which require monitoring relevant to the maintenance of ecological character and their relative priority.

Monitoring needs required to both set baselines for critical components and processes and to assess against LAC are presented. It should be noted that the focus of the monitoring recommended in an ECD is an assessment against LAC and determination of changes in ecological character. This monitoring is not designed as an early warning system whereby trends in data are assessed to detect changes in components and processes prior to a change in ecological character of the site. This must be included in the management plan for the site.

Recommendations for the monitoring of ecological character for the Banrock Station Wetland Complex are presented in Table 17. The recommendations are based on the need to:

- Gather information to provide, or improve the benchmark descriptions (i.e. fill a knowledge gap identified in Section 8) and limits of acceptable change for the critical components, processes and services of the site; and
- Detect change in the ecological character of the site.

Note that parts of this work would be considered inventory and assessment, not monitoring *per se*. Working definitions for wetland inventory, assessment and monitoring are incorporated into the Ramsar *Framework for Wetland Inventory* (modified from Ramsar, 2002 Resolution VIII.6). They are:

> ***Wetland Inventory***: the collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities.
>
> ***Wetland Assessment***: the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities. It involves manipulation and interpretation of the data collected.

Wetland Monitoring*:* the collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management. The collection of time-series information that is not hypothesis-driven from wetland assessment is here termed *surveillance* rather than monitoring (refer to Resolution VI.1).

Table 17: Monitoring needs for the Banrock Station Wetland Complex.

Component/ process	Purpose	Indicator/s	Location/s	Frequency	Priority
Hydrology – ground water surface water interactions.	Assessment against LAC.	Depth to groundwater surface and salinity gradient. Vegetation health.	Banrock and Eastern lagoons, Wigley Reach.	Variable. Quarterly for depth to groundwater surface and salinity gradient.	High
Physical habitat – extent of River Red Gum, Black Box and Samphire.	Assessment against LAC.	Assess age, vigour, and extent to determine if stable, increasing or declining. Sapling survival rates.	Representative sites across wetland types and locations.	Variable.	Moderate to high
Threatened species – Southern Bell Frog.	Assessment against LAC.	Counts and calls (adults and juveniles).	Banrock Lagoon and inlet and outlet creeks.	Monthly during wet phase.	Moderate
Threatened species – Regent Parrot.	Assessment against LAC.	Counts of breeding adults and nesting trees.	Key Regent Parrot nesting sites.	Annually.	Moderate
Fish – Freshwater Catfish.	Establish presence of population.	Presence /absence.	Banrock Lagoon, inlet and outlet creeks and junctions between the River Murray.	Once off to establish presence of population.	High
Fish – general	Determine life cycle/behavioural response to wetland filling and drying.	Patterns of movement. Abundance and community composition and structure (size classes).	Banrock Lagoon, inlet and outlet creeks.	In response to wetting and drying and natural flood events.	Moderate
Waterbirds – general	Assessment against LAC Determine behavioural response to wetting and drying. Determine whether fox control and hydrological regime makes wetland more suitable for migratory species, ground nesting birds and for rare species such as Southern Stone Curlew	Determine abundance and behavior of key species in generalist and specialist feeding groups. Number of species breeding and breeding success	Banrock and Eastern lagoons. Wigley Reach when flooded.	Monthly during wet phase.	Low

10 Communication and education

This final section of the ecological character description provides a very brief description of the key communication, education and public awareness messages that should be included in the management plan for the site. These messages are based on the following:

- Why the site is important;
- The criteria that the site was listed as a Wetland of International Importance;
- Species present at the site;
- Threats to the site; and
- Status of the site.

The key public awareness messages identified in the preparation of this ecological character description for the Banrock Station Wetland Complex Ramsar site are:

<u>Importance</u>

The Banrock Station Wetland Complex is a floodplain system which straddles Lock 3 and falls within two geomorphic zones of the River Murray. It includes over 1000 ha of floodplain with a diverse range of wetland types. Adjacent to the wetlands are areas of mallee vegetation and the vineyards. The establishment of Lock 3 raised upstream river levels and caused the permanent flooding of Banrock Lagoon in 1925. Drowning of River Red Gums and extensive salt degradation across the floodplain was a consequence. However, the raised weir pool combined with flow regulators also provides the opportunity to mimic the natural hydrological regime of an intermittently inundated wetland.

Originally the wetlands provided the source of water for the vineyards, with the wetlands considered a permanent flow through system. However, since the irrigation pumps were moved to river in December 2006 and the introduction of first complete drying phase followed by flooding, the wetland type has changed to an intermittent wetland with major improvements in biodiversity.

