# Johnson Swamp
# Environmental Water Management Plan
Final

Connecting Rivers, Landscapes, People

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

Department of Environment, Land, Water & Planning

VICTORIAN ENVIRONMENTAL WATER HOLDER

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## EXECUTIVE SUMMARY

The Johnson Swamp Environmental Water Management Plan (EWMP) sets out the long-term objectives for the priority environmental values of Johnson Swamp, in the Pyramid Creek sub-catchment of the Loddon River basin. The EWMP is an important part of the Victorian Environmental Water Planning Framework. It provides the ten year environmental water management intentions, based on scientific information and stakeholder consultation, which can be used by the respective agencies; North Central Catchment Management Authority (CMA), Department of Environment, Land, Water and Planning (DELWP) and the Victorian Environmental Water Holder (VEWH); for both short and longer-term environmental water planning.

This EWMP is not a holistic management plan for the wetland, but is focused on environmental water management so that Johnson Swamp can provide environmental, social, cultural and economic values for all users. Actions such as floodplain connectivity investigations and pest plant and animal works are documented as complementary to environmental water management in this EWMP.

The following components are the main sections featured in the Johnson Swamp EWMP. A summary of the main conclusions to facilitate appropriate environmental water management into the future are summarised below.

**Catchment setting**

Johnson Swamp is situated approximately 15 kilometers south-east of Kerang on the lower Loddon floodplain and is traversed by the Pyramid Creek which separates it into Johnson Swamp East and Johnson Swamp West. The wetland is a State Wildlife Reserve and is of international and national significance being part of the Kerang Wetlands Ramsar site and listed in the Directory of Important Wetlands in Australia.

**Hydrology and system operations**

Johnson Swamp's natural water supply originates from overflows in Pyramid Creek. Historically the wetland would have been a black box dominated shallow freshwater marsh, receiving intermittent flooding for six to eight months of the year to a flood depth of less than half a metre. Pyramid Creek is now highly regulated and used to supply irrigation water to the Kerang Lakes in the Torrumbarry Irrigation Area and customers en route. To improve its hydraulic efficiency, the creek was deepened in the 1960s resulting in the construction of a large levee bank along much of its length. This increased the maximum depth of floodplain wetlands along Pyramid Creek including Johnson Swamp, and broke the natural hydrological connection and intercepted the underlying water table.

Until the late 1980s, Johnson Swamp was filled via pumping from Pyramid Creek and later from the Torrumbarry irrigation channel 4/7/2. The wetland was used as an operational outfall for rainfall rejection irrigation water occurring after heavy rains and surplus flows from the irrigation system. Environmental water was also frequently allocated to Johnson Swamp (and neighbouring Hird Swamp) to provide a drought refuge for waterbirds and recreational opportunities for duck hunting.

However system upgrades, increased efficiencies and the Millennium Drought (2001 to 2010) reduced outfall water and environmental allocations to Johnson Swamp. For the period of 2004 to 2010, Johnson Swamp remained almost completely dry until extensive flooding in January 2011. Environmental water was allocated to the wetland in 2015 and included a partial fill in autumn 2015 followed by a series of spring/ summer top-ups as required to maintain a water depth to support waterbird breeding.

At full supply level (FSL), 78.2 m AHD, Johnson Swamp West has a storage capacity of 1,772 ML and a maximum depth of 1.2 metres. Johnson Swamp East has a FSL at 78 m AHD with corresponding storage capacity of 143 ML and a maximum depth of 0.75 metres.

From a landscape perspective the wetland is particularly important as a drought refuge and has the potential to be reconnected back to its natural flow path which may contribute improving the health and productivity of Pyramid Creek.

**Water dependent values**

Johnson Swamp contributes to meeting five of the Ramsar Convention criteria supported by the larger Kerang Wetlands Ramsar site. The wetland is recognised predominately for its ability to support a high abundance of waterbirds and provides important habitat for breeding of threatened species such as brolga (*Grus rubicunda*), Australasian bittern (*Botaurus poiciloptilus*) and Australian little bittern (*Ixobrychus dubius*). It also supports important plants and vegetation communities such as the endangered Riverine Chenopod Woodland (EVC 103) and a diverse assemblage of native aquatic and amphibious plant species.

**Cultural and recreational values**

The wetland contains evidence of Aboriginal occupation, in the form of mounds, scar trees and middens and provides a range of important recreational values including duck hunting and bird watching, which provide economic and social benefits to local communities.

**Ecological condition and threats**

The hydrological changes at Johnson Swamp have resulted in a decline in the condition of the wetland with the most notable being the death of canopy trees, invasion by cumbungi (*Typha* spp.) and a reduction in the diversity of native plant species. Native vegetation has been significantly altered from its pre-European state with areas that once would have been Intermittent Swampy Woodland now more representative of Aquatic Herbland and Tall Marsh (due to the loss of understorey and canopy species).

Some species have been advantaged by the altered hydrological conditions, particularly the dominant cumbungi. While these species provide valuable protection and nesting habitat for wetland waterbirds, including the EPBC listed Australasian bittern, they also form dense stands which inhibiting the growth of other native plant species.

Environmental water management is required to provide appropriate conditions to rehabilitate the vegetation communities, reduce the proliferation of cumbungi and support waterbird breeding.

**Management objectives**

A long-term management goal has been defined for Johnson Swamp:

**Management goal**

Rehabilitate Johnson Swamp using environmental water management to reduce the extent of cumbungi (*Typha spp.*), expand the area of Aquatic Herbland (EVC 653), and improve the condition of Intermittent Swampy Woodland (EVC 813) and Lignum Swampy Woodland (EVC 823). This will provide the physical habitat and condition to support a high diversity and abundance of breeding and feeding waterbirds.

The ecological objectives and hydrological objectives that sit under the long-term management goal for Johnson Swamp were based on key environmental values and informed by Rakali (2014a) and Butcher and Cook (2016), and were refined during the development of this EWMP.

**Managing risks to achieving objectives**

The threats to achieving ecological objectives that are external to environmental water management are identified. Key threats include rising groundwater and salinity levels, pest animals (fox, rabbits and pigs) and introduced fish species (i.e. carp).

Risks associated with the delivery of environmental water include the potential for continued encroachment and dominance of cumbungi and excessive river red gum and lignum growth and recruitment.

**Environmental water delivery infrastructure**

The Torrumbarry 4/7/2 channel that supplies Johnson Swamp has a reported capacity of 100 ML/day. The outfall structure (automated) located on the western side of the wetland has a reported capacity of 80 ML/day. Johnson Swamp also has a 600 mm outlet (east side of Johnson Swamp West) with a door to drain into Pyramid Creek. At a flow rate of 80 ML/day it will take a minimum of 22 days to fill Johnson Swamp from empty subject to the availability of water, and the ability of the GMW system to deliver flows in conjunction with competing customer demands.

Potential upgrade options to improve operational management of Johnson Swamp water delivery infrastructure include:

- upgrading of the outlet structure or pumping to allow direct delivery of water from Pyramid Creek to the Johnson Swamp West
- scoping investigation to determine infrastructure requirements to water Johnson Swamp East (either via Pyramid Creek or from Johnson Swamp West siphoning) and enabling through flows to the Pyramid Creek, providing full throughflow connectivity.

**Demonstrating outcomes**

Monitoring is required to allow adaptive management of environmental water management (intervention monitoring). Monitoring is also required to enable the CMA and VEWH to demonstrate the long-term outcomes of the implementation of the Johnson Swamp EWMP. The Johnson Swamp EWMP recommends a suite of long-term and intervention monitoring activities that will inform the management of environmental water in the system.

**Consultation**

Local community members, key stakeholders and interest groups including DELWP, VEWH, Parks Victoria, Goulburn Murray Water (GMW), Gannawarra Shire, Birdlife Australia, Field and Game Australia and Game Management Authority were engaged during the development of this EWMP. Barapa Barapa traditional owners were also consulted to allow incorporation and alignment of indigenous and cultural values to ecological objectives at Johnson Swamp. The contribution of all involved, particularly through review and input into the history, values and management goal, is gratefully acknowledged.

**Knowledge gaps and recommendations**

Management actions in the Johnson Swamp EWMP are based on best available information; however there are a number of knowledge gaps and associated recommendations identified for future funding. In particular the benefit of releasing through flows from Johnson Swamp to Pyramid Creek, the relationship between environmental water management and the extent and density of cumbungi and the feasibility of connecting Johnson Swamp East and providing complete throughflow through Johnson Swamp West and East, requires future investigation and funding.

# ACKNOWLEDGEMENTS


## Acknowledgement of Country

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

## Contributions to the Johnson Swamp EWMP

The information contained in the Johnson Swamp EWMP has been sourced from a variety of reports and field inspections and from individual knowledge and expertise. The North Central CMA acknowledges the assistance of the following people in preparing this EWMP:

- Charlie Gillingham, Di Bowles, Rob Loats, Ken Hooper, Greg Maxwell, Carol Maxwell, Graeme Hill, Colin Myers, Craig McIntosh, Neville Goulding, Mark Daley, David McNabb and Daryl Snowdon (Field and Game Australia), Tavi Manescu (Game Management Authority), Simon Starr (Birdlife Australia) - Community Advisory Group
- Jamie Bell, Andrea Keleher, Mick Dedini and Minda Murray - Department of Environment, Land, Water and Planning
- Geoff Rollinson – Gannawarra Shire Council
- Leeza Wishart and Murray Thorson - Parks Victoria
- Bruce Mathers - Department of Economic Development, Jobs, Transport and Resources
- Erin Round - Victorian Environmental Water Holder
- Khane Mason and Ross Stanton - Goulburn Murray Water
- Rhonda Butcher (Water's Edge Consulting) and Damien Cook (Rakali Ecological Consulting)- Scientific Review Panel
- Uncle Ron Galway, Uncle Neville Whyman, Joy Galway, Uncle Ducky Charles, Debbie Webster, Dan Huttan (Forestry NSW), Colin Pardoe (archaeologist), Robyn McKay and Bambi Lees (North Central CMA)- Barapa Barapa site visit participants
- Bree Bisset, Michelle Maher, Darren White, Louissa Rogers, Bambi Lees, Phil Dyson, Robyn McKay, Genevieve Smith and Rebecca Horsburgh - North Central CMA.

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## 1. Introduction

Management of environmental water is planned and implemented through the Victorian Environmental Water Management Framework (Figure 1). The North Central Catchment Management Authority (CMA) has recently developed the North Central Waterway Strategy (NCWS) 2014-2022, which is an integrated strategy for managing and improving the region's waterways (rivers, streams and wetlands) (North Central CMA 2014). The NCWS is guided by the Victorian Waterway Management Strategy 2013 (VWMS) and the North Central Regional Catchment Strategy 2013 (RCS).

Johnson Swamp is part of a Ramsar listed wetland complex (Kerang Wetlands Ramsar site which includes 23 wetlands) and is a priority wetland in the NCWS. The wetland is part of the larger Kerang Lakes Complex (a total of 106 wetlands) and sits within the Lower Loddon Program Area. Current long-term projects that cover this area include the environmental watering program for the Central Murray Wetland Complex (which is part of the broader Environmental Water Reserve Officers project funded by DELWP) and Kerang Priority Wetlands Protection Project funded by the Australian Government under the National Landcare Project (due to conclude in 2018) which delivers on-ground works including pest plant and animal management, fencing and revegetation (North Central CMA 2014a). The specific long-term resource condition target outlined in the NCWS for Johnson Swamp is to protect and improve the ecological character of the Ramsar wetlands as measured by the Ecological Character Description (ECD) (Section 2.6).

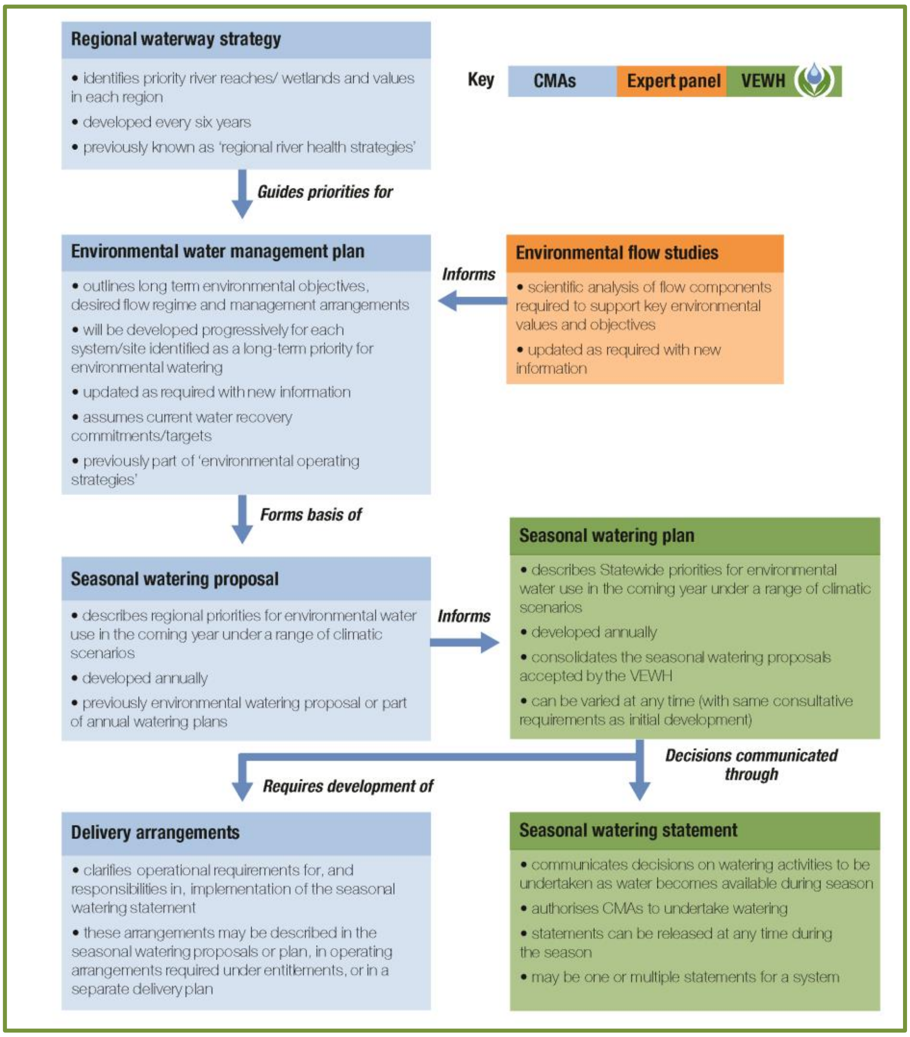


**Figure 1. Planning framework for decisions about environmental water management in Victoria (VEWH 2015a)**

## 1.1. Purpose and scope

The Johnson Swamp EWMP is a ten year management plan that describes the ecological values present, the long-term goal, priority ecological objectives and required watering regime. It is based on scientific information and input from community and traditional owners and will be used by the North Central CMA when making annual environmental watering recommendations, as well as Department of Environment, Land, Water and Planning (DELWP) and the Victorian Environmental Water Holder (VEWH) for short and long-term environmental water planning (DEPI 2014a).

The key purposes of this EWMP are to:

- identify the long-term objectives and water requirements for the wetland
- provide a vehicle for community consultation, including for the long-term objectives and water requirements of the wetland
- inform the development of future Seasonal Watering Proposals (SWPs) and seasonal watering plans.

The scope of this EWMP is the entirety of Johnson Swamp currently managed by Parks Victoria as a State Wildlife Reserve (Figure 2).

## 1.2. Development Process

Johnson Swamp has an Environmental Watering Plan (EWP) that was prepared by the North Central CMA in 2009 under the Goulburn Murray Water Connections Project (formerly the Northern Victoria Irrigation Renewal Project) (North Central CMA 2009). The purpose of the EWP was to establish a volume of mitigation water that Goulburn Murray Water Connections Project is required to set aside to address potential environmental impacts caused by reduced outfalls to Johnson Swamp. The EWP established ecological objectives and a watering regime for Johnson Swamp.

The Johnson Swamp EWMP is based on work undertaken for, and presented in, the *Johnson Swamp EWP* as well as new research and information collected since the EWP was finalised. The development process included:

- **Scoping and collating information:** Johnson Swamp has been the subject of a number of technical assessments and scientific analysis. The history of this work to date is shown in Table 1.

**Table 1. History of technical work undertaken for Johnson Swamp**

| Report name | Author | Date | Summary |
|---|---|---|---|
| Conservation value of the wetlands in the Kerang Lakes Area | Lugg et al. | 1989 | A report that assesses the conservation value of Johnson Swamp in relation to key attributes including its size, rarity and waterbird use. The report outlines that the wetland has been greatly modified from an intermittent black box wetland to a deep freshwater marsh, although still recognised to be of high value due to its habitat value for waterbirds (breeding and habitat). The need to control cumbungi (*Typha* spp.) and saline groundwater intrusions are outlined as key areas for management and monitoring with the report further recommending that the wetland be maintained as semi-permanent freshwater wetland into the future. |
| Development of an Environmental Water Management Strategy for Johnson Swamp | SKM | 1996 | A report that assesses the environmental watering requirements of Johnson Swamp and proposes a flushing and drying cycle to enhance environmental values and assist with rising salinity levels. The study included the use of surface and groundwater modelling to conclude that filling the wetland every two to three years was insufficient to flush/dry salt out of the wetland. The report recommended that the wetland be filled every year in spring (to 78.4 m AHD) and be drained in January every third year. The report recommends an outlet be installed to facilitate flushing. |

| Report name | Author | Date | Summary |
|---|---|---|---|
| Kerang Wetlands Ramsar Site: Strategic Management Plan | Parks Victoria | 2000 | A plan that establishes management objectives for the entire Kerang Wetlands Ramsar site. Site specific management strategies for Johnson Swamp include managing breeding habitat for freckled duck, control of cumbungi, recreation, groundwater intrusion and water quality. |
| Johnson Swamp (West Side) Watering and Operational Plan | SKM | 2001 | A plan that reviews the water related management at Johnson Swamp and recommends a more adaptive water regime due to the following key influencing factors:<br>1. Groundwater levels in the wetland<br>2. Vegetation composition (cumbungi)<br>3. Breeding stage of waterbird species in the wetland. |
| Technical comments on current hydrogeological status and environmental risk of Johnson Swamp in reference to future water management | Reid and O'Brien | 2009 | A report that describes the hydrogeology of Johnson Swamp during a period of low groundwater levels (drought) and implications for environmental watering. The following key observations applicable to future management are discussed:<br>• A low risk of salinisation at the time of the report provides favourable conditions for periodic environmental watering<br>• The possibility of generally lower watertables in the future, combined with lower volumes of applied irrigation water, adds further weight to the benefits of occasional inundation of the wetland using environmental water. |
| Johnson Swamp EWP | North Central CMA | 2009 | A technical study which recommends filling the west side of Johnson Swamp to capacity one in five years, with top-ups provided in the following year to maintain inundation of the open water assemblage before completely drying. The EWP recommends that there is no mitigation water allocated to Johnson Swamp due to the low volumes of outfall water supplied to the wetland in comparison to the volumes required to support the wetland's environmental values. |
| Wetland and Terrestrial Vegetation Conditioning Monitoring: Kerang Wetlands, Richardson's Lagoon and Leaghur State Park | Australian Ecosystems | 2012 | A flora list and vegetation condition assessment that identifies, describes and maps EVCs, vegetation composition, condition, extent and tree health at key wetlands including Johnson Swamp. The study includes an assessment of ecological condition (Index of Wetland Condition), advice on water quality and wet/ dry tolerances of the vegetation as well as incidental fauna observations. |
| Johnson Swamp bathymetry survey and rating table | Northern Land Solutions (NLS) | 2015 | A contour plan and associated rating table which includes a:<br>• Full Digital Elevation Model of swamp bed out to the nominated full supply level<br>• Survey of infrastructure, including, inlets and outlets, regulators and drainage lines as well as nearby waterways<br>• Survey of all levees, roads and tracks, fences and the position of private property to assist in the analysis of the full supply level. |
| Murray-Darling Basin Plan EWMP Program Scoping Report | North Central CMA | 2014 | A scoping report that reviews 17 sites that are known to have high environmental values and the potential to receive environmental water. The report recommends that an EWMP be prepared for Johnson Swamp, once the transfer of management responsibility from GMW to North Central CMA is complete (as part of Connections Project). |
| Kerang Ramsar and other Significant Wetlands Monitoring Project | Rakali Ecological Consulting | 2014 | A repeat survey using the methodology adopted in Australian Ecosystems 2014 including a vegetation assessment which identifies, describes and maps EVC, composition, tree health, condition and extent. The survey also includes an IWC assessment, provides advice on water quality and wet/ dry tolerances of the vegetation present, records all incidental fauna observations and compares the results from the 2012 survey. |

| Report name | Author | Date | Summary |
|---|---|---|---|
| Mapping of *Typha* species *and Phragmites australis* in three Central Murray Wetlands | Rakali Ecological Consulting | 2014 | A report that maps vegetation at Hird, Johnson and McDonalds swamps with a particular focus on quantifying the extent of cumbungi and common reed. The data provides a baseline to assist with determining the current wetland composition and to set appropriate long term management goals for each wetland. |
| Ecological response of Johnson Swamp to environmental watering | Rakali Ecological Consulting | 2015 | A report that demonstrates that outcomes of environmental water delivery in 2015-16 including germination of aquatic plants, maturing of tadpoles into young frogs (e.g. barking marsh frog), breeding of eastern long-necked turtles and the provision of suitable conditions for brolga and Australasian bitterns to breed. |
| Notes on an Australasian Bittern survey at Johnson Swamp | Rakali Ecological Consulting | January 2016 | A summary of observations from the Australasian bittern and brolga surveys in 2015-16 including the presence of nests with eggs and evidence of young fledging. The report recommends that water levels be maintained until fledging is complete, before allowing the wetland to drawn down to provide food resources for young and to dry out where cumbungi had germinated during summer. |
| Hydrogeological assessment of Johnson Swamp | North Central CMA | 2016 | A report that summarises the surface and groundwater interactions at Johnson Swamp using bore data to discuss the potential risks of salinisation at the wetland. |
| Technical Review Johnson Swamp Draft EWMP | Butcher and Cook | 2016 | A report that summarises the outcomes of a scientific panel review of the management objectives and environmental watering actions included in the EWMP. The project involved participation in a workshop with CMA staff and key stakeholder to develop/ refine the the management goal, environmental objectives, hydrological requirements, proposed watering regime and monitoring requirements for Johnson Swamp. |

- **Stakeholder, community and indigenous consultation:** The conversion of the Johnson Swamp EWP to EWMP has been undertaken in collaboration with key stakeholders including DELWP, Parks Victoria, VEWH, GMW, local landholders and Barapa Barapa traditional owners (Appendix 1).