This site is not only important for its ecological values but also the social and cultural values. Of particular relevance is the promotion of the site as a demonstration of the concept of wise use, with the conservation of wetland values, combined with increasing awareness and provision of educational experiences going hand in hand with sustainable use of natural resources. Ramsar listing has resulted in the owners of Banrock Station employing 2 Rangers to oversee the implementation of the Management Plan. Management of the water regime of the site, control of invasive species (notably Common Carp), rehabilitation of vegetation associations are all actions which are well publicised at the site with extensive information on these activities available for visitors, all of which provide the public with a unique insight to the issues involved in managing wetland ecosystems. In addition Banrock Station is willing to share information about its management regimes to assist others in managing important natural resources.

Criteria

- Southern Bell Frogs breed on site and can be seen from the boardwalk when the wetland is full.
- Regent Parrots breed on site can be seen from the Wine and Wetland Centre deck late in the afternoon in winter/spring traveling to and from their mallee feeding areas.
- The site is considered important in the passageway of native fish around Lock 3.
- The site provides habitat for a number of migratory waterbird species covered under several international treaties.

Species present

- Waterfowl are a diverse group of waterbirds with a range of different feeding habits. Species regularly observed include Australasian Shoveler, Pink-eared Duck, Hardhead, Grey Teal, Chestnut Teal, Wood Duck, Pacific Black Duck, Black Swan, (rarest ducks include Musk Duck and Freckled Duck).
- Cryptic species – Buff-banded Rail, Spotted Crake, Spotless Crake, Nankeen Night Heron,
- Large piscivorous birds including Australian Pelican, Darter, Little Pied Cormorant, Little Black Cormorant, Pied Cormorant, Great Cormorant also frequent the site.
- Two species of spoonbill, Yellow Billed Spoonbill and Royal Spoonbill.
- Migratory birds including Rainbow Bee-eater (terrestrial), Latham's Snipe, Wood Sandpiper, Greenshank,
- Mallee Birds including Blue-faced Honeyeater,
- Lace Monitor. Sand Goanna and Murray-Darling Carpet Python.
- Broad Shell Turtle, Murray Short-necked Turtle, Long Necked Turtle.

Threats to the site

- Salinisation caused by lack of overbank flows exceeding 60,000 ML/day in the river. The last event occurred in 1996.
- A dry phase in Banrock Lagoon that exceeds 18 months will cause dieback in the surrounding River Red Gum community.
- Feral predators, fox, feral cat.
- Fire
- Failure to upgrade inlet and outlet regulators, leading to leakage and water losses.

Status of the site

The ecological character of the site has undergone a change, shifting from a permanently inundated to intermittently inundated wetland system. There have been some strong ecological gains from the drying of the wetland. However careful management of the water regime is required to ensure the balance between restoring a more natural water regime and not stressing the wetland through prolonged drying is achieved.

11 References

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Glossary

Definitions of words associated with ecological character descriptions (DEWHA 2008) (see DEWHA 2008 for references cited below).

Administrative Authority	the agency within each Contracting Party charged by the national government with oversight of implementation of the Ramsar Convention within its territory [http://www.ramsar.org/about/about_glossary.htm].
Adverse conditions	ecological conditions unusually hostile to the survival of plant or animal species, such as occur during severe weather like prolonged drought, flooding, cold, etc (Ramsar Convention 2005).
Alkalinity	The property of water to neutralize acids. Usually expressed in terms of calcium carbonate equivalents (USA EPA 1999)
Aquifer	a water-bearing horizon, sufficiently permeable to transmit groundwater and yield such water to wells and springs (Ramsar 2006).
Assessment	the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (as defined by Ramsar Convention 2002, Resolution VIII.6).
Baseline	condition at a starting point. For Ramsar wetlands it will usually be the time of listing of a Ramsar site.
Benchmark	a standard or point of reference (ANZECC and ARMCANZ 2000). a pre-determined state (based on the values which are sought to be protected) to be achieved or maintained.
Benefits	benefits/services are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems (Ramsar Convention 2005, Resolution IX.1 Annex A). See also "Ecosystem Services".
Biogeographic region	a scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc (Ramsar Convention 2005).
Biological diversity	the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity), and of ecological processes. This definition is largely based on the one contained in Article 2 of the Convention on Biological Diversity (Ramsar Convention 2005).
Calcium carbonate	naturally occurring compound with the chemical formula $CaCO_3$, the major component of carbonate rocks including limestone and marble (Ramsar 2006).
Catchment	the total area draining into a river, reservoir, or other body of water (ANZECC and ARMCANZ 2000).
Change in ecological character	is 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).
Chamber	an enlargement in a cave passage or system (Ramsar 2006)
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).
Community Structure	all the types of taxa present in a community and their relative abundances (ANZECC and ARMCANZ 2000).
Conceptual model	wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Gross 2003)
Contracting Parties	are countries that are Member States to the Ramsar Convention on Wetlands; 153 as at September 2006. Membership in the Convention is open to all states that are members of the United Nations, one of the UN specialized agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice

	[http://www.ramsar.org/key_cp_e.htm].
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	is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. Within this context, ecosystem benefits are defined in accordance with the variety of benefits to people (Ecosystem Services). (Millennium definition of ecosystem services as "the benefits that people receive from ecosystems" (Ramsar Convention 2005, Resolution IX.1 Annex A). The phrase "at a given point in time" refers to Resolution VI.1 paragraph 2.1, which states that "It is essential that the ecological character of a site be described by the Contracting Party concerned **at the time of designation for the Ramsar List**, by completion of the Information Sheet on Ramsar Wetlands (as adopted by Recommendation IV. 7).
Ecological communities	any naturally occurring group of species inhabiting a common environment, interacting with each other especially through food relationships and relatively independent of other groups. Ecological communities may be of varying sizes, and larger ones may contain smaller ones (Ramsar Convention 2005).
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, e.g. habitat, species and genes) (Millennium Ecosystem Assessment 2005).
Ecosystem processes	are the changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological. (Ramsar Convention 1996, Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment, that result in existing ecosystems and bring about changes in ecosystems over time (Australian Heritage Commission 2002)
Ecosystem services	are the benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (e.g. food and water), regulating (e.g. flood control), cultural (e.g. spiritual, recreational), and supporting (e.g. nutrient cycling, ecological value). (Millennium Ecosystem Assessment 2005). See also “Benefits”.
Ecologically Sustainable Development	development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ANZECC and ARMCANZ 2000).
Geomorphology	the study of water-shaped landforms (Gordon *et al*. 1999)
Groundwater	a subsurface water that lies below the water table in the saturated or phreatic zone (Ramsar 2006)
Indicator species	species whose status provides information on the overall condition of the ecosystem and of other species in that ecosystem; taxa that are sensitive to environmental conditions and which can therefore be used to assess environmental quality (Ramsar Convention 2005).
Indigenous species	a species that originates and occurs naturally in a particular country (Ramsar Convention 2005).
Introduced (non-native) species	a species that does not originate or occur naturally in a particular country (Ramsar Convention 2005).
Limestone	sedimentary rock containing at least 50 % calcium carbonate by weight (Ramsar 2006)
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 Partiy 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 [http://www.ramsar.org/about/about_glossary.htm].
Monitoring	the collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management (Ramsar Convention 2002, Resolution VIII.6).
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" [http://www.ramsar.org/about/about_glossary.htm].
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. http://www.ramsar.org/about/about_glossary.htm
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 [http://www.ramsar.org/index_very_key_docs.htm].
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 (http://www.ramsar.org/about/about_glossary.htm).
Ramsar List	the List of Wetlands of International Importance [http://www.ramsar.org/about/about_glossary.htm].
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 [http://www.ramsar.org/about/about_glossary.htm].
Ramsar Sites Database	repository of ecological, biological, socio-economic, and political data and maps with boundaries on all Ramsar sites, maintained by Wetlands International in Wageningen, the Netherlands, under contract to the Convention [http://www.ramsar.org/about/about_glossary.htm].
Spring	point where underground water emerges on to the surface, not exclusive to limestone, but generally larger in cavernous rocks (Ramsar 2006)
Threatened ecological community	an ecological community which is likely to become extinct in nature if the circumstances and factors threatening its extent, survival or evolutionary development continue to operate (Ramsar 2006)
Waterbirds	(Criteria 5 and 6) - The Convention functionally defines waterfowl (a term which, for the purposes of these Criteria and Guidelines, is considered to be synonymous with "waterbirds") as "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*
Water table	the top surface of a body of groundwater that fills the pore spaces within a rock mass. Above it lies the freely draining vadose zone, and below it lies the permanently saturated phreas. Individual cave conduits may be above or below the water table, and therefore either vadose or phreatic, and the water table cannot normally be related to them. The water table slope (hydraulic gradient) is low in limestone due to the high permeability, and the level is controlled by outlet springs or local geological features. High flows create steeper hydraulic gradients and hence rises in the water level away from the spring (Ramsar 2006).
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 Assessment	the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Finlayson *et al*. 2001; Ramsar Convention 2002).
Wetland Ecological Risk Assessment	a quantitative or qualitative evaluation of the actual or potential adverse effects of stressors on a wetland ecosystem
Wetland types	as defined by the Ramsar Convention's wetland classification system [http://www.ramsar.org/ris/key_ris.htm#type].
Wise use of wetlands	is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches[1], within the context of sustainable development[2]" (Ramsar Convention 2005 Resolution IX.1 Annex A). 1. Including *inter alia* the Convention on Biological Diversity's "Ecosystem Approach" (CBD COP5 Decision V/6) and that applied by HELCOM and OSPAR (Declaration of the First Joint Ministerial Meeting of the Helsinki and OSPAR Commissions, Bremen, 25-26 June 2003). 2. The phrase "in the context of sustainable development" is intended to recognize that whilst some wetland development is inevitable and that many developments have important benefits to society, developments can be facilitated in sustainable ways by approaches elaborated under the Convention, and it is not appropriate to imply that 'development' is an objective for every wetland.