The outputs of these tasks were analysed to provide justification and evidence for the following sections of the EWMP:

- **Water dependent values:** environmental values were derived from various sources identified during the scoping phase. Terrestrial species that, due to large-scale clearing of woodland habitat throughout the catchment, are dependent on the vegetation surrounding the wetland are also documented as well as social, cultural, recreation and economic values.
- **Ecological condition, condition trajectory and threats**: Available information, including IWC assessments, was used to describe the current condition and water related threats to Johnson Swamp. A 'do-nothing' scenario is further considered to understand the condition trajectory if no action is undertaken.
- **Management objectives**: The water management goal and the ecological objectives for Johnson Swamp are based on the water dependent values recorded for the wetland, the current condition and the condition trajectory. The objectives are also aligned with the broader environmental outcomes proposed in the Basin Plan Environmental Watering Strategy.
- **Managing risks:** The risks to achieving the ecological objectives for Johnson Swamp are based on best-available scientific knowledge and community concerns. Management actions to mitigate each risk have been recommended and residual risk identified (assuming full adoption of management action).
- **Environmental water delivery infrastructure:** Current constraints to delivery of environmental water are identified as well as recommendations to allow future environmental water delivery.

- **Demonstrating outcomes**: Monitoring to adaptively manage the delivery of environmental water and to demonstrate the outcomes against the ecological objectives are based on best available science monitoring methods. Justification for a suite of long term and intervention monitoring recommendations are given.
- **Knowledge gaps and recommendations:** A number of knowledge gaps were identified during the process of developing the ecological objectives, management actions and risk analysis sections. A series of recommended activities as well as a priority ranking is given for each knowledge gap/ recommendation.

## 2. Site overview

### 2.1. Site location

Johnson Swamp is situated approximately fifteen kilometers south-east of Kerang in the Pyramid Creek sub-catchment of the Loddon River basin (Figure 2). It is a State Wildlife Reserve and a wetland of international and national significance as part of the Kerang Wetlands Ramsar site and listed in the Directory of Important Wetlands in Australia (KBR 2011; Environment Australia 2001).

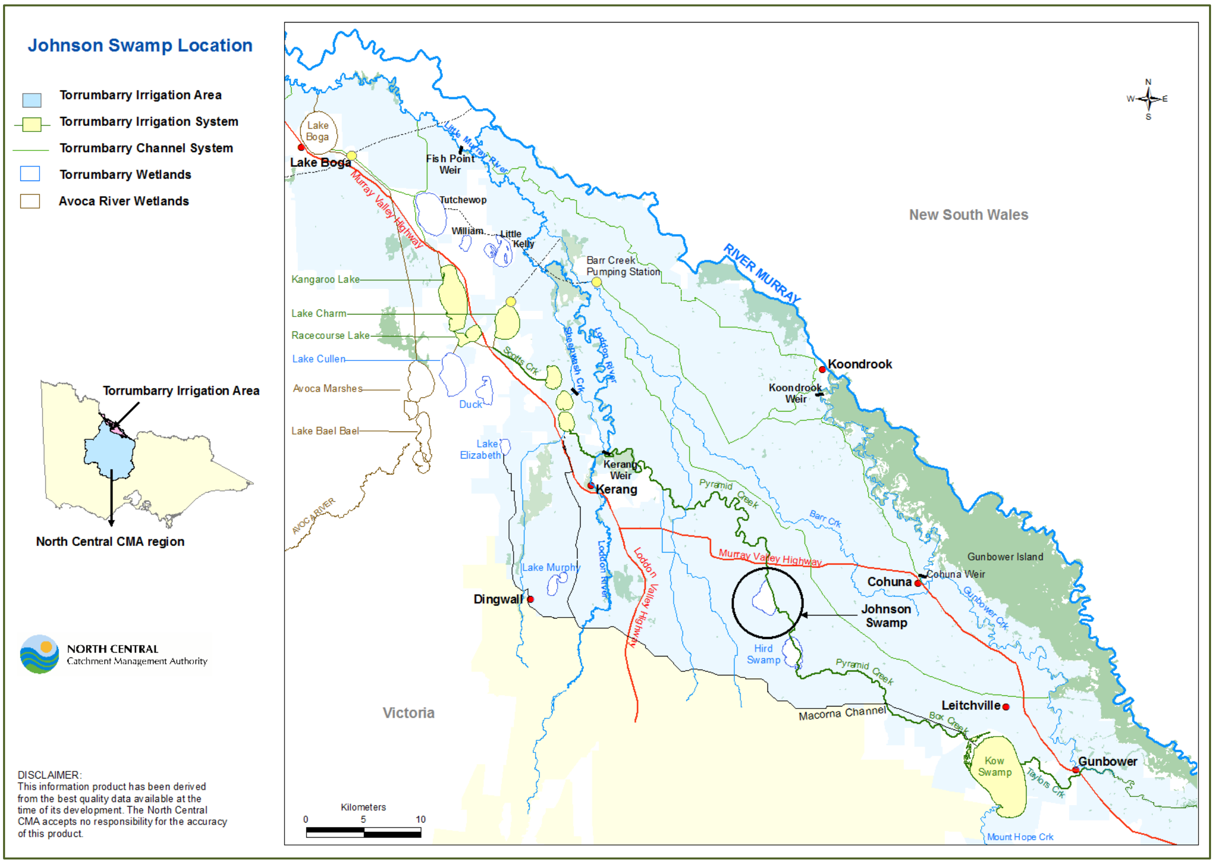


Figure 2. Location of Johnson Swamp

### 2.2. Catchment setting

#### Climate

Climate data were obtained for the closest meteorological station, Kerang Station 080023, from the Bureau of Meteorology (BOM). Median rainfall in Kerang is 368 mm/year, with May to October (median of 32.08 mm/month) significantly wetter than November to April (average of 17.45 mm/month). Average daily temperature ranges from 31.6°C maximum in January to 4°C minimum in July at, with an average of five days a year when the temperature drops below zero degrees (BOM 2015).

#### Hydro-physical characteristics

Johnson Swamp is located on the lower Loddon floodplain and is traversed by Pyramid Creek which separates it into Johnson Swamp East and Johnson Swamp West. Pyramid Creek is a tributary of the Loddon River and it connects the Loddon River to Gunbower Creek via Kow Swamp and Taylors Creek (Figure 3). The wetland is situated within a heavily cleared landscape that is mostly used for grazing and irrigated agriculture.

Pyramid Creek flows across a flat alluvial plain and has been significantly modified over time as a result of flood mitigation, irrigation and drainage works. In the late 1960s the creek was dredged to increase its capacity and hydraulic efficiency. As a result the creek is now an artificially deepened and narrowed channel that lacks typical creek geomorphological components, such as run/riffle and pool structure (Jacobs 2014).

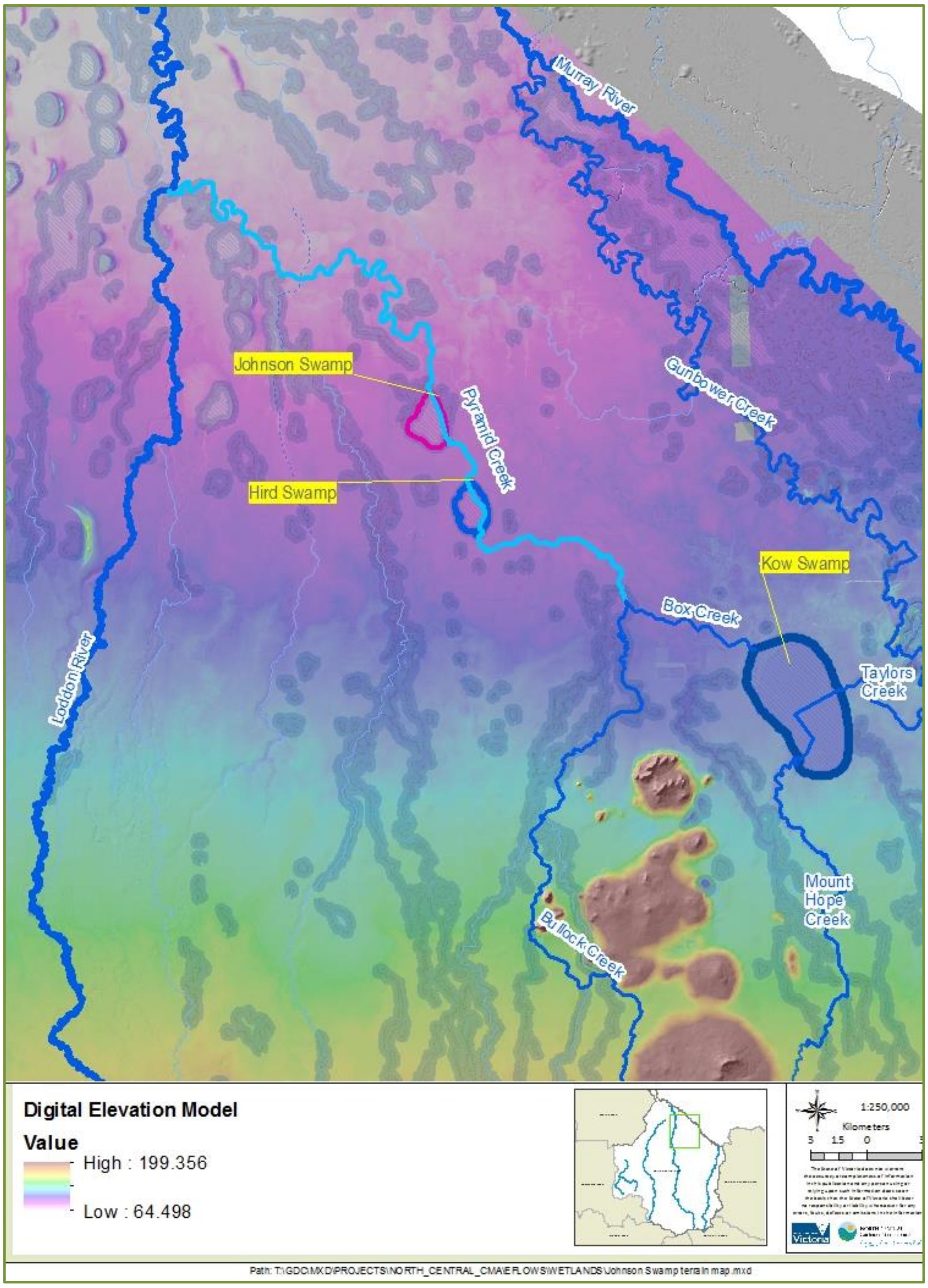


**Figure 3. Terrain of the Lower Loddon River catchment**

Johnson Swamp is 399 hectares. The western portion of the wetland is 351 hectares (88 percent of the wetland area) and has a gentle sloping bed gradient that transition into a deeper central zone (bed level of 77 m AHD) directly adjacent to Pyramid Creek. A number of small islands (<0.1 hectare in size) have been constructed up to a height of 78.8 m AHD, which rise approximately 0.6 metres above the Full Supply Level (FSL) of 78.2 m AHD. The eastern side of the wetland is 48 hectares and is a slightly higher elevation (bed level of 77.25 m AHD) with slightly steeper gradient due to it originally forming the most eastern fringe of the wetland. Due to the close proximity of neighboring farmland, the current FSL for this section of the wetland is approximately 78 m AHD (Table 3 and Appendix 4).

Johnson Swamp occurs on the border of the Victorian Riverina and Murray Fans bioregions (DELWP 2015a) (refer to Appendix 2):

- Johnson Swamp West is located in the Victorian Riverina Bioregion, which occurs in northern Victoria between the highlands of the north-east, and the Mallee country in the west. The Victorian Riverina is an ancient riverine floodplain, which is characterised mainly by river alluvium and fertile soils that make the area suitable for irrigated agriculture (DSE 2013a).
- Johnson Swamp East is located in the Murray Fans bioregion. The Murray Fans bioregion occurs in the north west of the state and is characterised by a flat to gently undulating landscape on recent unconsolidated sediments with evidence of former stream channels (DSE 2013b).

## 2.3. Land status and management

**Land use**

Johnson Swamp is located with the Torrumbarry Irrigation Area with the surrounding land use dominated by irrigated cropping typically for pasture and hay to support dairies (North Central CMA 2009).

**Land tenure**

Johnson Swamp is a State Wildlife Reserve under the *Crown Land (Reserves) Act 1978* and is managed by Parks Victoria under the *Wildlife Act 1975*. Wildlife reserves are managed to conserve and protect species, communities or habitats of indigenous animals and plants while permitting education and recreational use including in season hunting as specified by the land manager (VEAC 2008).

**Environmental water management**

There are several agencies directly involved in environmental water management in Victoria. Other agencies, such as public land managers, play an important role in facilitating the delivery of environmental watering outcomes. Table 2 describes the key stakeholders that have involvement in the management of Johnson Swamp.

**Table 2. Roles, responsibilities and interest in the management of Johnson Swamp**

| Agency/group | Responsibilities/involvement |
|---|---|
| Department of Environment, Land Water and Planning (DELWP Victoria) | • Manage the water allocation and entitlements framework.<br>• Develop state policy on water resource management and waterway management for approved by the Minister for Water and Minister for Environment and Climate Change.<br>• Develop state policy for the management of environmental water in regulated and unregulated systems.<br>• Act on behalf of the Minister for Environment and Climate Change to maintain oversight of the VEWH and waterway managers (in their role as environmental water managers).<br>• Legislative responsibilities for the management of flora and fauna.<br>• Approve EWMPs and endorse SWPs. |
| Victorian Environmental Water Holder(VEWH) | • Make decisions about the most effective use of the water holdings, including use, trade and carryover.<br>• Authorise waterway managers to implement watering decisions.<br>• Liaise with other water holders to ensure coordinated use of all sources of environmental water.<br>• Publicly communicate environmental watering decisions and outcomes.<br>• Author of the Statewide Seasonal Watering Plan.<br>• Provides final endorsement of SWPs.<br>• Approves delivery of environmental water (Seasonal Watering Statement) and funds some environmental water related monitoring and infrastructure works. |

| Agency/group | Responsibilities/involvement |
|---|---|
| Commonwealth Environmental Water Office (CEWO) | • Support the Commonwealth Environmental Water Holder to make decisions about the use of Commonwealth water holdings, including providing water to the VEWH for use in Victoria.<br>• Liaise with the VEWH to ensure coordinated use of environmental water in Victoria.<br>• Report on management of Commonwealth water holdings. |
| Murray-Darling Basin Authority (MDBA) | • Implement the Murray-Darling Basin Plan - the Basin Plan sets legal limits on the amount of surface water and groundwater that can be taken from the Basin from 1 July 2019 onwards.<br>• Integrate Basin wide water resource management.<br>• Manage The Living Murray water entitlements. |
| North Central Catchment Authority (North Central CMA) | • Waterway Manager.<br>• Identify regional priorities for environmental water management in the Regional Waterway Strategy<br>• In consultation with the community assess water regime requirements of priority rivers and wetlands to identify environmental watering needs to meet agreed objectives<br>• Identify opportunities for, and implement, environmental works to use environmental water more efficiently.<br>• Propose annual environmental watering actions to the VEWH and implement the VEWH environmental watering decisions.<br>• Provide critical input to management of other types of environmental water (passing flows management, above cap water).<br>• Report on environmental water management activities undertaken. |
| Goulburn Murray Water (GMW) | • Water Corporation – Storage Manager and Resource Manager.<br>• Work with the VEWH and Waterway Managers in planning the delivery of environmental water to maximise environmental outcomes.<br>• Operate water supply infrastructure such as dams and irrigation distribution systems to deliver environmental water.<br>• Ensure the provision of passing flows and compliance with diversion limits in unregulated and groundwater systems.<br>• Endorse SWP and facilitate on-ground environmental water delivery. |
| Parks Victoria | • Land Manager.<br>• Implement the relevant components of EWMPs, including (as agreed) operation and maintenance of infrastructure that is not part of the GMW irrigation delivery system.<br>• Where agreed, participate in the periodic review of relevant EWMPs.<br>• Endorse SWPs.<br>• Manage and report on other relevant catchment management and risk management actions required due to the implementation of environmental water. |
| Input, advice and interest in environmental watering | |
| Traditional Owners/ Community Groups | • The recognised traditional owner group of Johnson Swamp is Barapa Barapa. |
| Gannawarra Shire | • Local council for area that includes Johnson Swamp<br>• Responsible for regulation of local development through planning schemes and on-ground works.<br>• Committed to diversify the local economy through promotion of tourism, in particular social and recreational activities including game hunting. |
| Central Murray Wetland Complex Environmental Water Advisory Group (MEWAG) | • The MEWAG consists of key stakeholders and community representatives who provide advice and input into the North Central CMA on the best use of environmental water for the wetlands located on the Central Murray River floodplain. |
| Local community and interest groups | • Local landholders<br>• Recreational users of Johnson Swamp including Field and Game Australia and Birdlife Australia<br>• Members of the Central Murray Wetland Complex EWAG (see Appendix 3)<br>• Consulted in the development of this EWMP (see Appendix 1 for participant list). |

## 2.4. Wetland characteristics

Victoria's wetland classification and inventory was updated in 2013 and replaces the system developed by Corrick and Norman in the early 1980s. The updated classification is based on the

Australian National Aquatic Ecosystem (ANAE) Classification Framework with data on wetlands and their classification attributes converted into spatial Geographic Information System (GIS) layers.

The ANAE Framework structure produces 37 wetland categories. The first level of the classification hierarchy distinguishes between naturally-occurring from human-made wetlands. The second level of the classification hierarchy distinguishes between aquatic ecosystem habitats: palustrine, lacustrine and estuarine. The third level of the hierarchy distinguishes between wetland attributes such as water regime, salinity, landscape context, soils and wetland vegetation (DEPI 2014c).

Under Corrick and Norman, Johnson Swamp was once classified as a shallow freshwater marsh (Corrick and Norman 1750 classification). The development of the Torrumbarry Irrigation System and changing land use resulted in a shift in classification to a deep freshwater marsh (Corrick and Norman 1994 classification). Based on the new ANAE classification system, Johnson Swamp is a temporary freshwater marsh[1] (DEPI 2014c). An overview of the wetland characteristics is provided in Table 3.

**Table 3. Wetland characteristics of Johnson Swamp**

| Characteristics | Description |
|---|---|
| Name | Johnson Swamp |
| Mapping ID (Corrick) | 7726 3555320 |
| Mapping ID (DELWP) | 45222 |
| Area (ha) | 399 hectare wetland (west 351 ha; east 48 ha) (NLS 2015) within a 464 hectare reserve |
| Bioregion | Victorian Riverina with eastern edge in Murray Fans bioregion |
| Conservation status | Ramsar and Directory of Important Wetlands |
| Land status | State Wildlife Reserve |
| Land manager | Parks Victoria |
| Surrounding land use | Irrigated cropping and pasture |
| Water supply | Natural:<br>• Floodwater/ overflow from the Pyramid Creek<br>• Local catchment runoff from south and south east (approx. 300 ha) (SKM 2001)<br>Historic:<br>• Pumping (up until 1980s- post dredging of Pyramid Creek)<br>Current:<br>• Regulated:<br>o Western section: flows from Torrumbarry 4/7/2 channel (capacity of 160 ML/day) outfalling to an environmental water delivery conduit (80 ML/day)<br>• Natural:<br>o West and eastern section: Significant overbank flooding from Pyramid Creek (>2,000 ML/day) required to overtop banks |
| 1788 wetland category (Corrick and Norman) | Shallow freshwater marsh (< 8 months duration, <0.5 m depth) |
| 1994 wetland category (Corrick and Norman) | Deep freshwater marsh (<2 m depth)<br>Sub-category: reed (233 ha), open water (123 ha), lignum (54 ha) |
| 2013 Victorian wetland classification (DEPI 2014b) | Temporary freshwater marsh[1] |
| Wetland capacity (NLS 2015) | West: 1,772 ML at FSL of 78.2 m AHD (bed level of approx. 77 m AHD)<br>East: 143 ML at FSL of 78 m AHD (bed level of approx.. 77.25 m AHD) |
| Wetland depth at capacity (NLS 2015) | West: 1.2 m at FSL<br>East: 0.75 m at FSL |

[1] Under the 2013 ANAE classification, Johnson Swamp is classified as an 'unknown' wetland type. However, based on the criteria for each wetland type, Johnson Swamp has been classified as a temporary freshwater swamp (as per Butcher and Cook 2016).

## 2.5. Environmental water sources

Environmental water available for use at Johnson Swamp can come from three sources, as described below and summarised in Table 4. Water shares are classed by their reliability and there are two types in Victoria:

- High-reliability water shares (HRWS), which is a legally recognised, secure entitlement to a defined share of water.
- Low reliability water shares (LRWS) which are water shares with a relatively low reliability of supply. Allocations are made to high-reliability water shares before low-reliability shares (DEPI 2014d).

Water availability can vary from season to season according to climatic conditions, volumes held in storage and carryover entitlements. In addition unregulated flows can be utilised in the Murray System during declared unregulated periods.

**Bulk Entitlement (River Murray Flora and Fauna) Conversion Order 1999**

The Victorian River Murray Flora and Fauna Bulk Entitlement provide 29,782 ML HRWS, 3,897 ML LRWS and 40,000 ML of unregulated flows in the Murray System. It is held by the VEWH for the purpose of providing for flora and fauna needs (VEWH 2015b). It has been used in a range of wetlands including Gunbower Forest (Living Murray icon site and Ramsar site) and the Kerang Wetland Ramsar site. It can also be traded on the water market on an annual basis (Victorian Government 2011).

**Commonwealth Environmental Water Holder (CEWH)**

Commonwealth water holdings are the direct result of government purchases of entitlements and a substantial investment in more efficient water infrastructure in the Murray Darling Basin. As at 30 June 2016, the Commonwealth environmental water holdings totalled 345,920 ML for the Victorian Murray Catchment. Johnson Swamp sits within the Loddon Catchment management area in which a total of 3,356 ML HRWS AND 527 ML of LRWS exists (CEWH 2016). The use of this water for wetlands in the North Central region is not guaranteed and is at the discretion of the CEWH (CEWH 2016).

**Temporary water allocation donations**

Individuals with water shares can donate water to their local CMA for environmental use. Additionally, money can be donated to non-governmental organisations to buy temporary water for environmental use. While the scale of donated water is generally small relative to other water sources, it can provide a valuable contribution, especially in times of critical needs.

**Table 4. Potential environmental water sources for Johnson Swamp**

| Water entitlement | Volume | Flexibility of management | Conditions on availability and use | Responsible agency |
|---|---|---|---|---|
| Bulk Entitlement (River Murray – Flora and Fauna) Conversion Order 1999 (incl. Amendments Orders and Notices 2005, 2006, 2007 and 2009) | 29,782 ML<br>3,894 ML<br>40,000 ML | HRWS<br>LRWS<br>Unregulated | Entitlement held in Hume and Dartmouth reservoirs, with unused water able to be carried over. For use in the Murray River system, such as:<br>1. Murray River wetlands (including Johnson Swamp)<br>2. Barmah Forest<br>3. Gunbower Forest<br>4. Kerang Lakes wetlands<br>5. Hattah Lakes system<br>6. Cardross Lakes and other Mallee wetlands systems<br>7. Lindsay/ Walpolla/ Mulcra Island systems. | VEWH |

| Water entitlement | Volume | Flexibility of management | Conditions on availability and use | Responsible agency |
|---|---|---|---|---|
| Commonwealth Environmental Water Holdings – Loddon Catchment | 3,356 ML<br>527 ML | HRWS<br>LRWS | Managed in accordance with the Murray Darling Basin Plan | CEWH |
| Temporary water donations | Variable | N/A | Agreement is required with private donor | VEWH/ CMA |

## 2.6. Related agreements, legislation, policy, plans and activities

There are a range of international treaties, conventions and initiatives, as well as National and Victorian State Acts, policies and strategies that direct management of wetlands within Northern Victoria. Those which have particular relevance to Johnson Swamp and the management of its environmental and cultural values are listed below.

**International agreements:**

- *Ramsar Convention on Wetlands 1971*- The Ramsar Convention, to which Australia is a signatory, provides a framework for national action and international cooperation for the conservation and wise use of wetlands and their resources (DSE 2004). Ramsar wetlands in Australia are protected by the federal *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999*. Johnson Swamp contributes to the site meeting five of the Ramsar Convention criteria (at the timing of listing) which is supported by the larger Ramsar site:
    - 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.
    - Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
    - Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
    - Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their lifecycles, or provides refuge during adverse conditions.
    - Criterion 6: A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird (KBR 2011).

  The act of designating a wetland as a Ramsar site carries with it certain obligations, including managing the site to retain its ecological character and to have procedures in place to detect if any threatening processes are likely to alter, or have altered, the ecological character. The Ramsar Convention has defined ecological character and change in ecological character as:

    - "Ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time" and
    - "…change in ecological character is the human induced adverse alteration of any ecosystem component, process and or ecosystem benefit/service." (Ramsar 2005).

- *Japan Australia Migratory Birds Agreement (JAMBA) 1974* - eight of the species listed under this agreement have been recorded at Johnson Swamp.
- *China Australia Migratory Birds Agreement (CAMBA) 1986* - ten of the species listed under this agreement have been recorded at Johnson Swamp.
- *Republic of Korea Australia Migratory Birds Agreement (ROKAMBA) 2002* - six of the species listed under this agreement have been recorded at Johnson Swamp.
- *Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) 1979* - seven of the species listed under this convention have been recorded at Johnson Swamp.

**Commonwealth legislation and policy:**

- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Part IIA) – Johnson Swamp is known to support places of cultural significance/ sensitivity with fourteen sites registered with Victoria.
- *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) – ten migratory waterbird species, two water dependent fauna species and three water depedent flora species listed under this Act have been recorded at Johnson Swamp.
- *Water Act 2007* – to provide for the protection of ecological values at Johnson Swamp through appropriate management of Murray-Darling Basin water resources.

**Victorian legislation:**

- *Aboriginal Heritage Act 2006* - Johnson Swamp is an area of cultural sensitivity.
- *Catchment and Land Protection Act 1994* - governs the management of land surrounding Johnson Swamp i.e. pest plant and animal control.
- *Water Act 1989* - provides for the integrated management of water in Victoria.
- *Wildlife Act 1975* - Parks Victoria manages Johnson Swamp in accordance with this Act.
- *Flora and Fauna Guarantee Act 1988* (*FFG Act*) – ten fauna species and six flora species listed under this Act have been recorded at Johnson Swamp.
- *National Parks Act 1975*- regulation that prescribes activities relating to the preservation and protection of natural and cultural heritage values of parks.

**National policies and strategies:**

- *The National Cultural Flows Research Project* – this project is investigating indigenous water values and uses to form the basis for cultural flow water entitlements. These would be legally and beneficially owned by the Indigenous Nations and are of a sufficient and adequate quantity and quality to improve the spiritual, cultural, environmental, social and economic conditions of those Indigenous Nations. The cultural flows framework is under development but may influence Johnson Swamp as it is an area of cultural sensitivity.

**Victorian policy and strategies:**

- *Victorian threatened flora and fauna species (DEPI advisory lists)* – 30 fauna species (24 water dependent) and eleven flora species (ten water dependent) are on the DEPI advisory lists have been recorded at Johnson Swamp.

- *Victorian Waterway Management Strategy (VMWS) 2014* - this strategy outlines the direction for the Victorian Government's investment over an eight year period (beginning in 2012-13). The overarching management objective is to maintain or improve the environmental condition of waterways to support environmental, social, cultural and economic values (DEPI 2013a).

**Regional strategies and plans:**

- *North Central Regional Catchment Strategy (RCS) 2013-2019* – this strategy sets regional priorities for the management of natural assets, sets overall direction for investment and coordination of effort by landholders, partner organisations and the wider community. The lower reaches of the Loddon River are identified as critical vegetation corridors which provide habitat for a range of threatened flora and fauna species. The river also has influence on a number of wetlands including the Kerang Wetlands Ramsar Site and the Boort wetland system which provides an extensive and diverse waterbird habitat and aquatic refuge (North Central CMA 2012).
- *North Central Waterway Strategy (NCWS)* – this regional strategy is an action out of the Victorian Waterway Management Strategy and provides the framework for managing rivers and wetlands with the community over the next eight years. It delivers key elements of the VWMS including developing work programs to maintain or improve the environmental condition of waterways in the north central region. Johnson Swamp is a priority wetland for this eight year planning period (North Central CMA 2014a).
- *Loddon River EWMP* - the North Central CMA has developed a EWMP for the Loddon River and associated waterways including Pyramid Creek (the Loddon River System).
- *Kerang Wetlands Ramsar Site Action Plan*- the Action Plan (to be finalised 2016) is a key action out of the NCWS and aims to provide a more coordinated approach to management of the Ramsar site in line with conservation objectives and principles of wise use. This will be a key document to guide management from 2016-2022.
- *Native Fish Recovery Plan, Gunbower and Lower Loddon*- the Recovery Plan outlines a suite of on-ground actions to restore native fish populations in the North Central CMA region in conjunction with irrigation supply and associated water deliveries. These actions include the construction of fishways, screening of irrigation channels, delivery of environmental flows and habitat rehabilitation (i.e. re-snagging and riparian revegetation) with the aim of addressing the three key factors responsible for the decline of native fish populations within the Murray Darling Basin- loss of connectivity for fish movement and migration, altered natural flow regimes and habitat loss. Pyramid Creek, which dissects Johnson Swamp, is considered a priority waterway in the Plan.

## 3. Hydrology and system operations

Wetland hydrology is the most important determinant in the establishment and maintenance of wetland types and processes. It affects the chemical and physical aspects of the wetland which in turn affects the types of flora and fauna that the wetland supports (DSE 2005). A wetland's hydrology is determined by surface and groundwater inflows and outflows in addition to precipitation and evapotranspiration (Mitsch and Gosselink 2000). Duration, frequency and seasonality (timing) are the main components of the hydrological regime for wetlands and rivers.

### 3.1. Natural hydrology

Prior to European settlement Johnson Swamp would have been a shallow freshwater marsh dominated by black box (*Eucalyptus largiflorens*), with a depth of less than half a metre. The wetland's natural water supply originates from overflows in Pyramid Creek, a tributary of the Loddon River and connects the Loddon River to the Gunbower Creek via Kow Swamp and Taylors Creek (refer to Figure 2). Johnson Swamp would have received intermittent flooding originating from a large catchment area to the south and southeast. Water from Bendigo Creek flowed into Kow Swamp which would have overflowed during extended wet periods, into Pyramid Creek (North Central CMA 2009). The natural hydrological cycle of Johnson Swamp would have consisted of flooding in winter and spring with drawdown due to evaporation occurring over the summer months (SKM 2001).

The Loddon and Murray floodplain and associated wetlands would have originally been regularly inundated by floods in the Loddon and Murray River and other tributaries such as Bendigo Creek and Bullock Creek (Macumber 1969 cited in Jacobs 2014). It is not possible to infer a natural flow regime for Pyramid Creek and therefore the natural flooding regime of Johnson Swamp, because it has been operated as a major irrigation distribution system for over 100 years. The full supply level (FSL) of Kow Swamp was increased to its current level in 1900 (GMW 2014).

### 3.2. Historic/current hydrology

The hydrology of Pyramid Creek and adjacent alluvial plains has been altered with the advent of flood control works, irrigation and drainage works. From 1884 regular irrigation during the summer months commenced and Johnson Swamp was operated as a freshwater irrigation storage. The high operating level required in Pyramid Creek to supply downstream Kangaroo Lake irrigators, created a constant high water level in Johnson Swamp for eight months of the year. Many of the black box trees were drowned and cumbungi began to flourish. Increased irrigation in the region saw rising groundwater levels and salinity problems in the wetland from the early 1930s (North Central CMA 2009; Jacobs 2014).

Between 1967 and 1969, approximately 70 kilometres of Pyramid Creek was completely channelised to increase its capacity and hydraulic efficiency so that it could be used to transfer irrigation water from Kow Swamp to the Loddon River and Kerang Lakes (Lugg et al. 1993; McGuckin and Doeg 2000). The increased channel capacity and constructed levee banks (top of levee raised to 78.4 m AHD which is approximately 0.8 metres above the original bank height) disconnected Johnson Swamp from Pyramid Creek in all but high flows/flood events (>2,000 ML/day). The bed of the wetland became perched above the typical operation height of Pyramid Creek (North Central CMA 2009). Typical flows in Pyramid Creek are 700 to 1,200 ML/day during the irrigation season (15 August to 15 May), reducing to 100 ML/day in the winter months with regulation controlled by Kow Swamp, which has a capacity of approximately 51,000 ML (Jacobs 2014).

In response to the decision to dredge Pyramid Creek and subsequently drain Hird and Johnson swamps, Victorian Field and Game Association (now Field and Game Australia) lead a vigorous rebuttal process between 1963 and 1965, giving evidence to the Victorian Government as to why preservation of both wetlands was necessary. This saw the installation of outlets to return water to

Pyramid Creek and the use of pumps to fill and maintain both wetlands at full supply level each year (0.8-1.2 metres in both wetlands). This was the first time in Australian history that the government had made an environmental water allocation to preserve wetlands (FGA 2016). However with time, the delivery of water became more ad-hoc, due to low funding allocations and political issues and consequently both wetlands began to experience prolonged dry periods (K. Hooper 2016, pers comm., 13 July).

In the 1980s management was transferred to Parks Victoria and in 1982 the Kerang Wetlands (of which Johnson Swamp is part) was listed as a Wetland of International Importance under the Ramsar Convention. Johnson Swamp was later connected to the Torrumbarry irrigation channel 4/7/2 (Refer to Section 7, Figure 8), and was used as an operational outfall for rainfall rejection irrigation water that occurred after heavy rains as surplus flows in the irrigation system. The average outfall volume between 1998 and 2008 was 250 ML/year (GMW data); however anecdotal information, suggests that historically larger outfall volumes provided a wetter watering regime (North Central CMA 2009).

Environmental water from the *Murray Flora and Fauna Bulk Entitlement 1999* was regularly allocated to Johnson Swamp (and neighbouring Hird Swamp) to provide a drought refuge for waterbirds and recreational opportunities for duck hunting during the 1990s and early 2000s (DSE 2006). However in the mid to late 2000s system upgrades, increased efficiencies and the Millennium Drought (between 2001 and 2010) reduced the volume of outfall water and the availability of environmental allocations to Johnson Swamp.

In 2009 an Environmental Watering Plan (North Central CMA 2009) was developed for the GMW Connections Project (previously Northern Victoria Irrigation Renewal Project) which assessed the hydrological contribution from outfall water to Johnson Swamp and the environmental benefit it was providing. The plan recommended that the wetland be filled one in five years to support the lignum/black box and open water habitats. No mitigation water was recommended to maintain the environmental values at the wetland due to the low volumes of outfall water supplied in the baseline year[1] (a total of 92.5 ML of outfall water recorded in the baseline year 2004-05) (North Central CMA 2009).

For the period of 2005 to 2010, Johnson Swamp remained dry until extensive flooding occurred in January 2011. Environmental watering in 2015 included a partial fill in autumn 2015 followed by a series of spring/ summer top-ups as required to maintain a water depth to support waterbird breeding, in particular endangered Australasian bittern and threatened brolga (see Section 4.1.1). The cycle of wetting and drying at Johnson Swamp between 1996 and 2016 and water sources is summarised in Table 5.

**Table 5. Johnson Swamp wetting/ drying calendar**

| **Year** | **96-97** | **97-98** | **98-99** | **99-00** | **00-01** | **01-02** | **02-03** | **03-04** | **04-05** | **05-06** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Status** | W | W | W | W | W | W | D | W | D | W |
| **Water source** | U | E/C? | E/C | E/C | E/C | E/C | - | E/C | - | E/C |
| **Year** | **06-07** | **07-08** | **08-09** | **09-10** | **10-11** | **11-12** | **12-13** | **13-14** | **14-15** | **15-16** |
| **Status** | D | D | D | D | W | W-D | D | D | W-D | W-D |
| **Water source** | - | - | - | - | F | - | - | - | E | E |

W: water present, D- dry, W-D: drawdown
Water source: T: irrigation tailwater/ E: Environmental Water/ C: Channel outfall/ F: Natural flooding / U: Unknown

[1] The baseline water year, 2004-2005, was selected to quantify the savings as part of the GMW Connections Project. The comparison of estimated water savings with a baseline year is necessary to convert the savings to water entitlements and ensure that there are no impacts on service delivery or reliability for existing entitlement holders. The baseline year was used to guide the quantification of mitigation water required for wetlands taking into account the average annual patterns of availability. Johnson Swamp received a total of 92.5 ML of outfall water in 2004-2005. The timing of the outfalls is over the irrigation period of August to May.

## 3.3. Groundwater/surface water interactions

The principal aquifers influencing saline groundwater within the region of Johnson Swamp comprise prior streams within the Shepparton Formation and the regional Parilla Sand. Groundwater heads and watertable depth are most likely controlled by transfers between the pressures of the Shepparton Formation and the underlying Parilla Sand Aquifer. The salinity of groundwater in the immediate area is generally very high and in some instances exceeding 50,000 EC (greater than the salinity of sea water).

Groundwater data presented in Figure 4 has been obtained from observation wells established in the Shepparton Formation in the early 1990s. However none of the wells monitor the underlying Parilla Sand aquifer. The data recorded illustrates that groundwater fluctuated consistent with seasonal rainfall patterns in more stable climates up until 2001. In these times saline groundwater discharge occurred when the level of water within the wetland was low. As the drought intensified the seasonal response in the water table weakened and groundwater levels fell below the wetland bed after 2005. The water table recovered during 2010-11 following extensive flooding in the region, reaching similar levels to the early 1990s. The water table has since retreated to levels similar to the dry years of the early 2000s.

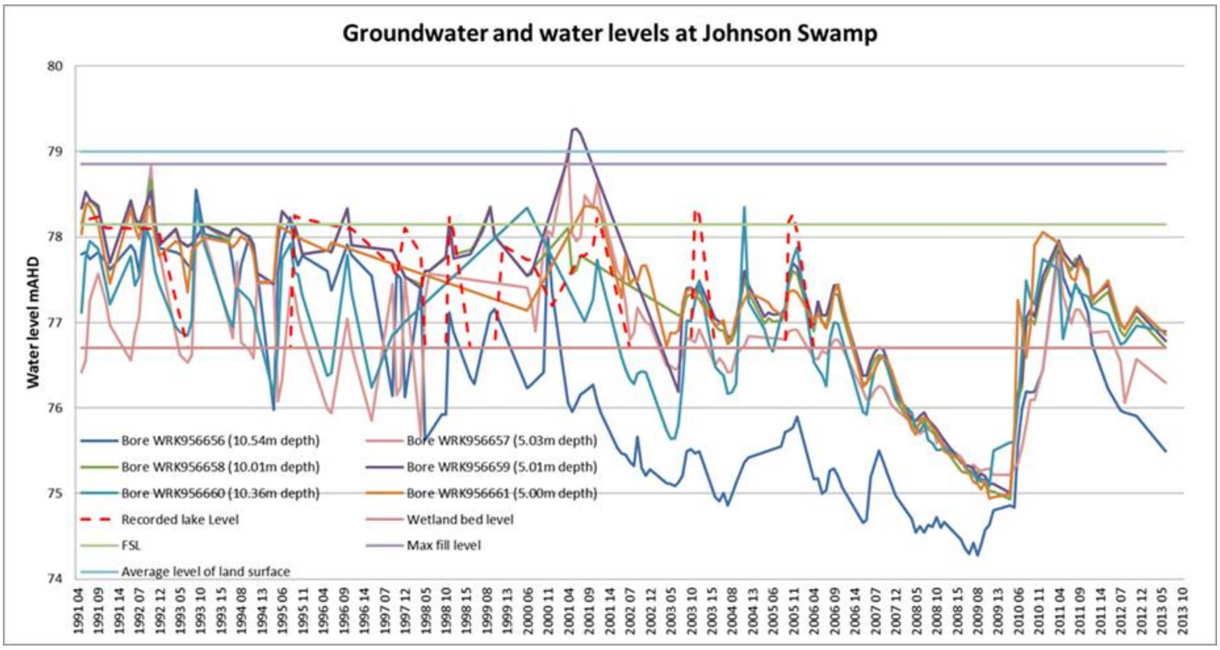


**Figure 4. Groundwater hydrographs constructed from data collected from observation wells in the immediate region of Johnson Swamp**

An important risk of environmental watering is shallow saline groundwater within the immediate area of the wetland. The regional groundwater occurs at an elevation close to that of the wetland floor (except during severe droughts and floods). Filling the wetland to the proposed full supply level of 78.2 m AHD would sustain a downward hydraulic gradient that would prevent groundwater discharge into the wetland, which would reduce the salt load to the wetland. However there is a risk that filling the wetland to this level may induce a local increase in the water table that could pose a salinity risk to the surrounding land.

It is recommended that monitoring is undertaken when delivering environmental water to Johnson Swamp to attempt to gain a more informed understanding of the wetland-groundwater interactions given the shallow depth and shallow saline groundwater in the region (North Central CMA 2016a) (see Section 9).

## 3.4. Water Quality

Due to the variable hydrological nature of wetlands there are no definitive water quality guidelines for wetlands in Victoria. When discussing water quality parameters of Johnson Swamp, the Environmental Protection Authority (EPA) *Environmental Water Quality Guidelines for Victorian Lakes* (2010) for shallow (<5 metres) inland lakes and the Australian and New Zealand Environment Conservation Council (ANZECC) *Guidelines for Fresh and Marine Water Quality Volume 1* (2000) have been used as a guide.

Spot monitoring of water quality at Johnson Swamp is undertaken by agency staff when water is present at the wetland (DEDTJR surface water monitoring 2011-2016). Recent data for pH, salinity, turbidity and dissolved oxygen has been collected during the recent floods in 2011 and environmental watering event in 2015-16.

The wetland pH is relatively neutral with most of the monitoring site record sitting within the EPA guidelines of 6.5 to 8.5. Inflows of irrigation water to Johnson Swamp maintains a freshwater environment, however as the water levels fall the salinity can exceed 3,000 EC.

Turbidity in the wetland is variable ranging from 20 NTU to 500 NTU. All of the turbidity readings exceed EPA guidelines of 15 NTU (EPA 2010). Dissolved oxygen levels in the wetland are low with readings below 3 mg/L for 50 percent of the monitoring record.Table 6 summarises the results of spot water quality monitoring.

**Table 6. Maximum and minimum water quality records for Johnson Swamp (2011 and 2015-16 wet periods)**

| Record | pH | Salinity (EC) | Turbidity (NTU) | Dissolved Oxygen (mg/L) |
|---|---|---|---|---|
| Maximum | 6.75 | 3,000 | 500 | 6.21 |
| Minimum | 8.99 | 684 | 20 | 1.8 |

# 4. Values

## 4.1. Listings

Johnson Swamp is an internationally important wetland being part of the Kerang Wetlands Ramsar site and also being listed under the Directory of Important Wetlands (KBR 2011; Environment Australia 2001). At the time of listing, the wetland contributed to five of the Ramsar Convention criteria that are supported by the larger Kerang Wetlands Ramsar site. It is recognised predominately for its habitat value for waterbirds; specifically providing feeding and breeding habitat supporting a high abundance of waterfowl species (see Section 4.8). Of particular note is the large number of threatened flora and fauna species, including the *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999 a*nd International Union for Conservation of Nature (IUCN) red listed Australasian bittern (*Botaurus poiciloptilus*) in which the wetland regularly supports at least one percent of the individuals in the flyway[2] population (Butcher 2016).

Table 7 details the national and state conversation legislation and international treaties and agreements that are relevant to Johnson Swamp. A full list of fauna and flora recorded at Johnson Swamp is in Appendix 5 and Appendix 6.

**Table 7. Significance of Johnson Swamp and its associated species**

| Legislation, Agreement or Convention | Jurisdiction | Listed |
|---|---|---|
| Ramsar Convention on Wetlands | International | ✓ |
| Japan Australia Migratory Birds Agreement (JAMBA) | International | ✓ |
| China Australia Migratory Birds Agreement (CAMBA) | International | ✓ |
| Republic of Korea Australia Migratory Birds Agreement (ROKAMBA) | International | ✓ |
| Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) | International | ✓ |
| *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* | National | ✓ |
| *Flora and Fauna Guarantee Act 1988 (FFG Act)* | State | ✓ |
| DELWP advisory lists | State | ✓ |

## 4.1. Water dependent environmental values

### 4.1.1. Fauna

Sixty-six waterbirds, seven amphibians and one water dependent reptile species have been recorded at Johnson Swamp. Of the waterbird species recorded, twenty-eight are listed as significant with nine, including Latham's snipe (*Gallinago hardwickii*), marsh sandpiper (*Tringa stagnatilis*), red-necked stint (*Calidris ruficollis*), sharp-tailed sandpiper (*Calidris acuminata*), common greenshank (*Tringa nebularia*) and wood sandpiper (*Tringa glareola*) protected under at least one migratory agreement (Table 9). These species visit Australia in their non-breeding season (Rogers and Ralph 2011) and have been recorded foraging in the productive shoreline habitat of Johnson Swamp, in particular the margins of the Aquatic Herbland zone (see Section 4.1.2), during wet periods (Rakali 2015).

When inundated, the dense beds of reeds and rushes at Johnson Swamp also provide habitat for a breeding population of the EPBC and *Flora and Fauna Guarantee* (FFG) *Act 1988* listed species Australasian bittern (*Botaurus poiciloptilus*) (Table 9). This population is of particular note representing one percent of the flyway population (Butcher 2016). In November 2015 up to twenty individuals where recorded using the wetland. In the months following, a number of nests and juveniles were observed at the wetland (Rakali 2016) (Plate 1). Over the past twenty years the species has frequently been observed at Johnson and Hird swamps (S. Starr [Birdlife Australia] 2016, pers. comm. 1 August), suggesting a high degree of site fidelity in the region. The FFG listed

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[2]A flyway is the entire range of a migratory bird species (or groups of related species or distinct populations of a single species) through which it moves on an annual basis from the breeding grounds to non-breeding areas, including intermediate resting and feeding places as well as the area within which the birds migrate.

Australian little bittern (*Ixobrychus dubius*) was also recorded breeding during the 2015-16 watering event at Johnson Swamp (Plate 1). Similar to Australasian bittern, the Australian little bittern camouflages itself within dense vegetation foraging mainly at night on insects, snails, yabbies, frogs and other small birds and mammals (Birdlife Australia 2016a). Although not recorded, it is also probable that Johnson Swamp supports the EPBC listed Australian painted snipe (*Rostratula australis*), a species also previously recorded at neighbouring Hird Swamp (Birdlife Australia (2016a).