Appendix A: Method

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

Project Inception:
Consultant team leader Rhonda Butcher and Jennifer Hale held a teleconference with DEWHA project manager Ryan Breen and staff to confirm the scope of works and timelines as well as identifying relevant stakeholders that would be consulted. In addition Rhonda Butcher, Ryan Breen (DEWHA) and Kate Thorn (Banrock Station) attended a steering committee meeting at Banrock Wine and Wetland Centre to introduce the concept of preparing an ECD and the national framework.

Task 1: Review and compilation of available data
The consultant team reviewed the original RIS and management plan for the site which included a brief section on ecological character.

The consultant team then undertook a thorough desktop review of information on the ecology of the Banrock Station Wetland Complex to complement the data already collated in the RIS and management plan. Relevant experts and team members were consulted to ensure a focus on key documents and relevant data.

Task 2: Development of a draft ECD
Consistent with the national guidance and framework (DEWHA 2008) the following steps were undertaken to describe the ecological character of the Banrock Station Wetland Complex.

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 above literature review describe the site in terms of: location, land tenure, Ramsar criteria, and 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.	Conceptual character models were included from work developed by the MDFRC for semi-arid wetlands. A stressor conceptual model highlighting key threats to the site was developed.
5. Set Limits of Acceptable Change	For each critical component process and service, establish the limits of acceptable change. This included a review of LAC set in the management plan.
6. Identify threats to the site	This process identified both actual and potential future threats to the ecological character of the wetland system. Included in this section is the stressor conceptual model.
7. Describe changes to ecological character since the time of listing	This site has undergone a recent change in hydrological regime which constitutes a change in ecological character. Available data are presented on how the character of the site has changed.
8. Summarise knowledge	This identifies the knowledge gaps encountered during the

Steps from the national draft (2008) framework	Activities
gaps	preparation of the ECD.
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 3: 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 RIS in the standard format provided by Ramsar. Sections of the RIS that were modified (notably the justification section for the criteria met) were detailed at the end of the RIS for DEWHA consideration.

Task 4 Finalising the ECD and RIS
The draft ECD and RIS were submitted to DEWHA and the steering committee for review and comment. Dr Bill Phillips, Mainstream Environmental Consulting, Dr Chris Gippel Fluvial Systems, Mr Tony Sharley and Dr Ben Smith SARDI Aquatic Sciences reviewed the draft ECD.

A.2 Consultant team for ECD development

The consultant team was led by Dr Rhonda Butcher of Water's Edge Consulting in association with Jennifer Hale, Dr Kerri Muller (Kerri Muller NRM), and Dr Halina Kobryn (Murdoch University).

Dr Bill Phillips (Mainstream Environmental Consulting) and Dr Chris Gippel (Fluvial Systems) provided expert peer review of the first draft of the ECD. In addition Dr Ben Smith provided expert technical input on fish.

Rhonda Butcher (team leader)
Rhonda is considered an expert in wetland ecology and assessment. She has a BSc (Hons) and a PhD in wetland ecology and biodiversity assessment together with over twenty years of experience in the field of aquatic science. She has 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. She has been operating Water's Edge Consulting since 2004.