**Plate 1. Left: Australasian bittern 23 March 2016 (D. Cook, Rakali Ecological Consulting). Right: Juvenile Australian little bittern 29 February 2016 (D. Cook, Rakali Ecological Consulting).**

The open water and mudflat zones of Johnson Swamp support at least seven other FFG listed waterbird species including the endangered blue-billed duck (*Oxyura australis*), freckled duck (*Stictonetta naevosa*) and intermediate egret (*Ardea intermedia*) as well as the vulnerable eastern great egret (*Ardea modesta*) and brolga (*Grus rubicunda*). Johnson Swamp is of particular importance to the local brolga population, with the species being recorded in almost all surveys since the mid-1990s. In March 2016 the wetland supported a group of fourteen individuals, a flock size considered to be one of the largest observed in the Kerang region in recent years (D. Cook [Rakali Ecological Consulting] 2016, pers comm., 29 March). Brolga benefit from the high biomass of food resources at Johnson Swamp, and use the ample supply of nesting material including grasses, sedges and reeds. Nests and juveniles have been observed on numerous occasions including during the recent 2015-16 watering event (Plate 2) (Rakali 2015). Table 8 shows the most recent recorded waterbird breeding events at Johnson Swamp.

**Plate 2. Left: Brolga nest and eggs 25 November 2015 (D. Cook, Rakali Ecological Consulting). Right: Brolga at Johnson Swamp 25 November 2015 (D. Cook, Rakali Ecological Consulting).**

**Table 8. Most recent waterbird breeding events at Johnson Swamp**

| Common Name | Scientific Name | year of record | Data Source |
|---|---|---|---|
| Australasian Bittern* | *Botaurus poiciloptilus* | 2016 | Rakali 2015 |
| Australian Little Bittern* | *Ixobrychus dubius* | 2016 | Rakali 2015 |
| Australian Shelduck | *Tadorna tadornoides* | 2000 | BirdLife Australia 2016a |
| Australian Wood Duck | *Chenonetta jubata* | 2000 | BirdLife Australia 2016a |
| Black Swan | *Cygnus atratus* | 2006 | BirdLife Australia 2016a |
| Brolga* | *Grus rubicunda* | 2015 | Rakali 2015 |
| Great Crested Grebe | *Podiceps cristatus* | 2005 | BirdLife Australia 2016a |
| Grey Teal | *Anas gracilis* | 2005 | BirdLife Australia 2016a |
| Masked Lapwing | *Vanellus miles* | 2000 | BirdLife Australia 2016a |

| Common Name | Scientific Name | year of record | Data Source |
|---|---|---|---|
| Pacific Black Duck | *Anas superciliosa* | 2000 | BirdLife Australia 2016a |
| Red-kneed Dotterel | *Erythrogonys cinctus* | 2006 | BirdLife Australia 2016a |
| Sacred Kingfisher | *Todiramphus sanctus* | 2001 | BirdLife Australia 2016a |
| White-faced Heron | *Egretta novaehollandiae* | 2000 | BirdLife Australia 2016a |
| **Key:** *Denotes threatened species see Table 9 | | | |

Johnson Swamp also regularly supports a significant number for other waterbird species, including thousands of grey teal (*Anas gracilis*), Eurasian coot (*Fulica atra*), pink-eared duck (*Malacorhynchus membranaceus*), pacific black duck (*Anas superciliosa*) and straw-necked ibis (*Threskiornis spinicollis*) as well as vulnerable hardhead (*Aythya australis*), Australasian shoveler (*Anas rhynchotis*) and near threatened whiskered tern (*Chlidonias hybrida*). A number of the duck species recorded in high numbers are listed game species in Victoria.

The diverse habitat of Johnson Swamp supports a number of amphibian species and the state listed eastern-long necked turtle (*Chelodina longicollis*) which breeds at the wetland. The majority of frog species recorded are considered generalists, being found in waterbodies that retain water for short (i.e. < 3-6 months) to long (or permanent) periods of time (Ralph and Rogers 2011). In 1982, the vulnerable EPBC and FFG listed growling grass frog (*Litoria raniformis)* was recorded at the wetland (VBA 2016). This species has a habitat preference for emergent, submergent and floating native plants in fringing wetland zones and would have been abundant historically at Johnson Swamp and neighbouring Hird Swamp. However due to a range of factors including habitat loss and drought impacts, this once common and wide spread species is presumed lost from the region. Known populations of the species are now isolated in scattered localities particularly in north-western and south-western Victoria (Clemann and Gillespie 2012), with only two records of the species since 1982 within a 40 kilometre radius of Kerang (recorded in 2008 in Murrabit West and in 2004 on the No. 5 Channel near Capels Crossing, some 14 kilometres north of Kerang (Clemann et al. 2013; Smith et al. 2008). Table 9 shows the significant water dependent fauna species that have been recorded at Johnson Swamp.

**Table 9. Significant water dependent fauna species recorded at Johnson Swamp**

| Common Name | Scientific Name | last record | International treaty | EPBC status | FFG status | DELWP status |
|---|---|---|---|---|---|---|
| **Waterbirds** | | | | | | |
| Australasian Bittern | *Botaurus poiciloptilus* | 2016 | | EN | L | EN |
| Australasian Shoveler | *Anas rhynchotis* | 2016 | | | | VU |
| Australian Little Bittern | *Ixobrychus dubius* | 2016 | | | L | EN |
| Baillon's Crake | *Porzana pusilla palustris* | 2015 | | | L | VU |
| Blue-billed Duck | *Oxyura australis* | 2016 | | | L | EN |
| Brolga | *Grus rubicunda* | 2016 | | | L | VU |
| Cattle Egret | *Ardea ibis* | 2002 | C, J | M | | |
| Common Greenshank | *Tringa nebularia* | 2006 | B, C, J, R | M | | VU |
| Eastern Great Egret | *Ardea modesta* | 2016 | C, J | M | L | VU |
| Freckled Duck | *Stictonetta naevosa* | 2016 | | | L | EN |
| Glossy Ibis | *Plegadis falcinellus* | 2016 | B, C | M | | NT |
| Hardhead | *Aythya australis* | 2016 | | | | VU |
| Intermediate Egret | *Ardea intermedia* | 2014 | | | L | EN |
| Latham's Snipe | *Gallinago hardwickii* | 2016 | B, C, J, R | M | N | NT |
| Marsh Sandpiper | *Tringa stagnatilis* | 2016 | B, C, J, R | M | | VU |
| Musk Duck | *Biziura lobata* | 2016 | | | | VU |
| Nankeen Night Heron | *Nycticorax caledonicus* | 2016 | | | | NT |
| Pied Cormorant | *Phalacrocorax varius* | 2014 | | | | NT |
| Red-necked Stint | *Calidris ruficollis* | 2006 | B, C, J, R | M | | |
| Royal Spoonbill | *Platalea regia* | 2016 | | | | NT |
| Sharp-tailed Sandpiper | *Calidris acuminata* | 2016 | B, C, J, R | M | | |
| Whiskered Tern | *Chlidonias hybrida* | 2016 | | | | NT |

| Common Name | Scientific Name | last record | International treaty | EPBC status | FFG status | DELWP status |
|---|---|---|---|---|---|---|
| White-bellied Sea-Eagle | *Haliaeetus leucogaster* | 2016 | C | | L | VU |
| White-winged Black Tern | *Chlidonias leucopterus* | 2005 | | | | NT |
| Wood Sandpiper | *Tringa glareola* | 2006 | B, C, J, R | M | | VU |
| **Other** | | | | | | |
| Eastern long-necked turtle | *Chelodina longicollis* | 2015 | | | | DD |
| Growling Grass Frog | *Litoria raniformis* | 1982 | | VU | L | EN |

**Key:**
**International treaty**: B= Bonn, C= CAMBA, J= JAMBA, R= ROKAMBA
**EPBC status**: M= Migratory species, EN= endangered, VU= vulnerable
**FFG status**: L= Listed as threatened
**DELWP status**: EN= endangered, VU= vulnerable, NT= near threatened, DD= data deficient
**Source**: Australian Ecosystems 2012; Rakali 2014a; Rakali 2014b, Rakali 2015; Rakali 2016; DELWP 2015b; DELWP 2016a; VBA 2016; Ermaea eBirds 2016

### 4.1.2. Vegetation communities and flora

Five water dependent Ecological Vegetation Classes (EVCs) have been recorded at Johnson Swamp as mapped in Appendix 7 (Rakali 2014a). The status of these are summarised in Table 10 with photographs of each EVC shown in Plate 3.

Riverine Chenopod Woodland (EVC 103) is present at the eastern border of Johnson Swamp east and a small, small area of reserve on either side of the Pyramid Creek at the entry and exit to the wetland. This EVC is located on the higher alluvial terraces (>78.5 m AHD) of the wetland and is characterised by a relatively healthy canopy of black box with a shrubby undestorey of species such as nitre goosefoot (*Chenopodium nitrariaceum*), tangled lignum (*Duma florulenta*), hedge saltbush (*Rhagodia spinescens*) and berry saltbush (*Atriplex semibaccata*). In Johnson Swamp east, this zone transitions into Intermittent Swampy Woodland (EVC 813) at elevations below 77.2 m AHD. This EVC, which is also found as small isolated pockets (< 0.1 hectares in size) on a number of artificial islands in Johnson Swamp West, would have historically extended across much of the wetland area. All of the large, old black box and river red gum (*Eucalyptus camaldulensis*) trees characteristic of this EVC, have now drowned although there are patches of significant river red gum regeneration, most likely from the 2010-11 floods. This EVC supports the highest diversity of threatened plant species including FFG listed winged water-starwort (*Callitriche umbonata*) and rare branching groundsel (*Senecio cunninghamii var. cunninghamii*), brown beetle-grass (*Leptochloa fusca subsp. fusca*) as well as floodplain fireweed (*Senecio campylocarpus*). It has also been the focus of species enrichment planting and now supports FFG listed ridged water-milfoil (*Myriophyllum porcatum*), river swampy wallaby-grass (*Amphibromus fluitans*), wavy marshwort (*Nymphoides crenata*) and stiff groundsel (*Senecio behrianus*) (Rakali 2015). The western boundary of Johnson Swamp, at elevations above 79.2 m AHD, supports a small 0.5 hectare patch of Lignum Shrubland (EVC 808). This EVC supports a relatively open cover of tangled lignum and herbaceous ground-layer.

At elevations below 77.85 m AHD, the vegetation composition transitions into Lignum Swampy Woodland (EVC 823), which is also characterised by a black box overstorey and tangled lignum understory, although the lignum is more robust and relatively dense. River red gum and eumong (*Acacia stenophylla*) trees are also present. This zone typically represents the shallow edges of the wetland and can be broken into four health zones (refer to Appendix 7):

- Zone 1: occurs in an isolated patch at the south end of Johnson Swamp East and bordering the northern side of the natural inlet of Pyramid Creek into Johnson Swamp West, has a relatively healthy canopy and shrub-layer although low in species diversity when compared to a healthy representative of this EVC.
- Zone 2: is mainly found along the southern west border of Johnson Swamp West and in the northern tip of Johnson Swamp East, has a dead black box canopy and a highly degraded undestorey layer.

- Zone 3: sits on the border between Lignum Swampy Woodland and Lake Bed Herbland (EVC 107) and/ or Tall Marsh (EVC 821), is similar to Zone 2 although heavily invaded by cumbungi.
- Zone 4: an isolated patch in the northern portion of Johnson Swamp East has been recently burnt and contains low indigenous species diversity and high weed cover.

Photo 1: Riverine Chenopod Woodland (EVC 103)
(North Central CMA, February 2009)

Photo 2: Intermittent Swampy Woodland (EVC 813)
(Rakali Ecological Consulting, October 2015)

Photo 3: Lignum Shrubland (EVC 808)
(Rakali Ecological Consulting, October 2015)

Photo 4: Lignum Swampy Woodland (EVC 823)
(Rakali Ecological Consulting, October 2015)

Photo 5: Tall Marsh (EVC 821)
(North Central CMA, November 2015)

Photo 6: Aquatic Herbland (EVC 653)
(North Central CMA, February 2016)

Photo 7 and 8: Aquatic Herbland (EVC 653) species (Rakali Ecological Consulting, October 2015)

**Plate 3. Vegetation communities of Johnson Swamp**

Below 77.85 m AHD, trees become sparser. The bed of the wetland contains dense stand of Tall Marsh (EVC 821) and small area of open water containing Aquatic Herbland (EVC 653), which alternates with Lake Bed Herbland (EVC 107) when the wetland is dry. The Tall Marsh component is mainly confined to the more elevated areas of this zone, and contains dead river red gum and black box trees, lignum and an extensive monoculture of cumbungi and common reed (*Phragmites australis*) which is encroaching into open water and Aquatic Herbland zone. The Aquatic Herbland zone has a much higher diversity of native species including flood responsive common nardoo (*Marsilea drummondii*), coarse water-milfoil (*Myriophyllum caput-medusae*) and common blown-grass (*Lachnagrostis filifolia s*.l.) (Refer to photo 6 in Plate 3). When dry this zone supports species such as pale knotweed (*Persicaria lapathifolia*), sprawling saltbush (*Atriplex suberecta*) and native liquorice (*Glycyrrhiza acanthocarpa*) (Rakali 2014a; Rakali 2014b). Table 11 summarises the significant water dependent flora species recorded at Johnson Swamp. A conceptualisation of the EVCs across the wetland is also given in Figure 5.

**Table 10. Description and conservation status of water dependent EVCs at Johnson Swamp**

| EVC no. | EVC name | Area of EVC (ha) | Bioregional conservation status | |
|---|---|---|---|---|
| | | | Victorian Riverina | Murray Fans |
| 103 | Riverine Chenopod Woodland | 37.5 | VU | EN |
| 653/ 107 | Aquatic Herbland/ Lake Bed Herbland | 208.9 | EN/ D | VU/ VU |
| 808 | Lignum Shrubland | 0.5 ha | EN | EN |
| 813 | Intermittent Swampy Woodland | 25.4 | EN | EN |
| 821 | Tall Marsh | 50.65 | D | LC |
| 823 | Lignum Swampy Woodland | 129.6 | VU | VU |

**Key:**
**Bioregional conservation status**: EN: endangered, VU: vulnerable, D: depleted, LC: least concern
**Source:** Frood and Papas 2016; Rakali 2014a; DELWP 2015a

**Table 11. Significant water dependent flora species recorded at Johnson Swamp**

| Common Name | Scientific Name | Type | Last record | EPBC status | FFG status | DELWP status | EVC within |
|---|---|---|---|---|---|---|---|
| Branching Groundsel | *Senecio cunninghamii var. cunninghamii* | AM | 2015 | | | r | 813 |
| Brown Beetle-grass | *Leptochloa fusca subsp. fusca* | AM | 2015 | | | r | 823, 813 |
| Floodplain Fireweed | *Senecio campylocarpus* | D | 2015 | | | r | 813 |
| Ridged Water-milfoil+ | *Myriophyllum porcatum* | AM | 2015 | vu | L | v | 813 |
| River Swamp Wallaby-grass+ | *Amphibromus fluitans* | AM | 2015 | vu | L | | 813 |
| Salt Paperbark+ | *Melaleuca halmaturorum subsp. halmaturorum* | AM | 2012 | | L | v | 103 |
| Stiff Groundsel+ | *Senecio behrianus* | AM | 2015 | en | L | e | 813 |
| Water Nymph+ | *Najas tenuifolia* | OA | 2015 | | | r | 813 |
| Wavy Marshwort+ | *Nymphoides crenata* | AM | 2015 | | L | v | 813 |
| Winged Water-starwort | *Callitriche umbonata* | AM | 2015 | | L | r | 813 |

**Key:**
**Type**: AM= amphibious, D= dampland, OA= obligate aquatic
**EPBC status**: en= endangered, vu= vulnerable
**FFG status**: L= Listed as threatened
**DELWP status**: e= endangered, v= vulnerable, rare= rare
**+**= Planted. N.B. with the exception of salt paperbark all threatened species planting was undertake in October and November 2015
**Source**: Australian Ecosystems 2012; Rakali 2014a; Rakali 2014b, Rakali 2015; Rakali 2016; VBA 2016

## 4.2. Terrestrial environmental values

A number of threatened terrestrial flora and fauna species have been recorded during the dry phase or within the woodland zones of Johnson Swamp. A number of the fauna species are reliant on water dependent vegetation (i.e. living and dead river red gums for feeding, nesting and roosting) whilst others utilise the wetland as a watering point when it is inundated. Some of these terrestrial species provide important resources for water dependent species including food sources (i.e.

reptiles, small mammals, terrestrial plant material and vantage points for foraging raptors) and habitat for supporting critical life history stages of water-dependent species (i.e. nesting habitat). Although not directly influenced by the water regime, these species are considered an important aspect of the overall biodiversity of Johnson Swamp.

### 4.2.1. Fauna

Johnson Swamp supports at least eighty-five terrestrial native birds, four mammals and three reptile species. Six of these species are listed as significant including the near threatened brown treecreeper (*Climacteris picumnus victoriae*) and brown quail (*Coturnix ypsilophora*) as well as FFG listed carpet python (*Morelia spilota metcalfei)*. Table 12 summarises the significant terrestrial fauna species recorded at Johnson Swamp.

**Table 12. Significant terrestrial fauna species recorded at Johnson Swamp**

| Common Name | Scientific Name | Type | last record | International status | EPBC status | FFG status | DELWP status |
|---|---|---|---|---|---|---|---|
| Black-eared Cuckoo | *Chalcites osculans* | TB | 2005 | | | | NT |
| Brown Quail | *Coturnix ypsilophora* | TB | 2016 | | | | NT |
| Brown Treecreeper | *Climacteris picumnus victoriae* | TB | 2000 | | | | NT |
| Carpet Python | *Morelia spilota metcalfei* | R | 2001 | | | L | EN |
| Grey-crowned Babbler^ | *Pomatostomus temporalis* | TB | 2001 | | | L | EN |
| White-throated Needletail | *Hirundapus caudacutus* | TB | 2016 | | | | VU |

**Key:**
**Type**: TB= terrestrial bird, R= reptile
**FFG status**: L= Listed as threatened
**DELWP status**: EN= endangered, VU= vulnerable, NT= near threatened
**^**denotes breeding at the site
**Source**: Australian Ecosystems 2012; Rakali 2014a; Rakali 2014b, Rakali 2015; Rakali 2016; DELWP 2015b; DELWP 2016a; VBA 2016; Ermaea eBirds 2016

### 4.2.2. Vegetation communities and flora

There has been no terrestrial EVC mapping at Johnson Swamp. The wetland however supports at least twenty-five native terrestrial plant species including the poorly known black roly-poly (*Sclerolaena muricata*) observed in the Lignum Swampy Woodland and Riverine Chenopod Woodland EVC zones. Table 13 summarises the significant terrestrial flora species recorded at Johnson Swamp.

**Table 13. Significant terrestrial flora species recorded at Johnson Swamp**

| Common Name | Scientific Name | Type | Last record | EPBC status | FFG status | DELWP status | EVC within |
|---|---|---|---|---|---|---|---|
| Black Roly-poly | *Sclerolaena muricata* | T | 2015 | | | k | 823, 103 |

**Key:**
**Type**: T= terrestrial
**DELWP status**: k: poorly known
**Source**: Australian Ecosystems 2012; Rakali 2014a; Rakali 2014b, Rakali 2015; Rakali 2016; DELWP 2015b; VBA 2016

## 4.3. Wetland type depletion and rarity

Johnson Swamp is classified as a temporary freshwater marsh under the 2013 Victorian Wetland Classification framework and a deep freshwater marsh under the former Corrick and Norman classification. Deep freshwater marsh is considered a depleted wetland type with up to 82 percent of the total pre-European area now lost. This is primarily due to drainage to increase agricultural productivity for grazing and/ or cropping (DNRE 1997). Under the classification of temporary freshwater marsh, Johnson Swamp contributes less than one percent of the total wetland area, with the exception of the Murray Fans bioregion were it represents twelve percent of the total area of this wetland type. Table 14 illustrates the area, proportion, depletion and rarity of each wetland type across the various defined landscapes.

**Table 14. Area, depletion and rarity of wetland classifications in the region**

| Region | Corrick and Norman classification Deep freshwater marsh | | | | Current classification temporary freshwater marsh | |
|---|---|---|---|---|---|---|
| | Pre-European area (ha) | Current area (ha) | Reduction (%) | Wetland contribution to current area (%) | Current area (ha) | Wetland contribution to current area (%) |
| Victoria | 176,044 | 54,360 | 31 | 0.7 | 224,456 | 0.18 |
| North Central catchment | 10,526 | 4,880 | 46 | 8.2 | 153,024 | 0.26 |
| Loddon catchment | 8,361 | 3,753 | 44 | 10.7 | 114,083 | 0.35 |
| Victoria Riverina bioregion[1] | 8,784 | 3,687 | 42 | 9.5 | 42,589 | 0.82 |
| Murray Fans bioregion[1] | 470 | 384 | 82 | 13 | 416 | 12.02 |

[1] Approximately 350 ha of Johnson Swamp is located within the Victorian Riverina bioregion and the remaining 50 hectares is within the Murray Fans bioregion. These areas have been used when assessing the contribution of the wetland to this bioregion.

## 4.4. Ecosystem function

Ecosystem functions are activities or actions which occur naturally in wetlands as a product of the interactions between the ecosystem structure and processes. Functions as defined by Ramsar include flood water control, nutrient, sediment and contaminant retention, food web support, shoreline stabilisation and erosion controls, storm protection and stabilisation of local climatic conditions, particularly rainfall and temperature (Ramsar Convention 2012). Functions relate to the structural components of an ecosystem (i.e. vegetation, water, soil, atmosphere and biota) and how they interact with each other, within ecosystems (i.e. site specific) and across ecosystems (i.e. landscape) (Maynard et al. 2012). This includes processes that are essential for maintaining life such as storage, transport and nutrient cycling as well as the provision of resources that support biodiversity such as habitat, food and shelter.

The Loddon River floodplain was once characterised by a diversity of wetland types however hydrological change through land clearing, farming activities and river regulation has significantly reduced the diversity and abundance of wetlands across the region. Johnson Swamp is of one of only a handful remaining wetlands that continues to provide a variety of wetland habitats from fringing river red gum and black box, lignum, reed, rushes, aquatic herbs, open water and associated mudflats. These habitats provide the necessary resources to support the different life cycle stages of a diversity and abundance of fauna species including waterbirds, frogs and turtles.

Further, although now watered through the irrigation system, Johnson Swamp is still linked to its natural flow path through input of water originating from Kow Swamp. There is also the potential to release water back into Pyramid Creek via the outlet structure located on the eastern side of the wetland. Although artificial, this water exchange has the potential to provide carbon, nutrients, seeds, macroinvertebrates and other propagules between the upper and lower Pyramid Creek catchment and the wetland, closing an important landscape scale ecosystem loop.

These functions not only contribute to the wider Pyramid Creek catchment and Kerang Wetlands Ramsar site but also the North Central CMA region.

Table 15 broadly shows the ecosystem functions, processed and services provided by Johnson Swamp from a local, regional and international scale (specifically migratory waterbird species).

**Table 15. Ecosystem processes, function and services of Johnson Swamp from a local, regional and international scale**

| Local | Regional | International |
|---|---|---|
| • **Convert matter to energy for uptake by biota**- primary producers fix carbon that then sustains the food web, either directly by ingestion of plant material of indirectly by the detrital cycle.<br>• **Provide shade and shelter for biota**- this includes amelioration of extremes in temperature, sunlight exposure and wind as well as protection from predators.<br>• **Provision of water for consumption** - retention and storage of water for use by biota to enhance growth and development and to ensure survival and reproduction.<br>• **Reproduction-** recruitment of new individuals requires sufficient shelter from predators, food for growth, resources for nest building and cues for breeding (i.e. water level changes, temperature, rainfall etc.). Adequate resources to support juveniles are also required, including shelter, food and provision of water for consumption. Plants also require specific germination and growth conditions (including flood cues, follow up flooding, drying etc.) to ensure successful recruitment. | • **Movement/ dispersal**- Johnson Swamp provides an avenue for movement of individuals which is required as part of the life cycle of some species (i.e. migration). Movement is important for maintaining genetic diversity within the landscape; it reduces the risk of local species extinction and assists with recolonisation.<br>• **Cycle nutrients and store carbon**- important for essential ecological processes such as respiration and carbon sequestration.<br>• **Population persistence**- a number of species require specific habitat components to breed. With a dramatic reduction in the area of shallow freshwater marsh in the landscape, the population of species such as brolga are aging, which results in reduced fecundity and recruitment.<br>• **Biological diversity**- the provision of a sufficient number and range of habitat types in the landscape supports a diversity of native species. This in turn assists to safe guard the region from the impacts of local catastrophic events (i.e. loss of habitat through fire and clearing) due to there being sufficient alternative habitats available. This supports the maintenance of genetic and species diversity in the region. | • **Flyway for migratory waterbirds**- During migration, waterbirds rely on a chain of highly productive wetlands to rest and feed, building up sufficient energy to fuel the next phase of their journey. Generally, these species migrate from their breeding areas in north East Asia, to their feeding grounds in Australia and New Zealand for the southern hemisphere summer. |
| Note: The above ecosystem services are particularly important for species with low or restricted mobility. | | |

The Murray-Darling Basin Plan specifies the need to 'identify priority environmental assets and priority ecosystem functions, and their environmental watering requirements' (Australian Government 2012). Section 8.50 of the Basin Plan outlines the method for identifying ecosystem functions that require environmental watering and their environmental watering requirements (Schedule 8 – Criteria for identifying and environmental asset and Schedule 9—Criteria for identifying an ecosystem function). As part of a Ramsar site, Johnson Swamp meets criterion 1 as a priority asset, as well as several other criteria as shown in Appendix 8.

## 4.5. Social and economic values

### 4.5.1. Cultural heritage

Johnson Swamp is located on Barapa Barapa country which extends south-west to Boort, north-east to Murrabit, east to Kow Swamp and south-west to Mitiamo. The land has sustained Barapa Barapa people for tens of thousands of years and is considered one of the most archaeologically important areas of Victoria (VACL 2016). In particular the Pyramid Creek corridor and floodplain contains a high density of archaeological sites, predominately oven mounds and scarred trees. Like other wetlands on Barapa Barapa country, pre-settlement flows cannot be reinstated; however regimes that mimic natural flows can provide or enhance ecosystem services that support cultural values and associations.

Johnson Swamp has fourteen sites of cultural sensitivity registered with Aboriginal Affairs Victoria. These sites are predominately mounds, artefact scatters and scar trees and are located around the margins of the wetland indicating its use for camping and resource gathering during wet phases. The wetland itself is noted to provide an array of food resources including plants, seeds, tublers, mussels, eggs, fish as well as medicinal plants and resources for shelter and tools. This is supported by the discovery of turtle and fish bones as well as quartz pieces (indicating tool usage) at a damaged mound during the EWMP site visit on the 20 July 2016. For present day Barapa Barapa people, Johnson Swamp continues to hold special significance through its ample supply of cultural resources, spiritual and ancestral connections, physical and intangible values and opportunities to learn more and be involved in on-ground natural resource management (see Appendix 1).

#### 4.5.2. Recreation

Recreational values at Johnson Swamp are passive and active recreational activities. Passive recreational pursuits include wildlife observation (i.e. Field Naturalist Club and bird watchers) and picnicking when there is water in the wetland.

Johnson Swamp is a State Game Reserve and open to hunting during an open season (generally March to June each year). Bag limits exist in Victoria for game deer, duck and quail with Parks Victoria and the Game Management Authority responsible for regulating hunting activity in Victoria to ensure the sustainable management of game species. Under the *Wildlife Act 1975*, wetlands can be closed to duck hunting on occasion to protect late-breeding waterbirds from disturbance, when there are significant numbers of threatened non-game birds (i.e. freckled duck) or to provide refuge to waterbirds and game species during periods of drought.

Pyramid Creek is a high valued recreation area for fishing, particularly in the lower reaches near Kerang and near the outfall of Kow Swamp (Box Creek). The *Native Fish Recovery Plan - Gunbower and Lower Loddon* of which Pyramid Creek is part, identifies additional works (including infrastructure, instream habitat, riparian revegetation etc.) to increase the native fish diversity and abundance by with the long term vision of a fully recovered, resilient and self-sustaining native fish population.

#### 4.5.3. Economic

The Torrumbarry Irrigation Area is a valuable and highly productive irrigation area comprising dairy, pasture, beef, sheep and irrigated horticulture.The actual economic value of Johnson Swamp to the regional economy is difficult to measure and for the purpose of this EWMP, a general discussion of the economic benefit of wetlands is provided, based on the Australian Conservation Foundation (ACF) (2010).

There are direct and indirect uses of wetlands which generate economic benefit on a local, regional and wider scale. Direct use of Johnson Swamp include recreational and cultural tourisms while indirect uses include ecosystem services such as groundwater discharge, flood mitigation, nutrient treatment and carbon storage (ACF 2010). In 2013, the economic contribution of sustainable hunting (including pest animals) to the Gannawarra Local Government Area was estimated at $10.4 million with $3.3 million of this attributed to duck hunting. Sustainable hunting was estimated to have generated 1.6 per cent of the Shire’s total economy in 2013 and resulted in $8.9 million in expenditure in the township of Kerang alone (DEPI 2013b).

### 4.6. Ecological condition and threats

The hydrological changes described in Section 3 have resulted in a decline in the condition of Johnson Swamp with the most notable changes being the death of canopy trees, invasion of reeds and sedges and a reduction in native species diversity. The following section describes the results of a number of assessments used to describe the current condition of Johnson Swamp.

### 4.6.1. Current condition

**Index of Wetland Condition**

In 2012 and 2014, a partial Index of Wetland Condition (IWC) assessment was undertaken at Johnson Swamp to assess the biota sub-indices only (Australian Ecosystems 2012; Rakali 2014a). The wetland was in a dry phase during both assessments. The biota sub-index is based on assessing the individual EVC/zones of the wetland compared to the wetlands presumed pre-1750s benchmark (traditional IWC methodology) and is made up of four components; critical lifeforms, weeds, indicators of altered processes and vegetation structure and health. A full IWC assessment which also considers physical form, hydrology, water properties and soil sub-indices, has not been undertaken at Johnson Swamp to date.

The biota sub-indices scored 'very poor' for both the 2012 and 2014 assessments at 5.37 and 6.50 out of 20 respectively. The slight improvement noted in the 2014 score is likely attributed to a reduction in weed cover, the result of drier climatic conditions compared to when the first survey was completed (just post 2010-11 floods). Both assessments noted a significant loss in original tree canopy, with areas of low indigenous species diversity, high weediness and the proliferation of cumbungi. Table 16 summarises the results of the biota sub-index assessment for Johnson Swamp in 2012 and 2014. The pre-European EVCs are shown in Appendix 7.

**Table 16. IWC biota sub-index scores for Johnson Swamp in 2012 and 2014 using the standard IWC methodology**

| EVC name and number | 2012 IWC assessment | | | | 2014 IWC assessment | | | |
|---|---|---|---|---|---|---|---|---|
| | sub-index score (out of 20) | % of wetland | Result (score x %) | condition category | sub-index score (out of 20) | % of wetland | Result (score x %) | condition category |
| Riverine Chenopod Woodland (EVC 103) | 12.53 | 2 | 0.25 | Poor | Not assessed | | | |
| Intermittent Swampy Woodland (EVC 813)[1] | 4.48 | 63 | 2.82 | Very poor | 5.168 | 68.1 | 3.994 | very poor |
| Lignum Shrubland (EVC 808) | 14.78 | 2 | 0.29 | Moderate | 14.73 | 0.12 | 0.02 | Moderate |
| Lignum Swampy Woodland (EVC 823)[1] | 6.1 | 33 | 2.01 | Very poor | 7.44 | 31.78 | 2.45 | very poor |
| **IWC score** | **-** | **-** | **5.37** | **Very poor** | **-** | **-** | **6.5** | **Very poor** |

**Key:**
[1] In the 2014 assessment, EVC 813 and EVC 823 were divided into five and into four zones, respectively, based on health (see Section 4.1.2 for description). Each zone was scored separately with the average used to provide a score in the above table.
**Source:** Australian Ecosystems 2012; Rakali 2014a

The biota sub-index was also assessed in 2014 using a non-standard IWC methodology which compares the current EVC form against a benchmark of an undisturbed and intact example of the same EVC. This was undertaken to recognise the value that some vegetation communities provide, even though they may be the direct result of major human-induced disturbance. For Johnson Swamp, this assessment revealed a poor IWC biota score of 10.2, with particularly low scores given to critical life forms and vegetation structure and health in EVCs with zone 3 and 4 delineations (see Appendix 7). The Intermittent Swampy Woodland (EVC 813) and Lignum Swampy Woodland (EVC 823) zones were considered to be in the poorest condition, again impacted significantly by changed hydrology and salinisation (Rakali 2014a). Table 17 summarises the results of the non-standard EVC methodology for Johnson Swamp biota in 2014 including a general description of the condition of each EVC. Appendix 9 shows details the full biota IWC results for each EVC, including scoring for each assessment unit. It is recommended that the non-standard EVC methodology be adopted for the future management of Johnson Swamp; with benchmarks for EWMP objectives to be based on the modified assessments (see Section 5).

**Table 17. IWC biota sub-index scores for Johnson Swamp in 2014 using the non-standard IWC methodology**

| EVC name and number | Zone | sub-index score (out of 20) | Proportion of wetland area (%) | Result (score x proportion) | Condition category | Site description of EVC |
|---|---|---|---|---|---|---|
| Lake Bed Herbland (EVC 107) | 1 | 11.79 | 39 | 4.61 | Poor | EVC formerly consisted of an open tree canopy with the deeper sections naturally treeless. However all trees are now dead with the understorey supporting a mixture of indigenous lake bed species and weeds. |
| | 2 | 11.55 | 11 | 1.29 | Poor | |
| Tall Marsh (EVC 821) | 1 | 13.17 | 12 | 1.61 | Moderate | Dominated by tall emergent graminoids such as cumbungi and common reed which has formed a number of thick species-poor swards. A number of dead river red gum and black box trees are present. |
| Intermittent Swampy Woodland (EVC 813) | 1 | 3.6 | 6 | 0.22 | Very poor | This zone consists of a number of artificial islands that have been revegetated with a combination of non-local native species (i.e. swamp yate) as well as Intermittent Swampy Woodland species. Trees are mostly young and healthy with a relatively high cover of indigenous understorey species, although only a small portion is characteristic of this EVC (the rest being terrestrial). In Johnson Swamp East, this EVC is found in the deepest part of the wetland with all trees and lignum killed by a recent fire. The area of this EVC supports a high cover of weeds and low diversity of indigenous species. |
| | 2 | 11.5 | 0 | 0.01 | Poor | |
| | 3 | 3.85 | 0 | 0.00 | Very poor | |
| Lignum Shrubland (EVC 808) | 1 | 14.73 | 0 | 0.02 | Moderate | Relatively intact zone characterised by an open shrubland of tangled lignum with a groundlayer dominated by grasses and herbs. Few weeds present. |
| Lignum Swampy Woodland (EVC 823) | 1 | 12.92 | 2 | 0.29 | Poor | EVC mainly characterised by dead black box which has been degraded by salinity and/or fire and invaded by a high cover of weeds and cumbungi. A small, slightly higher elevated section bordering Pyramid Creek at the south, has a healthy black box canopy and shrub-layer with low species diversity. |
| | 2 | 7.50 | 15 | 1.10 | Very poor | |
| | 3 | 7.50 | 13 | 1.00 | Very poor | |
| | 4 | 1.84 | 1 | 0.02 | Very poor | |
| **Overall biota score 2014** | | | | **10.2** | **Poor** | |
| Source: Rakali 2014a | | | | | | |

### Tree condition

The condition of twenty-three black box and seven river red gum trees was assessed by Australian Ecosystems in May 2012 using the *Protocol for The Living Murray Tree Condition Assessment of River Red Gum and Black Box* methodology (Souter et al. 2010). Attributes assessed included crown extent and density, leaf new top and epicormic growth, reproduction, leaf die-off, bark cracking and presence of mistletoe infestations. All trees were located alongside the natural drainage line between Pyramid Creek and the south-west of Johnson Swamp.

The average crown extent of the surveyed black box trees was approximately 80 percent (ranged from 50 to 95 percent), which is considered an assessable crown that supports a medium to major extent of live leaves. The remaining black box trees were categorised as supporting medium to maximum crown extent. For river red gum trees, the majority of the sample supported medium to maximum crown extents, with only one tree recording a crown extent of 45 percent. Crown density, which is defined as the percent of skylight blocked by foliated portions of the crown, was considered to be medium to major for approximately 87 percent of the sampled black box trees. For river red gum trees, average crown density was approximately 65 percent indicating a medium to major foliated crown.

Flowering, fruiting, buds and/or capsules, were observed on 70 percent of the sample trees, indicating maintenance growth and/or recovery was occurring. There was also an abundance of seedlings (over 100) present indicating strong recruitment. However epicormic growth was scarce (present, but not readily visible) and new tip growth was largely absent (90 per cent of the sample group). None of the trees exhibited leaf die-off, mistletoe or bark cracking (Australian Ecosystems 2012). A summary of the tree condition assessment at Johnson Swamp is shown in Table 18.

**Table 18. Tree condition assessment for Johnson Swamp (combined results of black box and river red gum)**

| Attribute | Percentage of trees (n=30) (%) | | | |
|---|---|---|---|---|
| | **Absent** | **Scarce** | **Common** | **Abundant** |
| New tip growth | 90% | 10% | 0% | 0% |
| Epicormic growth | 20% | 43.33% | 36.67% | 0% |
| Reproduction | 6.67% | 20% | 3.33% | 70% |
| Leaf die-off | 100% | 0% | 0% | 0% |
| Bark cracking | 100% | 0% | 0% | 0% |
| Mistletoe infestation | 100% | 0% | 0% | 0% |
| **Source**: Australian Ecosystems 2012 | | | | |

Although the tree health assessment undertaken in 2012 suggest that the condition of trees at Johnson is reasonable to good, the assessment does not take into consideration dead trees (some of which are scar trees), which are present in the main basin area of the wetland. As per Section 4.6.1, the death of these trees is due to periods of permanent to near-permanent inundation and or rising groundwater impacts (Rakali 2015).

**Displacement of wetland vegetation communities**

Many of the pre-European wetland EVCs have been displaced as a result of the altered water and salinity regimes. The dominant pre-1750 wetland EVC was most likely Intermittent Swampy Woodland (EVC 813) occurring as a complex with Aquatic Herbland (EVC 653) during wet periods and Lake Bed Herbland (EVC 107) during dry periods. This is indicated by the numerous dead black box and river red gums throughout the wetland bed (Australian Ecosystems 2012; Rakali 2014a). The density of the trees would have varied from very open woodland in the deeper parts of the wetland to open woodland in shallower parts (Rakali 2014). This zone would have been fringed by Lignum Swampy Woodland (823), Riverine Chenopod Woodland (EVC 103) and Lignum Shrubland (EVC 808) on the higher terraces (Rakali 2014a) (see Appendix 7).

At Johnson Swamp some species have benefited from the altered hydrological conditions, including lignum which has now expanded into the deeper areas of the wetland (D. Cook [Rakali Ecological Consulting] 2016, pers comm., 11 July; C. McIntosh [community member] 2016, pers comm., 20 July). Of concern is the dominance of cumbungi that have become abundant to the detriment of species diversity in these areas. While these species provide valuable protection and nesting habitat for wetland waterbirds including the EPBC listed Australasian bittern, they also form dense stands which heavily shade the area beneath them and inhibit the growth of other species. Vegetation mapping undertaken in 2014 using aerial imagery from 2011, noted that approximately 46 per cent of the area of Johnson Swamp was occupied by cumbungi (see Appendix 10). This was attributed to the long period of almost continuous inundation between 1995 and 2006. It was noted during the on ground component of this project, that some of the cumbungi showed signs of die back which was attributed to almost two years of completely dry conditions following the floods of 2010-11. However during the most recent 2015-16 watering event (which was geared at maintaining water levels for breeding waterbirds), dense germination of cumbungi seedlings in the shallower parts of the wetland occurred. This demonstrates the need for strategic management of this species into the future (Rakali 2015).

**Exotic flora and fauna species**

Sixty-six exotic flora species have been recorded at Johnson Swamp, accounting for 36 per cent of all flora species recorded (see Appendix 6) (Rakali 2014a). High threat terrestrial and amphibious species include African box-thorn (*Lycium ferocissimum*), spiny rush (*Juncus acutus subsp. acutus*), willow (*Salix spp.*), variegated thistle (*Silybum marianum*), bathurst burr (*Xanthium spinosum*) and water couch (*Paspalum distichum*). Terrestrial weeds within the bed of the wetland are a lesser concern for management, with wet phases aiding in management (Australian Ecosystems 2012; Rakali 2014a). The distribution of high threat weeds were mapped in 2012 and are shown in Appendix 11. These species have been targeted for management under the *Protecting and Enhancing Priority Wetlands Project* which ran from 2012-2016 and the current *Kerang Priority Wetlands Protection Project.*

A total of thirteen exotic fauna species have been recorded at Johnson Swamp. Exotic mammals include brown hare (*Lepus capenis*), European rabbit (*Oryctolagus cuniculus*), European fox (*Vulpes vulpes*), sheep (*Ovis aries*) and feral pig (*Sus scrofa*). Exotic bird species include European goldfinch (*Carduelis carduelis*), house sparrow (*Passer domesticus*) and common starling (*Sturnus vulgaris*). Deer (*Cervus* spp.) have also recently been sighted at Hird Swamp, suggesting likelihood of movement into Johnson Swamp. As deer are considered a registered game species they do not fall under normal pest animal management (T. Manescu [Game Management Authority] 2016, pers comm., 20 July). In addition five exotic fish species have also been recorded at Johnson Swamp; common carp (*Cyprinus carpio*), eastern gambusia (*Gambusia holbrooki*), goldfish (*Carassius auratus*), tench (*fam. Cyprinidae gen. Tinca*) and redfin (*Carduelis carduelis*) (see Appendix 5).

Although no rabbit warrens were detected during mapping undertaken in 2012, rabbits and foxes are considered the highest threat exotic fauna species at Johnson Swamp. Recent baiting programs has shown poor uptake of both rabbit and fox baits, however visual sightings are common (A. Martins [North Central CMA project manager] pers comm., 2016, 6 May). Rabbits threaten native flora through grazing, prevent the successful recruitment of woody species and disturb soil, including areas of cultural sensitivity, through digging. Foxes pose a threat to waterbirds and other native fauna, particularly through predation of eggs and/ or young (Australian Ecosystems 2012).

### 4.6.2. Condition trajectory – do nothing

Johnson Swamp has undergone dramatic change since European settlement. Historically the wetland was a black box dominated shallow freshwater marsh experiencing relatively frequent, but short, through-flow flooding in response to flows in Pyramid Creek. However the advent of irrigation practices saw periods of almost permanent inundation (i.e. when acting as a freshwater storage) followed by periods of sporadic and often unseasonal filling through channel outfall and other water management decisions. These changes disconnected the wetland from its natural flow source, increased salinity and changed the vegetation composition and values supported by the wetland. Compared to its pre-European benchmark condition, the wetland is now considered to be in very poor condition.

Johnson Swamp still supports an array of ecological, cultural and recreational values that make it an important wetland from a regional, national and international perspective. However without environmental water some of the key habitat values of Johnson Swamp, namely a loss of open water habitat through encroachment of cumbungi, complete loss of standing timber (i.e. through timber decay) and continued degeneration of the lignum, black box and river red gum communities would occur. These values are essential for supporting the high waterbird abundance and species richness for which Johnson Swamp is primarily recognised, and ensuring that the wetland continues to support the values of the wider Kerang Wetlands Ramsar site in the future.

As a complementary action to the RCS, the North Central CMA is developing the North Central Climate Change Adaptation and Mitigation Plan, which predicts the long term impacts of climate change under a range of scenarios. Although the timeframes and severity of impacts change depending on the scenario considered, the following impacts are expected to occur across all scenarios:

- Increased temperature across all seasons
- More hot days and less very cold days
- Decrease in winter rainfall
- Possible increase in summer rainfall
- Increase intensity of extreme rainfall
- Continued rainfall variability
- Increased frequency and severity of bushfire and flood events.

Under these predictions Johnson Swamp is likely to continue to experience less natural rainfall in the winter period, coupled with higher summer temperatures and increased evaporation during summer. This may result in a long term trend towards less frequent winter and spring inundation, with sporadic summer rainfall causing sharp rises and falls in water temperature. Without environmental water management, these changes could see less reliable winter/spring flooding, which would impact on waterbirds and other water dependent fauna. Increased summer inundation could further promote cumbungi proliferation.

## 4.7. Conceptualisation of the site

The EWMP conceptualises the current values and ecological functions of Johnson Swamp (Figure 5). The numbers in the figure are described on the following page.