Rhonda has specialist expertise in the areas of aquatic biological monitoring, biodiversity assessment, invertebrate ecology as well as wetland and river ecology. Having worked on a diverse range of ecosystems, Rhonda has garnered a broad understanding of the ecology of aquatic biota including macrophytes, fish, waterbirds, and amphibians, and their responses to varying hydrological regimes. 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. ECD projects Rhonda has had technical input to include the Coorong and Lakes Alexandrina and Albert, Lake MacLeod, and Peel-Yalgorup Ramsar sites.

Jennifer Hale

Jennifer has over eighteen 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 wetland, riverine and estuarine systems. She is qualified with a Bachelor of Science (Natural Resource Management) and a Masters of Business Administration. Jennifer is an aquatic ecologist with specialist fields of expertise including phytoplankton dynamics, aquatic macrophytes, sediment water interactions and nutrient dynamics. She has a broad understanding of the ecology of aquatic macrophytes, fish, waterbirds, macroinvertebrates and floodplain vegetation as well as geomorphic processes. She has a solid knowledge of the development of ecological character descriptions and has been involved in the development of ECDs for the Peel-Yalgorup, the Coorong, Lake MacLeod, Elizabeth and Middleton Reefs, Ashmore Reef and the Coral Seas Ramsar sites. Jennifer also has a solid knowledge and understanding of estuarine systems.

Kerri Muller

Kerri has more than 16 years experience in Natural Resource Management (NRM) establishing *Kerri Muller NRM* in 2004 with Brett Love to respond to a growing demand for provision of quality consulting services to the NRM sector. Kerri is recognised as a leader in the field of NRM. She has a unique blend of skills with 11 years of academic training and more than 15 years of on-ground experience working with rural landholders and indigenous communities. Kerri holds a Ph.D. in wetland ecology from The University of Adelaide and has worked as a University researcher and teacher, designer of constructed wetlands, catchment manager, NRM Project Officer, adult educator, meeting facilitator and consulting ecologist. She is a graduate of the Murray Darling Basin Leadership Program, is an EMS Associate Auditor (ISO14001) and has been a member of the Australian Society for Limnology since 1991. She is also a member of the Murray Darling Basin Ministerial Council Community Reference Group, providing advice on all aspects of the implementation of The Living Murray Business Plan to the Community Advisory Committee.

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.

Appendix B: Listed species and communities of conservation significance at the Banrock Station Wetland Complex

Plant species conservation status based on Barker et al. (2005) and regionally threatened communities based on Kahramanis et al. (2001). Data sourced from DEH (unpublished).

Bird records based on data supplied by Birds Australia (2009) and DEH (unpublished).

Fish conservation status at the State level is based on Hammer et al. (2007).

E = endangered, R = rare, V = vulnerable, E IUCN = globally endangered.

Group	Common Name	Scientific Name	National/ International	State
Waterbirds				
	Australasian Shoveler	*Anas rhynchotis*		R
	Australasian Darter	*Anhinga novaehollandiae*		R
	Intermediate Egret	*Ardea intermedia*		R
	Musk Duck	*Biziura lobata*		R
	Little Egret	*Egretta garzetta*		R
	Latham's Snipe	*Gallinago hardwickii*		R
	Blue-billed Duck	*Oxyura australis*		R
	Great Crested Grebe	*Podiceps cristatus*		R
	Baillon's Crake	*Porzana pusilla*		R
	Spotless Crake	*Porzana tabuensis*		R
	Freckled Duck	*Stictonetta naevosa*		V
	Wood Sandpiper	*Tringa glareola*		R
Wetland associated non waterbirds				
	White-bellied Sea Eagle	*Haliaeetus leucogaster*		E
	Regent Parrot eastern	*Polytelis anthopeplus*	E	V
Woodland birds				
	Bush-stone Curlew	*Burhinus grallarius*		V
	Pink Cockatoo	*Cacatua leadbeateri*		V
	Golden-headed Cisticola	*Cisticola exilis*		R
	White-winged Chough	*Corcorax melanorhamphos*		R
	Brown Quail	*Coturnix ypsilophora*		V
	Blue-faced honeyeater	*Entomyzon cyanotis*		R
	Peregrine Falcon	*Falco peregrinus*		R