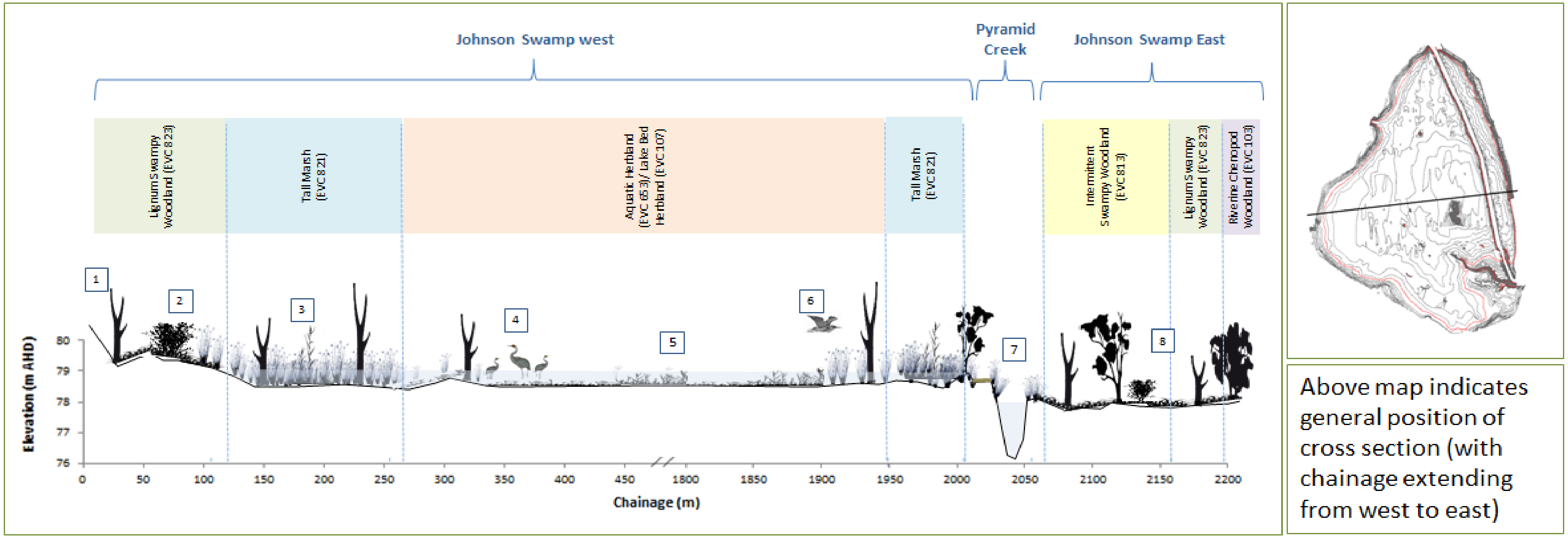



**Figure 5. Cross section indicating the conceptual understanding of the current ecology of Johnson Swamp (relationship between x and y axis not to scale)**

**Key descriptions for Figure 5:**

1. Many of the large **river red gum and black box trees** at Johnson Swamp are dead, the result of prolonged periods of inundation and salinsation. Dead and living trees provide feeding, roosting and nesting opportunities for a range of waterbirds and other fauna species and contribute to the habitat complexity of the wetland. Without regeneration of the tree cover, dead trees will eventually decay resulting in the loss of this important habitat feature from the wetland. Small areas of natural recruitment were noted during surveys in 2014; however most of this is confined to the artificial islands located in the bed of Johnson Swamp (Rakali 2014a).
2. The majority of **Lignum Swampy Woodland** vegetation at Johnson Swamp is degraded and confined to small pockets in the west of the wetland. Lignum provides an important nesting substrate for waterbirds, such as colonial breeding species such as royal spoonbill, straw-necked ibis, glossy ibis and little pied cormorant. It provides harbour for a range of macroinvertebrates, insects, frogs and small waterbirds that provide food sources to higher order predators. Lignum also facilitates the growth and persistence of some native understorey herbs species that might otherwise be unable to grow due to competition with invasive species (Rogers and Ralph 2011).
3. **Tall Marsh** provide essential foraging and nesting habitat for a range of cryptic waterbird species such as water hens, crakes and rails and threatened species such as Australasian bittern and Australian little bittern. Both cumbungi and common reed grow best in permanent to near-permanent conditions, with flowering occurring predominately between November and March. At Johnson Swamp cumbungi has grown into a dense mono-specific stands which has reduced the diversity of other plant species and has encroached on areas of open water (Rogers and Ralph 2011). Currently approximately 46 per cent of the area of Johnson Swamp is covered by cumbungi (Rakali 2014b).
4. **Brolga** requires shallow (25-75 cm), temporary or seasonal wetlands with areas of low tree cover (i.e. less than five percent of the wetland basin covered by trees with a canopy cover of approximately ten percent). The preferred vegetation is less than one metre high and includes species such as common spike-sedge (*Eleocharis acuta*), common nardoo (*Marsilea drummondii*) and *Juncus spp.*. Brolga breed between July and December with a fledging period of around 95 days. This leaves the species grounded for much longer than the average nesting waterbird and exposes the young brolga to predation by foxes and native predators. This is exacerbated when poor habitat quality (i.e. lack of water depth for a sufficient duration) results in starvation and malnutrition (Herring 2005). When inundated, Johnson Swamp is one of only a handful of wetlands in the Kerang region that supports appropriate feeding and breeding habitat for brolga.
5. **Amphibious and aquatic plants** can provide either a direct food source or can host biota that provides food for a range of waterbirds including threatened species such as brolga and Australasian bittern. Amphibious and aquatic plants generally germinate under temporary water regimes which see a surge of nutrients released from the soil. The egg bank is maintained during dry periods providing a recolonisation source when rewetted (Roberts and Marston 2011). Johnson Swamp supports at least sixty-six native plant species that are classified as either aquatic or amphibious (Rakali 2014a).
6. **Australasian bittern** and **Australian little bittern** require a complex suite of habitat characteristics for foraging and breeding to occur in the one location. For Australasian bittern, the species generally require shallow (less than 30 cm depth) with medium to low density of reeds (i.e. cumbungi, common reed), rushes (i.e. giant rush) and sedges (i.e. variable flat-sedge, common-spike sedge) for foraging of reptiles, insects, frogs, small mammals, leaves and fruit (Marchant and Higgins 1990 cited in DELWP 2016b). Nesting species require deeper water, with a medium to high density of reeds, rushes and

sedges (Pickering 2013 cited in DELWP 2016b). The nest is constructed in tall (up to 2.5 metres) and dense vegetation usually about 30 cm above the water level, so that the water level can fall during the breeding season and not impact on the nest (Marchant and Higgins 1990 cited in DELWP 2016b). The breeding season usually occurs between October and February with an incubation period of approximately 23 days followed by a further seven weeks for full fledging to occur (Pickering 2013 cited in DELWP 2016b). The current population estimate for Australia is less than 1,000 mature individuals (Garnett and Crowley 2010), with Johnson Swamp previously supporting at least one percent of the flyway population (Rakali 2015).

7. Historically Johnson Swamp filled during flooding events in the **Pyramid Creek**, however regulation and dredging of the creek now means that very large flood events (over 2 GL/day) are required to over-top the banks and inundate the wetland. Flows of this magnitude are rare in the system and as a result hydrological connectivity with the natural flow path has been lost. This connectivity is particularly important for cycling of nutrients, movement of propagules and macroinvertebrates, flushing of salts and sediments and providing landscape-scale cues for fauna (i.e. commencement of breeding of flood stimulated waterbirds) (MDBA 2014).

8. Since the dredging of Pyramid Creek, **Johnson Swamp East** has remained almost completely dry, with the exception of large over-bank flooding events in Pyramid Creek (i.e. 2010-11 floods). The east component of the wetland supports a fringe of Riverine Chenopod Woodland, Lignum Swampy Woodland and with depth Lake Bed Herbland, which historically would have comprised of Intermittent Swampy Woodland vegetation. The vegetation is generally degraded the result of recent fire, salinsation and lack of water (Rakali 2014a).

## 4.8. Significance

Johnson Swamp is part of the Kerang Wetlands Ramsar site, contributing to meeting five of the Ramsar Convention criteria supported by the larger Ramsar site. The wetland represents a depleted wetland type in Victoria and supports a high abundance of feeding and breeding waterbirds including migratory and threatened species such as Australasian bittern, Australian little bittern, marsh sandpiper and brolga. The wetland contains evidence of Aboriginal occupation, in the form of mounds and middens and provides a range of important recreational values, which provide economic and social benefits to local communities.

While the condition of Johnson Swamp has deteriorated severely since pre-European settlement, the wetland continues to support areas of healthy and diverse native water-dependent vegetation including a number of significant EVCs and threatened species. From a landscape perspective the wetland is particularly important for maintaining biological diversity within the region and has the potential to be reconnected back to its natural flow path contributing to an improvement in the health and productivity of Pyramid Creek.

The rehabilitation of key structural components at the wetland is required, particularly:

- a return of some of the live river red gum trees
- improvements to the condition of black box and lignum; and
- a reduction in the area of cumbungi and density of common reed to facilitate expansion of the open water and Aquatic Herbland zone.

This will maintain the current productivity of the wetland and may potentially provide new opportunities for values under-represented or absent from the site. As per Schedule 8 of the Murray-Darling Basin Plan, Johnson Swamp satisfies four of the five criteria used to identify environmental assets for purposes of environmental watering (Appendix 8).

# 5. Management objectives

## 5.1. Management goal

The long term management goal for Johnson Swamp has been derived from a variety of sources including technical reports, the Johnson Swamp EWP, VWMS, North Central Waterway Strategy, environmental values documented in Section 4.1 and 4.2 and scientific expert input (Butcher and Cook 2016). The long term management goal seeks to address and respond to the current condition and condition trajectory discussed in Section 4.6 of this EWMP.

**Johnson Swamp term management goal**

Rehabilitate Johnson Swamp using environmental water management to reduce the extent of cumbungi (*Typha spp.*), expand the area of Aquatic Herbland (EVC 653), and improve the condition of Intermittent Swampy Woodland (EVC 813) and Lignum Swampy Woodland (EVC 823). This will provide the physical habitat and condition to support a high diversity and abundance of breeding and feeding waterbirds.

Please note: The EWMP has taken into consideration the requirement to maintain the critical components, processes and services (CPS) found at Johnson Swamp which contribute to the character of the entire Ramsar site. Critical CPS relevant at Johnson Swamp include vegetation diversity, waterbird diversity and abundance, provision of habitat to support critical life stages (waterbird breeding and migration) and supporting more than one percent of the population of a species of waterbird (Australasian bittern). The EWMP has been developed so as to support or improve these critical CPS. The primary outcome of the proposed water management is the reduction of cumbungi which may have an impact on numbers of Australasian bittern supported at the site. Regular monitoring is required to ensure that there are no adverse changes to the CPS a Johnson Swamp (see Section 9).

## 5.2. Ecological objectives

Ecological objectives describe the intended outcomes of environmental water delivery and contribute towards achieving the long term management goal. The ecological objectives for Johnson Swamp are based on the key water dependent values at the wetland. Where appropriate these are expressed as the target condition or functionality for each key value, using one of the following trajectories:

- restore – recover a value that has been damaged, degraded or destroyed and return it to its original condition.
- rehabilitate – repair a value that has been damaged, degraded or destroyed but not to the extent of its original condition.
- maintain – maintain the current condition of a value. Note that under the Ramsar Convention, it is a requirement to maintain the character of the site as the time of listing.
- increase/ decrease the extent- manage wetland conditions to increase or decrease the extent of a value or threat.

Ecological objectives are presented as primary and secondary objectives. Primary objectives are related to the key values of Johnson Swamp and summarise the overall objectives for those values whilst secondary objectives are those that may support the primary objectives or provide benefit to other components of the landscape (i.e. Pyramid Creek). Each objective and associated justification as shown in Table 19, is consistent with the objectives of maintaining or where possible enhancing, the ecological character of the Ramsar site.

**Table 19. Ecological objectives and their justifications for Johnson Swamp**

| Objectives | Baseline/ benchmark | Justification |
|---|---|---|
| **Primary objectives** | | |
| 1. Reduce extent of cumbungi in Tall Marsh (EVC 821) by twenty percent at Johnson Swamp west by 2025<br>1.1 Corresponding increase in extent of Aquatic Herbland (EVC 653)<br>1.2 Reduce density of common reed in Tall Marsh (EVC 821). | Measured by an improvement in:<br>- 2014 extent mapping as shown in Appendix 10 (Rakali 2014b)<br>- 2014 IWC biota sub-index score as shown in Appendix 9 (Rakali 2014a). | - Tall Marsh is an important habitat component for cover-dependent/ cryptic waterbirds (i.e. Australasian bittern) however it has encroached on other important vegetation types (i.e. Aquatic Herbland). Reducing the extent of the dominate species cumbungi and reducing the density of common reed with increase the area of Aquatic Herbland and facilitate and increase in aquatic diversity.<br>- Aquatic Herbland supports a variety of waterfowl including freckled duck, swans as well as large and small waders including brolga and glossy ibis. The fringing drawdown/ mudflat zones further support migratory shoreline birds, small waders, swamphens and moorhens.<br>- Aquatic Herbland also provides shelter, food and refuge for frogs, reptiles and invertebrates, which provide food sources to higher order consumers. |
| 2. Rehabilitate Intermittent Swampy Woodland (EVC 813) and Lignum Swampy Woodland (EVC 823) at Johnson Swamp West and East by 2025<br>2.1 Improve condition of lignum fringing vegetation<br>2.2 Improve condition of existing river red gum and facilitate recruitment<br>2.3 Improve condition of existing black box woodland and facilitate recruitment. | Measured by an improvement in:<br>- 2014 IWC biota sub-index score as shown in Appendix 9 (Rakali 2014a)<br>- 2012 tree condition as shown in Table 18 (Australian Ecosystems 2012). | - Lignum, river red gum and black box provide a range of habitat functions for waterbirds including foraging, roosting and/ or nesting platforms, food resources as well as hollows for terrestrial based fauna. Shading, branch and leaf fall as well as capturing of sediments and water at the base, can alter the immediate micro-climate/ecosystem beneath the plant creating a localised change in vegetation composition. This encourages an increase in understorey diversity which improves the overall habitat structure of the wetland.<br>- As many of the trees and lignum at Johnson Swamp are degraded or dead, the current mid to upper canopy will eventually be lost through rot and breakdown. This will reduce the overall diversity of habitat available to native fauna. |
| 3. Maintain all waterbird feeding guilds, a waterbird species richness between 30 and 50 species and abundance levels in the thousands per month between October to January at Johnson Swamp, in three out of four targeted surveys over any 10 year period | Measured against:<br>- 2015-16 waterbird monitoring benchmark (DELWP 2016a- unpublished data). | - Johnson Swamp supports a high species richness and abundance of waterbirds belonging to a range of functional feeding groups including threatened species. |
| 4. Increase, or facilitate, breeding opportunities for waterbirds at Johnson Swamp through environmental water management by either:<br>- Providing improved habitat conditions for breeding (achieved through vegetation objectives 1 and 2); or<br>- Prolonging flooded conditions to allow successful fledging once a significant breeding event has commenced. | No baseline/ benchmark measurement set | - Johnson Swamp supports at least thirteen breeding waterbird species including threatened Australasian bittern, Australian little bittern and brolga.<br>- Fledging success would be supported by providing the appropriate watering duration.<br><br>N.B. A significant waterbird breeding events may include a large numbers of common species or threatened species. A significant breeding event may not occur every year the wetland is inundated. |

| Objectives | Baseline/ benchmark | Justification |
|---|---|---|
| **Secondary objectives** | | |
| 5. Create through flow conditions by rehabilitating lateral connectivity between wetland and Pyramid Creek | No baseline/ benchmark measurement set | - Rehabilitating lateral landscape connectivity, even partially, may assist with transporting carbon, nutrients, and provide avenues for the dispersal of organisms, fauna, eggs, propagules and seeds.<br>- Rehabilitating lateral connectivity is considered a key environmental outcome in the Basin-wide Environmental Watering Strategy (MDBA 2014) and will potentially provide benefits to the Pyramid Creek system.<br><br>N.B. The effectiveness of ecological gains associated with this objective is poorly understood and requires further investigation (see Section 10). |

## 5.3. Hydrological requirements

A series of hydrological requirements based on the ecological objectives detailed in Section 6.2 have been developed for Johnson Swamp. To meet the hydrological requirements of the Johnson Swamp EWMP, the environmental watering needs (i.e. volume, timing etc.) have been set with consideration for the following factors:

- the preferred timing of watering events
- the recommended duration for watering events
- the tolerable intervals between events (condition tolerances relevant to the key values)
- the volume required to provide these events – per event / per season.

The information provided in Table 20 is a summary of this information with additional context and justification supplied in Appendix 12.

**Table 20. Environmental watering requirements for Johnson Swamp**

<table>
<tr><th rowspan="3">Objective type</th><th rowspan="3">Ecological Objectives</th><th rowspan="3">Management phase (short/ long term)</th><th colspan="12">Hydrological requirements</th><th rowspan="3">Other comments</th></tr>
<tr><th colspan="3">Recommended number of events in 10 years</th><th colspan="3">Preferred interval between events once wetland is dry (months)</th><th colspan="3">Duration of ponding (months)</th><th rowspan="2">Preferred timing of inflows</th><th rowspan="2">Approximate target volume (ML) and depth (m AHD)[2]</th><th rowspan="2">Depth (m)[3]<br>N.B. based on average water depth for target vegetation zone</th></tr>
<tr><th>Min</th><th>Opt</th><th>Max</th><th>Min</th><th>Opt</th><th>Max</th><th>Min</th><th>Opt</th><th>Max</th></tr>
<tr><td colspan="16">Primary objectives</td></tr>
<tr><td rowspan="8">Vegetation</td><td>1. Reduce extent of cumbungi in Tall Marsh (EVC 821) by 20 percent at Johnson Swamp west) by 2025</td><td>Long term</td><td>2</td><td>3-4</td><td>5</td><td>24</td><td>36</td><td>>48</td><td>2</td><td>6-8</td><td>12</td><td>Most often autumn/ some years in spring</td><td><u>West:</u> <78.15 m AHD = 1,772 ML<br><u>East:</u> N/A</td><td>>0.3</td><td>Where possible, facilitate drawdown/ dry prior to summer; however if required (i.e. to support other values) avoid multiple consecutive wet summers (i.e. allow drawdown prior to summer every second watering cycle)</td></tr>
<tr><td>1.1 Corresponding increase in extent of Aquatic Herbland (EVC 653)</td><td>Long term</td><td colspan="12">Assumed to be met by achieving above objective</td><td>Main growth period is winter/spring. Drawdown should occur prior to summer to minimize the risk of damage to the plant. Seeds are viable in dry sediments for approximately 9 months.</td></tr>
<tr><td>1.2 Reduce density of Phragmites in Tall Marsh (EVC 821)</td><td>Long term</td><td colspan="12">Assumed to be met by achieving above objective</td><td>N/A</td></tr>
<tr><td>2. Rehabilitate Intermittent Swampy Woodland (EVC 813) and Lignum Swampy Woodland (EVC 823) at Johnson Swamp West and East by 2025</td><td>Long term – targeted for black box outcomes</td><td>1</td><td>2</td><td>2</td><td>36</td><td>60</td><td>120</td><td>1</td><td>3</td><td>6</td><td>As per natural</td><td rowspan="5"><u>West:</u> 77.85-78.2 m AHD= up to 1,775 ML<br><u>East:</u> <77.95 AHD = 143 ML</td><td>>0.3</td><td rowspan="3">Recession in spring-summer provides favourable growing conditions. Summer of first year likely to be stressful for seedlings (desiccation). Consider shallow inundation over summer period to support early root establishment.</td></tr>
<tr><td>2.1 Improve condition of lignum fringing vegetation</td><td>Short term – improve condition</td><td>1</td><td>2</td><td>2</td><td colspan="3">Avoid continuous flooding, optimal to re-flood after 60-84 months</td><td>3</td><td>5</td><td>7</td><td>As per natural</td><td>Not critical but typically <1</td></tr>
<tr><td rowspan="2">2.2 improve condition of existing river red gum and facilitate recruitment</td><td>Short term – improve condition</td><td>2</td><td>4</td><td>5</td><td>12</td><td>48</td><td>84</td><td>2</td><td>4</td><td>18</td><td>Winter to spring</td><td>Not critical</td></tr>
<tr><td>Long term- facilitate recruitment</td><td>2*</td><td>3*</td><td>5*</td><td colspan="3">*Following up flooding may be required</td><td>1</td><td>2</td><td>-</td><td>Late spring to early summer</td><td>0.2-0.3</td><td>River red gum does not maintain a seed bank therefore important to maintain adult trees in good condition so supply is readily available. Need to include explanation re drying time.</td></tr>
<tr><td>2.3 Improve condition of existing black box woodland and facilitate recruitment</td><td>Short term – improve condition</td><td>1</td><td>2</td><td>2</td><td>36</td><td>60</td><td>120</td><td>1</td><td>3</td><td>6</td><td>As per natural</td><td>0.3-1</td><td>Black box does not maintain a seed bank therefore important to maintain adult trees in good condition so supply is readily available.</td></tr>
<tr><td rowspan="2">Fauna</td><td>3. Maintain all waterbird feeding guilds, a waterbird species richness between 30 and 50 species and abundance levels in the thousands per month between October to January at Johnson Swamp, in three out of four targeted surveys over any 10 year period</td><td>Long term</td><td colspan="12">Feeding needs are variable dependent on the species. Aim to have a diversity of habitat types to support a greater diversity of species.</td><td>Each phase of the watering cycle will support a different range of waterbird feeding guilds. Each guild will opportunistically utilise the wetland until its feeding requirements are no longer supported. Most will then seek alternative feeding habitat elsewhere in the region.</td></tr>
<tr><td>4. Increase, or facilitate, breeding opportunities for waterbirds at Johnson Swamp through environmental water management by either:<br>- Providing improved habitat conditions for breeding (achieved through objectives for vegetation – see above); or<br>- Prolonging conditions to allow successful fledging once a significant breeding event has commenced.</td><td>Long term</td><td colspan="3">Breeding needs variable dependent on the species. Most species can breed most years if sufficient resources are available</td><td colspan="3">Drying is not critical for breeding success of many species; however flooding following drying (1-3 months) in temporary wetlands may enhance wetland productivity and breeding success</td><td colspan="3">Species dependent.<br>Following species utilised as a guide:<br><u>Brolga</u>: minimum of 2-4, optimum of 6-9 and maximum until fledging<br><u>Australasian bittern:</u> breeding requirements are not known however assumed to need 3-8</td><td>Autumn/ winter/ spring<br>Following species utilised as a guide:<br><u>Brolga:</u> June- Aug to commence<br><u>Bittern</u>: Oct-Feb</td><td><u>West</u>: >77.3 m AHD = 25 ML<br><u>East</u>: >77.65 m AHD = 47 ML</td><td>0.4-0.6</td><td>Generally stable water height required to ensure nests are not drowned out. Fledgling success closely linked to the duration of inundation post hatching and subsequent food and shelter availability. Drawdown to be timed to provide increased feeding opportunities post hatching.</td></tr>
<tr><td colspan="16">Secondary objectives</td></tr>
<tr><td>Process</td><td>5. Create through flow conditions by rehabilitating lateral connectivity between wetland and Pyramid Creek</td><td>Long term</td><td colspan="13">Facilitating hydrological connectivity through input and/or export of water between Pyramid Creek and/or Johnson Swamp east and/ or Johnson Swamp west (refer to Section 7). A dry interval matching that for supporting waterbird breeding, i.e. 1-3 months, should be adequate to supply terrestrial material to contribute to carbon and promote productivity (i.e. production of propagules, resting stages etc.).<br>N.B. The proposed pathway (via infrastructure) will not mimic the natural movement of water and material between a creek and floodplain. The amount of carbon and propagules that might be transported into Pyramid Creek is potentially low, and there are a number of potential risks (transmission of invasive species) that are yet to be fully assessed. Monitoring is therefore required to determine the benefit of undertaking this management strategy for Pyramid Creek in to the future (see Section 10)</td></tr>
</table>

## 5.4. Watering regime

The water regime required to meet the goal and ecological objectives (Section 5.1 and 5.2) for Johnson Swamp has been derived from hydrological requirements detailed in Section 5.3. To allow for adaptive and integrated management, the water regime is framed using the seasonally adaptive approach. The minimum water regime applies in drought or dry years, the optimum water regime in average conditions and the maximum water regime in wet or flood years.

The optimal, minimum and maximum water regimes are described below. The volume needed for any given year is to be estimated by the environmental water manager when watering is planned. A hydrograph depicting each regime over a ten year period is shown in Figure 6 with a conceptual cross section of the desired long term ecological outcomes at Johnson Swamp under the optimum regime shown in Figure 7.

**Minimum watering regime**

*Provide two water events every ten years (i.e. water every fifth year).*

Provide two filling events every ten years targeting 78.2 m AHD (fringe) on the western side, and 77.95 m AHD on the eastern side.

Commence delivery of environmental water between autumn and early spring, with delivery to occur most often in autumn (resulting in a total inundation duration of approximately 4-10 months) to facilitate drawdown and drying by early summer (to avoid consecutive wet summer events). If feasible (i.e. based on operation of Pyramid Creek, water quality etc.), facilitate through flows to Pyramid Creek through Johnson Swamp West outlet regulator in early spring. In the event that significant waterbird breeding is triggered, provide top-up/s to maintain the depth before facilitating a gradual drawdown to prevent nest abandonment and provide ample feeding opportunities post hatching and nest departure.

Ensure at least three to four years of complete dry between each watering event.

**Optimum watering regime**

*Provide four water events every ten years (i.e. water every third year).*

Provide four filling events every ten years, three of which target a fill to 78.2 m AHD (fringe), and one to target a level of 77.85 m AHD (wetland only) on the western side. In all events target a level of up to 77.95 m AHD on the eastern side.

Commence delivery of environmental water between autumn and early spring, with delivery to occur most often in autumn (resulting in total inundation duration of approximately 4-10 months) as to facilitate drawdown and drying by early summer (to avoid consecutive wet summer events). If feasible (i.e. based on operation of Pyramid Creek, water quality etc.), facilitate through flows to Pyramid Creek through Johnson Swamp West outlet regulator in early spring. In the event that significant waterbird breeding is triggered, provide top-up/s to maintain the depth before facilitating a gradual drawdown to prevent nest abandonment and provide ample feeding opportunities post hatching and nest departure.

Ensure at least two years of complete dry between each watering event with a dry period of three years at least once in every ten year period.

**Maximum watering regime**

*Provide five watering events every ten years (i.e. water every second year).*

Provide five filling events every ten years, three of which target a fill to 78.2 m AHD (fringe) and two to target a level of 77.85 m AHD (wetland only) on the western side. In all events target a level of up to 77.95 m AHD on the eastern side.

Commence delivery of environmental water between autumn and early spring, with delivery to occur most often in autumn (total duration of 4-10 months) as to facilitate drawdown and drying by early summer (to avoid consecutive wet summer events). If feasible (i.e. based on operation of Pyramid Creek, water quality etc.), facilitate through flows to Pyramid Creek through Johnson Swamp West outlet regulator in early spring. In the event that significant waterbird breeding is triggered, provide top-up/s to maintain the depth before facilitating a gradual drawdown to provide ample feeding opportunities post hatching and nest departure.

Ensure at least one year of complete dry between each watering event with a dry period of two years at least once in every ten year period.

The modelled average volume of water required to manage the optimal regime for Johnson Swamp in a watering year is 3,087 ML. The volume required in a year with maximum losses (high evaporation, low precipitation and filling from cracked clay) would be 2,476 ML. These volumes have been generated using a simplified version of the Savings at Wetlands from Evapotranspiration daily Time-series (SWET) and assume that there are no natural inflows. The model is based on the Tucker et al. (2002) recommendation of a 5 cm per day rise in wetland level through delivery of approximately 80 ML/day over a twenty-eight day period (average duration length to reach target level). A summary of each watering regime, including the averaged modelled water volume required per event, is provided in Table 21.

**Table 21. Summary of minimum, optimum and maximum water regimes over a ten year period**

| Parameters | Regime | | |
|---|---|---|---|
| | Minimum | Optimum | Maximum |
| **Event frequency** | 2 in 10 years | 4 in 10 years | 5 in 10 years |
| **Duration** | 4-10 months wet | 4-10 months wet | 4-10 months wet |
| **Fill timing** | Autumn- early spring | Autumn- early spring | Autumn- early spring |
| **Extent and target** | 2x events targeting fringe | 3x events targeting fringe<br>1x event targeting basin | 3x events targeting fringe<br>2x event targeting basin |
| **Dry between events** | 3-4 years dry | 2-3 years dry | 1-2 years dry |
| **Average volume required per fill event** | 2,196 ML | 3,087 ML | 2,195 ML |

### Adaptive management considerations

To ensure that climatic variability (i.e. flooding) and unplanned events including behaviour of key fauna species (i.e. breeding late in season on planned drawdown) is adequately planned for, the following 'rules' should be used to guide environmental water management decisions during each watering event:

*Wetting and dry frequency*

- If a natural flood event occurs ensure at least two to three years of complete dry to provide adequate time for soils to crack and aerate and for seeds to germinate, prior to the next environmental water delivery event.
- If prolonged drought occurs and there is insufficient water availability to deliver the minimum watering regime, a partial fill (the depth to be assessed with relevant ecologists prior to event) should be delivered (as per the minimum watering regime frequency) to sustain the amphibious plant assemblage and provide refuge for water dependent fauna.

*Watering timing, duration and extent*

- Encourage waterbirds to breed either earlier in the season or establish their nests higher in the wetland, by providing a higher fill in autumn or a top-up to reach designated water height as early in winter as possible (likely to be post 15 August to coincide with the start of the irrigation season). The rationale for this is that should a breeding event occur and there is a need to maintain depth into the summer months to support fledging and nest departure, the water level is elevated enough to reduce some of the spread of cumbungi into the deepest parts of the wetland (i.e. reducing the encroachment into the Aquatic Herbland zone). In 2014-15 bittern and brolga established their nests when the wetland was at approximately 30 percent capacity, equivalent to a maximum depth of about 30 cm. It is highly probable that low water levels over the summer period (and subsequent higher water temperatures) resulted in the spread of cumbungi into the deeper zones of the wetland.

*Through flows to Pyramid Creek*

- Undertake water quality monitoring prior to delivering through flows to Pyramid Creek to assess likely impact on Pyramid Creek.
- Where possible, avoid through flows in summer.
- Through flows may be used to facilitate drawdown (i.e. in the event of natural flooding, prolonged inundation threatened vegetation communities etc.).

*Catchment planning*

- To account for the range of watering activities undertaken across the landscape during each season, catchment scale planning is incorporated into the management of wetlands in the North Central CMA region. This process aims to not only understand the individual requirements of each actively managed wetland in the region but also the interactions between these, other non-regulated wetlands and Gunbower Forest from a landscape perspective.
- Catchment planning is particularly pertinent during periods of low allocations which can place increased pressure on key ecological values such as waterbird populations. Spreading watering across the landscape from a geographical perspective as well as staggering the timing of watering events is two methods adopted to ensure that sufficient resources and habitat is available for waterbirds and other fauna from year to year. Catchment planning is undertaken each year during the SWP development process and adaptively managed during each watering season to ensure the best use of water based on wetland requirements, climatic outlooks and resource allocations.

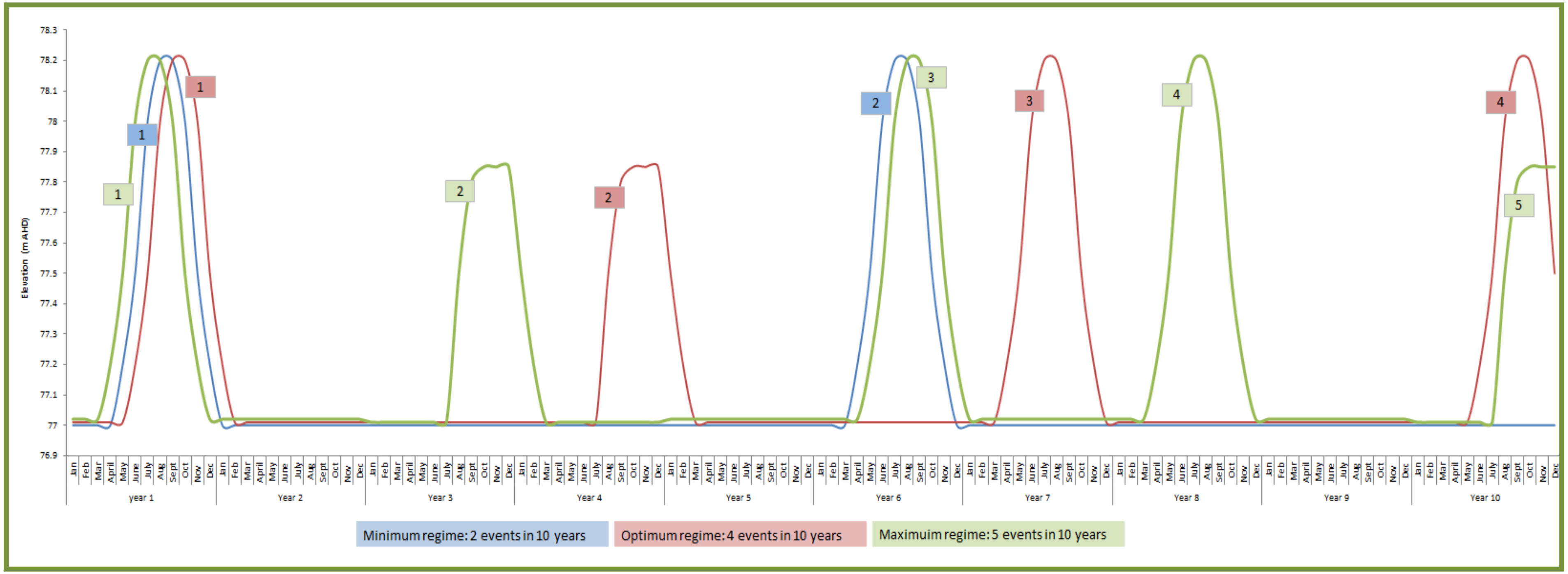
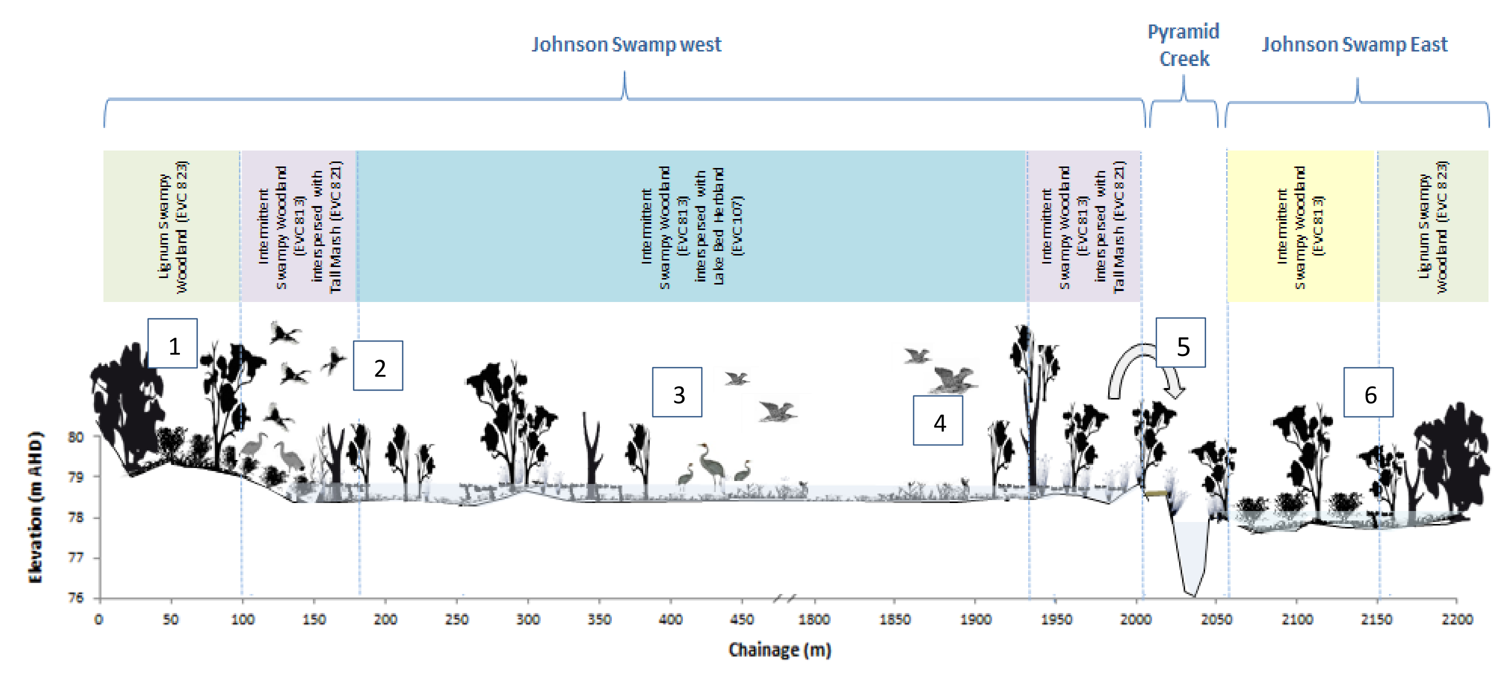



**Figure 6. Hydrographs of possible ten-year water regime at Johnson Swamp under a minimum, optimum and maximum regimes**




Above map indicates general position of cross section (with chainage extending from west to east)

**Figure 7. Cross section indicating the conceptual long term goal for the ecology of Johnson Swamp (relationship between x and y axis not to scale- see below numbers for descriptions)**

**Key descriptions for Figure 7:**

1. The **Lignum Swampy Woodland** zone will have a healthy canopy of black box representing a mix of age classes, with an understorey of lignum and associated native ground-layer species. The zone will provide important habitat for a range of water dependent fauna, including roosting and nesting waterbirds and frogs (when inundated) as well as terrestrial fauna such as reptiles, woodland birds and mammals. The zone will provide ample seed stock for the establishment of new black box seedling and ground-layer species.
2. A rehabilitated **Intermittent Swampy Woodland zone** would include a healthy fringing/ shallow water zone that contain lignum and associated native understorey species as well as an open canopy (becoming more sparse with increased depth) of live and dead river red gums belonging to a range of different age classes. This will provide a range of habitat functions including vantage points for foraging raptors (i.e. white-bellied sea eagle), roosting and/ or nesting platforms for ibis, spoonbills, cormorants and darters, hollows for terrestrial based fauna including bats and woodland birds and food sources, both directly through leaves, seeds, sap and nectar and indirectly through harbouring of insects, reptiles and mammals.
3. A healthy assemblage of vegetation will support a range of habitat types conducive to **waterbird breeding, feeding and roosting.** The water regime will be timed to promote and then support breeding and fledging of threatened species, such as Australasian bittern and brolga whilst also providing ample opportunity for feeding for a diversity of waterbirds.
4. A **diverse and productive aquatic and amphibious zone** will contain a mix of Intermittent Swampy Woodland vegetation interspersed with areas of Tall Marsh and open sections of Aquatic Herbland (deeper zones). Tall Marsh will be confined to discreet patches and will support cover-dependent/ cryptic waterbirds species such as Australasian bittern, Ballion's crake and Australian little bittern. Under a managed water regime some areas will transition into open zones containing a highly productive and diverse assemblage of native aquatic and amphibious plant species that provide food for grazing waterfowl, swans and waders including brolga and glossy ibis. The drawdown/ mudflat zones will opportunistically support migratory shoreline birds, small waders, swamphens and moorhens.
5. Under the proposed regime Johnson Swamp West will have **hydrological connectivity with Pyramid Creek** (at least partially) allowing an exchange of carbon and nutrients and dispersal of macroinverbrates, zooplankton, phytoplankton, eggs, seeds and propagules. The regime also includes watering of Johnson Swamp East (pending future connection, see Section 8) in unison with watering of Johnson Swamp West.
6. Under the proposed regime, **Johnson Swamp East** will receive environmental water resulting in an improvement in the health of native vegetation, in particular lignum, black box and red gum as well as an increase in the diversity of native amphibious understorey plant species. These plants provide shelter, food and nesting material for water-dependent and terrestrial fauna species including turtles (known to nest on eastern side of wetland), frogs and waterbirds.

# 6. Risk Assessment

A qualitative risk assessment has been undertaken to assign the level of risk of threats to achieving the objectives as well as risks related to the delivery of environmental water through the implementation of this EWMP. The relationship between likelihood (probability of occurrence) and the severity (severity of the impact) provide the basis for evaluating the level of risk (Table 22).

**Table 22. Risk matrix**

| | | Severity | | |
|---|---|---|---|---|
| | | Major | Moderate | Minor |
| **Likelihood** | Probable | High | High | Moderate |
| | Possible | High | Moderate | Low |
| | Improbable | Moderate | Low | Low |

The results from the Johnson Swamp EWMP risk assessment are presented in Table 23. Management measures relevant for the moderate to high level risks are recommended and the residual risk is then recalculated using the same risk matrix. Please note that short-term operational risks (i.e. environmental releases causes flooding of private land) are assessed as part of the development of the Central Murray Wetland Complex SWP.

**Table 23. Possible risks and mitigation measures associated with environmental water delivery to Johnson Swamp**

| Risk No. | Threat | Impacts | Relevant objective | Likelihood (L) | Severity (S) | Risk rating | Management Measure | Residual Risk rating |
|---|---|---|---|---|---|---|---|---|
| **1** | **Threats from environmental water** | | | | | | | |
| 1.1 | Excessive river red gum recruitment | The watering regime aims to rehabilitate river red gum trees and encourage recruitment into the base of the wetland. However excessive recruitment may result in a reduction in the habitat diversity at the wetland. | 1 (all)<br>2 (all)<br>3<br>4 | Possible | Moderate | Moderate | • Adaptively manage the water regime to ensure excessive recruitment is minimised (i.e. over top unwanted saplings during early phase of establishment to drown them)<br>• Undertake active intervention (i.e. slashing, spraying, grazing) to control recruitment<br>• Residual risk is calculated with a likelihood reduced to possible and severity to minor. | Low |
| 1.2 | Continued encroachment and dominance of cumbungi | The formation of a species-specific monoculture will result in further loss of the Aquatic Herbland and open water zone reducing habitat diversity and availability. Increased growth is most likely to be triggered if there are low summer water levels and/ or watering over the summer period to support waterbird breeding. | 1 (all)<br>2 (all)<br>3<br>4<br>5 | Possible | High | Major | • The optimum watering regime has been developed to limit the preferred growth conditions of the species (i.e. avoid watering over summer in consecutive years, dry periods of 2 to 3 years between events)<br>• Undertake active intervention (i.e. slashing, spraying, grazing) to control recruitment and growth<br>• Residual risk is calculated on reducing the severity to moderate. | Moderate |
| 1.3 | Excessive lignum growth and recruitment in wetland bed | Lignum is present in the open water zone of Johnson Swamp. Excessive growth and recruitment will reduce the area of Aquatic Herbland and open water impacting on the habitat diversity. | 1 (all)<br>3<br>4 | Possible | Moderate | Moderate | • Adaptively manage the water regime to ensure excessive recruitment is minimised (i.e. drown growth during early recruitment period)<br>• Undertake active intervention (i.e. spraying) to control recruitment<br>• Residual risk is calculated with a likelihood reduced to possible and severity to minor. | Low |

| Risk No. | Threat | Impacts | Relevant objective | Likelihood (L) | Severity (S) | Risk rating | Management Measure | Residual Risk rating |
|---|---|---|---|---|---|---|---|---|
| 1.4 | Prolonged inundation from follow up natural flooding event | Natural flooding after an environmental watering event could result in inundation beyond the critical tolerances of some values (i.e. adult river red gum trees) and/or provide a competitive advantage for some species that form monocultures (i.e. cumbungi- see risk 1.2) reducing habitat diversity. | 1 (all)<br>2 (all)<br>4 | Possible | Moderate | Moderate | • The outlet to Pyramid Creek could be opened to allow drawdown of the western side of the wetland whilst the eastern side could be managed through pumping<br>• Residual risk is calculated on reducing the severity to minor. | Low |
| 1.5 | Poor water quality (i.e. temperature fluctuations, turbidity, hypoxic blackwater, salinity and nutrients) | Changes to water quality may reduce/ alter primary production impacting on the availability and diversity of food resources available to fauna and for uptake by plants. It may encourage the encroachment of nutrient loving plants (i.e. cumbungi) and provide a competitive advantage for some invasive species. It may also change the temperature, light penetration and dissolved oxygen concentrations, thus reducing growth and germination of plant species (see Section 3.4). | All | Possible | Moderate | Moderate | • Provide freshening flows or open outlet to Pyramid Creek to flush/ dilute western side of wetland<br>• Monitoring groundwater bores to determine likelihood of salinity impacts prior to, during and post environmental water delivery<br>• Residual risk is calculated on reducing the severity to minor (this applies to most, but not all potential water quality parameters that could be impacted). | Low |
| 1.6 | Introduction of aquatic weeds and invasive fish during environmental water | Invasive fish and aquatic weeds can be introduced from the irrigation system into the wetland during a watering event or from the wetland into Pyramid Creek during through flow events (see risks 2.4 and 2.7 for impacts of these species). | All | Possible | Moderate | Moderate | • The optimum watering regime for the wetland includes dryings periods of 2 to 3 years between events. This will result in the death of invasive fish species and may limit the spread of some weed species.<br>• Undertaken regular weed control works in the wetland.<br>• Install carp screen on Torrumbarry 7/2 outfall regulator and potential outfall regulator to Pyramid Creek.<br>• Residual risk is calculated on reducing the severity to minor. | Low |

| Risk No. | Threat | Impacts | Relevant objective | Likelihood (L) | Severity (S) | Risk rating | Management Measure | Residual Risk rating |
|---|---|---|---|---|---|---|---|---|
| 1.7 | Failed waterbird nesting/ fledging due to insufficient follow-up watering | Nest abandonment and fledging death due to insufficient resources (i.e. both water and food). Drying may also expose eggs and fledglings to predation. | 4 | Possible | Major | High | • The optimum watering regime for the wetland includes providing top-ups to support significant waterbird breeding events<br>• The significance of a waterbird breeding event and need for environmental water, will be determined based on the abundance of breeding individuals, whether there are threatened species breeding and the condition of cumbungi (should the delivery of a top-up extend the duration into summer)<br>• Residual risk is calculated on reducing the severity to moderate. | Moderate |
| **2** | **Threats to ecological values** | | | | | | | |
| 2.1 | Loss of standing timber due to rot/ breakdown | Reduction in the diversity of habitat available for nesting and roosting waterbird and terrestrial fauna. Without replacement by new trees, the entire upper canopy could eventually be lost from the wetland. | 2.2<br>2.3<br>3<br>4 | Probable | Major | High | • The recommended watering regime has been developed to provide appropriate hydrological cues for growth and recruitment of native trees<br>• Undertake complementary works to plant and protect young trees<br>• Adaptively manage regime to promote establishment, growth and health of trees<br>• Residual risk is calculated with a likelihood reduced to possible and severity to minor. | Low |
| 2.2 | Lack of seedbank viability or propagules | Without a viable seedbank or source of propagules, environmental water will not facilitate the natural regeneration of the targeted species or EVCs. | 1.1<br>2 (all) | Possible | Major | High | • The recommended watering regime has been developed to provide appropriate duration and timing to allow plants to complete critical stages of their life cycle and produce seeds that can grow in response to subsequent watering events<br>• Undertake a direct seeding and revegetation program at appropriate times of the wetting and drying cycle<br>• Residual risk is calculated with severity reduced to minor. | Low |