	Major Mitchell Cockatoo	*Lophochroa leadbeateri*		V
	Restless Flycatcher	*Myiagra inquieta*		R
	Gilbert's Whistler	*Pachycephala inornata*		R
	Little Friarbird	*Philemon citreogularis*		R
	Striped Honeyeater	*Plectorhyncha lanceolata*		R
Fish				
	Freshwater Catfish	*Tandanus tandanus*		E
Amphibians				
	Southern Bell Frog	*Litoria raniformis*	E IUCN, V	V
Mammals				
Introduced to the site	Brush-tailed Bettong	*Betongia penicillata*	E	
Introduced to the site	Greater Bilby	*Macrotis lagotis*	E	
	Common Brushtail Possum	*Trichosurus vulpecula*		R
Reptiles				
	Broad-shelled Tortoise	*Chelondina expansa*		V
	Lace Monitor (Tree Goanna)	*Varanus varius*		R
Plants				
	Swamp Daisy	*Brachyscome basaltica* var. *gracilis*		R
	Tufted Burr-Daisy	*Calotis scapigera*		R
	Spiny Lignum	*Muehlenbeckia horrida* ssp. *horrida*		R
	Creeping Boobialla	*Myoporum parvifolium*		R
Regionally Threatened Communities within the South Australia Murray Darling Basin				
River corridor woodlands, *Eucalyptus camaldulensis* and *E. largiflorens* woodlands – no priority category but listed by Kahrimanis et al. (2001) as threatened.				
Lignum *Muehlenbeckia florulenta* Shrubland – no priority category but listed by Kahrimanis et al. (2001) as threatened.				
Common Reed *Phragmites australis* /Narrow-leaf Bulrush *Typha domingensis* Sedgeland – no priority category, but listed as threatened by Kahrimanis et al. (2001).				
Eucalyptus cyanophylla Open mallee (open scrub) with sparse sclerophyllous shrubs – priority 3 – poorly conserved				

Appendix C: Fish species and ecology

Fish species recorded from the Banrock Station Wetland Complex, including current and historic records (source Fredberg et al. 2009; Smith and Fleer 2007).

Migration type: P – Potamodromous.

Ecology and biological information sourced from FishBase (Froese and Pauly 2008) 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. Newly hatched larvae measure 4.8 mm TL on the average. 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.
Atherinidae	*Craterocephalus stercusmuscarum fulvus*	Unspecked hardyhead	P	Found predominantly in rivers but also in wetlands and billabongs. Preferred habitat includes pools and areas of low flowing or still water with vegetation, which is used for cover. Spawn in spring to summer triggered by water temperature around 23˚ C.
	Hypseleoris spp	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. King (2002) defines this group of species as low flow recruitment specialists. Little information is known regarding migration. Adults are often found in off-channel habitats, all species prefer vegetated shallow waters.
	Philypnodon macrostomus	Dwarf flat-headed gudgeon	P	Relatively little information available on this species. Mainly found in coastal basins with a few localities in the River Murray in South Australia and NSW. This species is not particularly abundant but is widespread in the SA Murray Darling Basin (Smith et al. in prep). Spawning induction is possibly variations in water temperature and quality.

Family	Scientific name	Common name	Migration type	Ecology/ biology
				Adults prefer calm waters over mud or rocks or in vegetation. Found in the main channel and occasionally uses off channel habitat such as large floodplain lakes, billabongs and terminal lakes (Mallen-Cooper 2001).
Eleotridae	*Philypnodon grandiceps*	Flat-headed Gudgeon	P	Demersal. Found in still and flowing waters; often abundant in dams and lakes, usually among weeds or over mud bottoms. Occurs in reservoirs and brackish estuaries, less common in gently flowing streams). Feeds on invertebrates and other fishes and tadpoles. In breeding season (mainly spring to summer), males darken and display more vibrant fin markings. Females lay a clutch of eggs on a hard surface such as a rock or piece of wood. The male cares for the nest, chasing away intruders and fanning the eggs with his pectoral fins. Hatching occurs after 4-6 days
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, NSW and southern QLD. This species is not particularly abundant but is widespread in the SA Murray Darling Basin (Smith et al. in prep). 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 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 and in Lakes Alexandrina and Albert near mouth of a river. Most commonly inhabit streams coursing through relatively dry eucalyptus-scrub or desert areas, preferring sluggish or quiet waters. Considered common everywhere in SA MDB in both in-stream and off-stream wetlands. 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. Maximum size is about 45 cm. 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

Family	Scientific name	Common name	Migration type	Ecology/ biology
	Tandanus tandanus	Freshwater Catfish	P	Demersal. Adults inhabit slow moving streams, lakes and ponds with fringing vegetation, typically a lowland species. They swim close to sand or gravel bottoms. More abundant in lakes than in flowing water. Usually solitary but juveniles sometimes form loose aggregations. Mainly bottom-feeders. Feed on insect larvae, prawns, crayfish, molluscs, and small fishes. Breeding occurs between spring and mid-summer when water temperatures rise to between 20° and 24°C. Once common in the Murray Darling Basin this species is now declining and are protected in South Australia. Main threats include cold water discharges from dams, barriers to movement, siltation/smothering of nesting substrate and spawned eggs, and competition from Carp and possibly over fishing.
	Macquaria ambigua	Golden Perch (Callop)	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 favor 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 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 kilometers by tagged fish have been documented). Eggs float near the surface and hatch in 24-36 hours. Males mature after 2-3 years (20-30 centimeters), females after 4 years (40 centimeters). 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.

Appendix D: Waterbird and wetland associated birds

Species listing: M-EPBC = Listed as migratory or marine under the EPBC Act; V-EPBC = Vulnerable under the EPBC Act; CE-EPBC= Critically endangered under the EPBC Act; C= CAMBA; J = JAMBA; R = ROKAMBA.

Species records based on data supplied by Birds Australia (2009). Taxonomy as per Christidis and Boles (2008).

Common name	Scientific name	Listed
Waterbirds		
Waterfowl		
Australasian Shoveler	*Anas rhynchotis*	M-EPBC
Australian Shelduck	*Tadorna tadornoides*	M-EPBC
Australian Wood Duck	*Chenonetta jubata*	M-EPBC
Black Swan	*Cygnus atratus*	M-EPBC
Blue-billed Duck	*Oxyura australis*	M-EPBC
Chestnut Teal	*Anas castanea*	M-EPBC
Freckled Duck	*Stictonetta naevosa*	M-EPBC
Grey Teal	*Anas gracilis*	M-EPBC
Hardhead	*Aythya australis*	M-EPBC
Musk Duck	*Biziura lobata*	M-EPBC
Pacific Black Duck	*Anas superciliosa*	M-EPBC
Pink-eared Duck	*Malacorhynchus membranaceus*	M-EPBC
Plumed Whistling Duck	*Dendrocygna eytoni*	M-EPBC
Grebes		
Australasian Grebe	*Tachybaptus novaehollandiae*	
Great Crested Grebe	*Podiceps cristatus*	
Hoary Headed Grebe	*Poliocephalus poliocephalus*	
Pelicans, Cormorants, Darters,		
Australasian Darter	*Anhinga novaehollandiae*	
Australian Pelican	*Pelecanus conspicillatus*	M-EPBC
Great Cormorant	*Phalacrocorax carbo*	
Little Black Cormorant	*Phalacrocorax sulcirostris*	
Little Pied Cormorant	*Microcarbo melanoleucos*	
Pied Cormorant	*Phalacrocorax varius*	
Herons, Ibis, Egrets, Spoonbills		
Australian White Ibis	*Threskiornis molucca*	M-EPBC, J
Glossy Ibis	*Plegadis falcinellus*	M-EPBC, C, J
Eastern Great Egret	*Ardea modesta*	M-EPBC, C, J (listed as *A. alba*)
Intermediate Egret	*Ardea intermedia*	M-EPBC
Little Egret	*Egretta garzetta*	M-EPBC
Nankeen Night-Heron	*Nycticorax caledonicus*	

Royal Spoonbill	*Platalea regia*	
Straw-necked Ibis	*Threskiornis spinicollis*	M-EPBC
White-faced Heron	*Egretta novaehollandiae*	
White-necked Heron	*Ardea pacifica*	
Yellow-billed Spoonbill	*Platalea flavipes*	
Crakes, Rails, Water Hens, Coots, Brolga		
Baillon's Crake	*Porzana pusilla*	
Australian Spotted Crake	*Porzana fluminea*	M-EPBC
Black-tailed Native-hen	*Tribonyx ventralis*	M-EPBC
Dusky Moorhen	*Gallinula tenebrosa*	
Eurasian Coot	*Fulica atra*	
Purple Swamphen	*Porphyrio porphyrio*	
Spotless Crake	*Porzana tabuensis*	M-EPBC
Waders/Shorebirds		
Black-fronted Dotterel	*Elseyornis melanops*	
Black-winged Stilt	*Himantopus himantopus*	M-EPBC
Common Greenshank	*Tringa nebularia*	M-EPBC, C, J, R
Latham's Snipe	*Gallinago hardwickii*	M-EPBC, C, J, R
Masked Lapwing	*Vanellus miles*	M-EPBC
Red-capped Plover	*Charadrius ruficapillus*	M-EPBC
Red-kneed Dotterel	*Erythrogonys cinctus*	M-EPBC
Red-necked Avocet	*Recurvirostra novaehollandiae*	M-EPBC
Red-necked Stint	*Calidris ruficollis*	M-EPBC, C, J, R
Sharp-tailed Sandpiper	*Calidris acuminata*	M-EPBC, C, J, R
Wood Sandpiper	*Tringa glareola*	M-EPBC, C, J, R
Gulls, Terns		
Caspian Tern	*Hydroprogne caspia*	M-EPBC, C
Gull-billed Tern	*Gelochelidon nilotica*	
Silver Gull	*Chroicocephalus novaehollandiae*	
Whiskered Tern	*Chlidonias hybrida*	
Wetland associated birds		
Hawkes, Eagles		
Swamp Harrier	*Circus approximans*	M-EPBC
White-tailed Sea Eagle	*Haliaeetus leucogaster*	M-EPBC, C
Wetland associated		
Australian Reed-Warbler	*Acrocephalus australis*	
Regent Parrot	*Polytelis anthopeplus*	
Sacred Kingfisher	*Todiramphus sanctus*	

Appendix E: Waterbird feeding and dietary guilds.

Feeding Guilds: F1= dense inundated vegetation; F2 = Shallows (<0.5m) and/or mud; F3= Deep water (> 1m); F4 = Away from wetland habitats
Dietary Guilds: D1= Plants and animals; D2 = Mostly plants; D3= Mostly animals; D4 = Fish. X = Common or usual, O = Occasional.

Waterbirds	Feeding Guilds				Dietary Guilds			
	F1	F2	F3	F4	D1	D2	D3	D4
Waterfowl								
Australasian Shoveler		X	X		X			
Australian Shelduck		X		X	X			
Australian Wood Duck				X	X			
Black Swan		X	X	X		X		
Blue-billed Duck			X		X			
Chestnut Teal		X	X		X			
Freckled Duck		X	X		X			
Grey Teal		X	X		X			
Hardhead		X	X		X			O
Musk Duck			X		X			O
Pacific Black Duck		X	X	X	X			
Pink-eared Duck		X	X		X			
Plumed Whistling Duck		X		X		X		
Grebes								
Australasian Grebe		X	X				X	X
Great Crested Grebe			X			O	X	X
Hoary-headed Grebe		X	X				X	X
Pelicans and Cormorants								
Australasian Darter			X				X	X
Australian Pelican			X				X	X
Great Cormorant			X				X	X
Little Black Cormorant			X				X	X
Little Pied Cormorant		X	X				X	X
Pied Cormorant			X				X	X
Herons, Ibis, Egrets and Spoonbills								
Australian White Ibis		X		X			X	X
Glossy Ibis		X				X	O	X
Eastern Great Egret		X		X		X	X	X
Intermediate Egret		X		X		X	X	X
Little Egret		X				X	X	X
Nankeen Night-Heron	X	X		X			X	X
Royal Spoonbill		X			O	X	X	X
Straw-necked Ibis		X		X		X		X
White-faced Heron		X		X		X	X	X
White-necked Heron		X				X	X	X
Yellow-billed Spoonbill		X				X	X	X
Crakes, Rails Water Hens, Coots and Brolga								
Baillon's Crake	X	X	X		X			

Australian Spotted Crake	X	X			X			
Black-tailed Native-hen	X	X		X	X			
Dusky Moorhen	X	X		X	X			
Eurasian Coot		X	X		X			
Purple Swamphen	X	X		X	X			
Spotless Crake	X	X			X			
Shorebirds								
Black-tailed Godwit		X				O	X	
Black-fronted Dotterel		X		X			X	
Black-winged Stilt		X				O	X	O
Common Greenshank		X			X			
Latham's Snipe		X					X	
Masked Lapwing		X					X	
Red-capped Plover		X		X	X			
Red-kneed Dotterel		X			X			
Red-necked Avocet		X				O	X	O
Red-necked Stint		X			X			
Sharp-tailed Sandpiper		X			X			
Wood Sandpiper		X					X	
Gulls and Terns								
Caspian Tern			X				X	X
Gull-billed Tern		X	X	X			X	X
Pacific Gull		X	X	X			X	
Silver Gull		X	X	X	X			X
Whiskered Tern		X	X				X	X
Hawks and Eagles								
Swamp Harrier	X	X		X			X	X
White-bellied Sea-Eagle		X	X	X			X	X