| Risk No. | Threat | Impacts | Relevant objective | Likelihood (L) | Severity (S) | Risk rating | Management Measure | Residual Risk rating |
|---|---|---|---|---|---|---|---|---|
| 2.3 | Recreational and tourism pressures | Potential impacts include mortality of non-target game species (duck hunting), nest abandonment and stress induced by disturbance (i.e. noise or visual), damage to vegetation and cultural heritage, introduction of weeds (i.e. brought in on vehicles) and rubbish dumping from camp sites. | 3<br>4 | Possible | Moderate | Moderate | • Monitor the species present (in particular threatened waterbirds) and abundance and report information to Field and Game, DELWP and Game Management Authority<br>• Educate recreational and educational users on importance of wetland rehabilitation, threatened species conservation and importance of track use (i.e. no off-road driving)<br>• Fence areas of cultural sensitivity or supporting vulnerable threatened species.<br>• Residual risk is calculated with severity reduced to minor. | Low |
| 2.4 | Introduced fish species (i.e. common carp, eastern gambusia) | A high abundance of introduced fish species have the ability to reduce water quality and limit the growth and establishment of aquatic plants (i.e. through uprooting, increasing turbidity etc.). However these species may provide an important food source for piscivorous waterbirds. | 1.1<br>2 (all) | Probable | Moderate | Moderate | • As per risk 1.6, the optimum watering regime includes dryings periods of 2 to 3 years between events. This will result in the death of invasive fish species.<br>• Install carp screen on Torrumbarry 7/2 outfall regulator<br>• Residual risk is calculated on reducing the severity to minor. | Low |
| 2.5 | European fox | Fox are regularly observed at Johnson Swamp. They predate on adult and juvenile waterbirds, freshwater turtles, frogs and reptiles and the eggs of waterbirds and turtles. They also provide a vector for disease, parasites and can introduce exotic plant seeds/ propagules through fur and/or gut content. | 1.1<br>3<br>4 | Probable | Major | High | • Fox control measures, such as baiting or shooting on public and private land surrounding the wetland, particularly at key nesting and hatching times for waterbirds and turtles.<br>• Although it is not possible to eliminate all fox predation the residual risk is calculated on reducing severity to moderate. | Moderate |

| Risk No. | Threat | Impacts | Relevant objective | Likelihood (L) | Severity (S) | Risk rating | Management Measure | Residual Risk rating |
|---|---|---|---|---|---|---|---|---|
| 2.6 | European rabbit | Rabbits graze on native vegetation and significantly impact recruitment of trees and shrubs and prevent the establishment of groundcover species. Rabbit warrens and grazing can lead to increased areas of bare ground and subsequent erosion by wind and water. They can also impact significantly on areas of cultural heritage and act as a vector for disease, parasites and the introduction of exotic plant seeds/ propagules through fur and/or gut content. | 1.1<br>2 (all) | Probable | Moderate | High | • Rabbit control measures, such as warren fumigation, baiting, and shooting (both on public and surrounding private land) and the erection of fences or other measures to exclude rabbits from selected areas (following due diligence, approvals and agreed methodologies with relevant parties)<br>• Although it is not possible to eliminate all rabbits the residual risk is calculated on reducing severity to minor. | Moderate |
| 2.7 | Introduced weeds | Competition with and potential decline in health and distribution of native species. | 1 (all)<br>2 (all)<br>5 | Possible | Major | High | • Monitoring and weed control (i.e spraying, manual removal).<br>• Providing a water regime that provides favourable conditions for native plant species<br>• As it is unlikely that all weeds can be removed from the wetland, residual risk is calculated on reducing severity to moderate. | Moderate |
| 2.8 | Grazing by introduced and native animals | New plant recruits can be grazed by livestock (nearby dairy farms), carp, mammals and waterbirds before they grow to a size that makes them resilient to such effects. | 1.1<br>1.3<br>2.1 | Probable | Major | High | • Construction of exclusion plots to prevent access by pest or native biota, particularly in high value or regeneration areas<br>• Monitor condition of perimeter fence to ensure it continues to exclude stock and seek funding if repairs are required<br>• Report compliances breaches (i.e. stock being allowed into reserve) to Parks Victoria<br>• Residual risk is calculated on reducing severity to moderate. | Moderate |

| Risk No. | Threat | Impacts | Relevant objective | Likelihood (L) | Severity (S) | Risk rating | Management Measure | Residual Risk rating |
|---|---|---|---|---|---|---|---|---|
| 2.9 | Fire | Habitat and resource loss (i.e. standing timber) as well as water quality deterioration. | All | Possible | Major | High | • Active management in partnership with Parks Victoria through planned burns/ cool burning techniques, fuel removal etc. (as required) following due diligence, approvals and agreed methodologies with relevant parties<br>• Monitoring (i.e. IWC) and adaptive management<br>• Residual risk is calculated on reducing severity to moderate. | Moderate |
| 2.10 | Rising groundwater height and salinity levels | Saline groundwater intrusion has the potential to induce a local increase in groundwater level that could pose a salinity risk to the surrounding land. In addition a saline water table may prohibit establishment of overstorey vegetation and cause taproots to develop laterally decreasing stability and increasing susceptibility to moisture stress. | 1 (all)<br>2 (all) | Possible | Major | High | • Groundwater bore monitoring and adaptive management of recommended watering regime and revegetation program accordingly<br>• Residual risk is calculated on reducing severity to moderate. | Moderate |
| 2.11 | Climate change | Higher temperatures may increase proliferation of cumbungi and common reed, change the distribution of species (i.e. both due to increased temperatures and changed rainfall patterns) and increase the mortality of juvenile waterbirds (i.e. heat stress). | All | Probable | Major | High | • Environmental water management to be adaptive and dependent on seasonal outlooks as identified in Section 5.4<br>• Residual risk is calculated on reducing severity to moderate. | Moderate |
| 2.12 | Lack of connection between wetland and a river or floodplain | Lack of cycling of nutrients, movement of propagules and macroinvertebrates, flushing of salts and sediments and providing landscape-scale cues for fauna (i.e. commencement of breeding of flood stimulated waterbirds). | 5 | Probable | Moderate | High | • Investigate potential to upgrade outlet to a versatile structure (i.e. to enable both delivery and drainage back into the Pyramid Creek) or pump water to create throughflow connection (see Section 7.2)<br>• Residual risk is calculated on reducing severity to moderate due to some inflows returning to Pyramid Creek; however the magnitude of through flows will not be large. | Moderate |

| Risk No. | Threat | Impacts | Relevant objective | Likelihood (L) | Severity (S) | Risk rating | Management Measure | Residual Risk rating |
|---|---|---|---|---|---|---|---|---|
| 2.13 | Inability to water Johnson Swamp East | Currently there is no infrastructure in place to facilitate delivery of environmental water to Johnson Swamp East. Therefore none of the ecological objectives outlined in Table 19 that are relevant to the east side can currently be achieved. | 2 (all)<br>5 | Probable | Major | High | • Investigate potential to either siphon or provide an independent water supply (i.e. pumping) to Johnson Swamp East (see Section 7.2)<br>• Residual risk is calculated on reducing likelihood to improbable and severity to through construction of appropriate infrastructure. | Low |

## 7. Environmental water delivery infrastructure

### 7.1. Current infrastructure

Delivery of water at appropriate times and in the required quantities is dependent on having appropriate infrastructure and access to spare channel capacity when required.

The Torrumbarry 4/7/2 channel that supplies Johnson Swamp has a reported capacity of 100 ML/day. The outfall structure (automated) located on the western side of the wetland has a reported capacity of 80 ML/day (Figure 8). Johnson Swamp also has a 600 mm outlet (east side of Johnson Swamp West) with a door to drain into Pyramid Creek. This structure supports the draw-down of the wetland if excessive inundation threatens black box survival (North Central CMA 2009).

At a flow rate of 80 ML/day it will take a minimum of twenty-two days to fill Johnson Swamp from empty subject to the availability of water, and the ability of the GMW system to deliver flows in conjunction with competing customer demands. There is less demand for channel capacity in the winter/spring period when it is the optimum time for delivery of environmental water. However, arrangements for water delivery will need to be adaptively managed as part of the seasonal watering plan development.

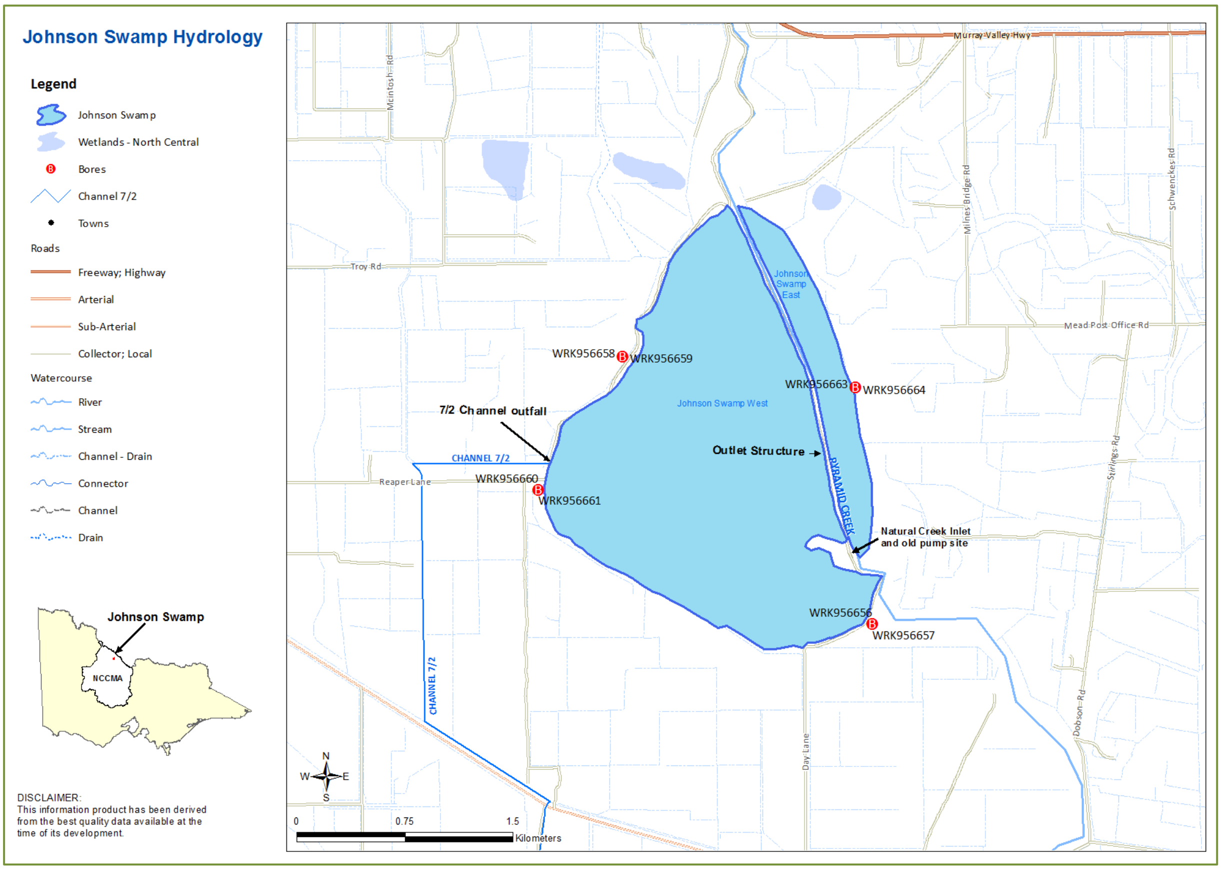



**Figure 8. Johnson Swamp water delivery infrastructure**

### 7.2. Infrastructure recommendations

Potential upgrade options to improve operational management of Johnson Swamp water delivery infrastructure include:

- Upgrade of the outlet structure to a versatile structure to enable both delivery and drainage. This would allow direct delivery of water from Pyramid Creek to the open water zone and enable through flows to the Pyramid Creek (North Central CMA 2009). Pumping may be the only viable option due to the large head difference between the bed of the wetland and Pyramid. Further scoping of this option is required.

- Scoping investigation to determine infrastructure requirements to water Johnson Swamp East, either through siphoning (from west side under Pyramid Creek) or by an independently supply (i.e. pumping). This project should also investigate an outfall option to allow through flows to re-enter Pyramid Creek, providing full throughflow connectivity. This is a priority project for the North Central CMA's *Environmental Water Technical Investigations, Works and Measures Program 2016-2020.*

## 8. Complementary actions

Table 24 documents the recommended actions for further investigation and /or adoption to complement the delivery of environmental water to Johnson Swamp.

**Table 24. Complementary actions to enhance the outcomes of environmental water**

| Activity | Rationale | Recommendation | Priority |
|---|---|---|---|
| Fox control | Foxes are commonly observed at Johnson Swamp. Impacts include predation on juvenile waterbirds, turtles, mammals and terrestrial birds and the introduction of disease, parasites and foreign plant material. | Fox control measures include baiting (including predator saturation baiting) and interactive fox drives both on public and surrounding private land. These actions should be intensified during wet phases, particularly if waterbird breeding occurs. Mesh may also be used to protect turtle nests. | High |
| Revegetation works (terrestrial and aquatic) | Species enrichment planting in terrestrial and aquatic zones to increase structure and diversity and aid in rehabilitation and progress towards long term objective. | Establish a number of revegetation exclusion plots around Johnson Swamp with a diversity of aquatic species. Revegetate the public land surrounding Johnson Swamp and protecting existing native vegetation on freehold land through land management agreements. Revegetation may also include cane grass, a species likely to have occurred naturally and favoured by a number of threatened waterbird species. | High |
| Reconnection between Pyramid Creek, Johnson Swamp West and East | Options to facilitate reconnection of Pyramid Creek and Johnson Swamp should be prioritised to facilitate movement and exchange of nutrients, macroinvertebrates etc. | See recommendations in Section 7.2. | High |
| Cumbungi | This species have been advantaged by altered hydrology and has formed large stands throughout the wetland. This has reduced native plant species diversity and the habitat available to support a range of fauna species. | Implementation of the prescribed watering regime in conduction with active management such as spraying, mowing and slashing (if required). Particular emphasis on timing the drawdown to avoid peak growth period, or drowning post slashing), will assist in controlling the extent of these species. Opportunity to work with traditional owners regarding cultural harvesting. | Moderate |
| Rabbit control | The presence of rabbits have been observed at Johnson Swamp; however no warrens were detected during mapping undertaken in 2012. Rabbits inhibit recruitment of native vegetation, disturb/ destroy culturally sensitive areas and introduce disease, parasites and foreign plant material. | Rabbit control measures include baiting, shooting, warren fumigation or destruction on public and private land (method dependent on whether a site is cultural sensitive) and community education activities such as rabbit buster. | Moderate |
| Exotic flora control | A total of sixty-six exotic flora species have been recorded at Johnson Swamp, accounting for 36 percent of all flora species recorded. | Focus on high threat terrestrial and amphibious weeds including boxthorn, spiny rush and water couch (mapped in Appendix 11). Terrestrial weeds within the basin of the wetland are likely to be displaced by native species during wet phases. | Moderate |
| Other pest animal control (i.e. pig and deer) | Wild pigs have been observed at Johnson Swamp and deer have also been observed at neighbouring Hird Swamp. Both species can cause significant damage to native vegetation and cultural heritage. | The primary control method for pigs is baiting and trapping. Shooting is used as a secondary control measure for pigs and the primary measure for deer. Control should be undertaken on both public and private land. | Moderate |

Where possible, traditional owners should be engaged to deliver key complementary actions to assist with capacity building and knowledge transfer.

# 9. Demonstrating outcomes

Monitoring is required to enable the North Central CMA and VEWH to justify the application of environmental water by demonstrating that environmental water management is achieving environmental outcomes. Two types of monitoring are recommended to assess the effectiveness of the proposed water regime on the targeted objectives and to facilitate adaptive management:

- Long-term condition monitoring
- Intervention monitoring

DELWP is currently developing WetMAP (Wetlands Monitoring and Assessment Program), which will be a long-term monitoring program aimed at assessing the effectiveness of environmental water achieving ecological outcomes. As the program is in its early stages of development a monitoring program has been developed specifically for the Johnson Swamp to demonstrate the achievement of the short and long-term objectives documented in this EWMP.

## 9.1. Long-term condition monitoring

Long-term condition monitoring will provide information on whether the watering regime is causing a change in, or maintaining, the overall condition of the wetland (trend over time). As there is currently no long-term condition monitoring program in place, Table 25 details monitoring required to demonstrate change in condition over time specifically focusing on the ecological objectives and long-term outcomes of the Johnson Swamp EWMP.

**Table 25. Required long-term condition monitoring for Johnson Swamp**

| Objective no. | Monitoring focus | Monitoring question | Method | When |
|---|---|---|---|---|
| Overarching management goal | | | | |
| N/A | Wetland condition | Has there been an overall rehabilitation in the condition of the wetland by 2025? | Undertake IWC assessment (using non-standard methodology- see Section 4.6.1) during a phase comparable to the 2014 benchmark (Rakali 2014a- see Appendix 10). | Every three years (i.e. after each watering event under optimum conditions) |
| Vegetation objectives | | | | |
| 1 | Tall Marsh (cumbungi and common reed) and Aquatic Herbland | Has there been a twenty percent reduction in the extent of cumbungi in Tall Marsh (EVC 821) at Johnson Swamp West by 2025 and a corresponding:<br>- increase in Aquatic Herbland<br>- reduction in common reed density? | Undertake comprehensive on ground mapping of the extent of Tall Marsh including the area of cumbungi and common reed as well as Aquatic Herbland. Undertake quadrat surveys to inform the average density of cumbungi and common reed. Compare results against the 2014 benchmark (Rakali 2014b- see Table 19). | Every three years (i.e. after each watering event under optimum conditions) |
| 2 | Intermittent Swampy Woodland, Lignum Swampy Woodland and river red gum and black box trees | Has there been a rehabilitation of Intermittent Swampy Woodland (EVC 813) and Lignum Swampy Woodland (EVC 823) at Johnson Swamp West and East through improved condition of:<br>- lignum fringe<br>- river red gums including recruitment<br>- black box including recruitment | Undertake comprehensive vegetation condition surveys and mapping including tree health, IWC (using non-standard methodology- see Section 4.6.1) , EVC condition, species presence and abundance and weediness (use of quadrats and transects that are stratified to record data from different wetland zones). Compare results against the 2014 benchmark (Rakali 2014a- see Table 19) or the 2012 benchmark for tree health (Australian Ecosystems 2012- see Table 19). | Every three years (i.e. after each watering event under optimum conditions) |

| Objective no. | Monitoring focus | Monitoring question | Method | When |
|---|---|---|---|---|
| Fauna objectives | | | | |
| 3 | Waterbird abundance, species richness and feeding guilds | Has there been maintenance of all waterbird feeding guilds, between 30 to 50 waterbird species and an abundance of thousands of waterbirds per month between October and January during at least three out of four targeted surveys in a 10 year period? | Long term analysis of intervention monitoring data (see Table 26) to determine compliance with objectives (i.e. are changes in functional feeding groups attributed to vegetation condition change). Compare results against the 2015-16 benchmark (DELWP 2016a- see Table 19).<br>If applicable, integrate data with larger data sets (i.e. Australasian bittern surveys across region, Field and Game surveys etc.) to understand movement patterns in landscape. | Undertake analysis every three years (i.e. after each watering event under optimum conditions) |
| Process objectives | | | | |
| 5 | Stream metabolism, fish, macro-invertebrates and productivity | Is the release of through flows contributing to an improvement in Pyramid Creek productivity? | Long term analysis of intervention monitoring data (see Table 26) to determine compliance with objectives (i.e. is there a long term trend in improved productivity near return point). Establish a benchmark to compare against. | Undertake analysis every three years (i.e. after each watering event under optimum conditions) |

## 9.2. Intervention monitoring

Intervention monitoring will assess the responses of key environmental values to environmental water management (intervention) and the achievement of ecological objectives i.e. maintenance of submerged aquatic vegetation. Monitoring the response to a watering event will be important to provide feedback on how the system is responding and whether any amendments need to be made to the operational management or determine if any risk management actions need to be enacted.

An ongoing environmental water resource planning program for wetlands in the North Central CMA region is implemented as part of the SWP. This includes the delivery of environmental water based on an assessment of the previous year's monitoring data and water availability. Due to limited resourcing the program focuses primarily on the collection of basic habitat condition (using a rapid condition assessment and photopoint monitoring primarily during years when watering will be targeted) and water depth and extent data. Johnson Swamp is currently a recipient of environmental water and has previously been monitored under this program.

Table 26 details the intervention monitoring required to adaptively manage Johnson Swamp over the next ten. The program is specific to monitoring short-term change based on the ecological objectives identified for the wetland.

**Table 26. Required intervention monitoring for the implementation of the Johnson Swamp EWMP**

| Objective no. | Monitoring focus | Monitoring question/s | Method | When |
|---|---|---|---|---|
| Vegetation objectives | | | | |
| 1 | Tall Marsh (cumbungi and common reed) and Aquatic Herbland | Is environmental water management resulting in a:<br>- Decrease in the extent of cumbungi?<br>- Increase in extent of Aquatic Herbland?<br>- Reduced density of common reed? | - Visual surveys through photopoint monitoring and rapid condition assessments<br>- Use of Landsat images/ aerial photograph and drone technology (potential for LiDAR to determine density) to map | Before and after each watering event |

| Objective no. | Monitoring focus | Monitoring question/s | Method | When |
|---|---|---|---|---|
| | | | changes in extent<br>- Compare against previous surveys results and 2014 benchmark (where applicable) | |
| 2 | Intermittent Swampy Woodland and Lignum Swampy Woodland | Is environmental water management resulting in:<br>- Improve condition of lignum fringing vegetation?<br>- Improve condition of existing river red gum and facilitate recruitment?<br>- Improve condition of existing black box woodland and facilitate recruitment? | - Visual surveys through photopoint monitoring and rapid condition assessments<br>- Compare against previous surveys results and 2014 and 2012 benchmark (where applicable) | Before and after each watering event |
| Fauna objectives | | | | |
| 3 | Waterbird feeding | In targeted survey months, is environmental water management resulting in (measured against 2015-16 benchmark data):<br>- A waterbird species richness of > 30 species?<br>- Maintenance of all feeding guilds?<br>- A waterbird abundance of >1,000 individuals?<br>- A change in the number and abundance of migratory species?<br>- Presence of threatened species? | - Monthly survey including abundance and diversity. Use of species specific monitoring techniques if required (i.e. Australasian bittern flushing and acoustic survey method).<br>- Ad-hoc visual monitoring as well as the use of monitoring cameras in key areas of the wetland (i.e. in trees over water) or audio recorders (at dusk and dawn for cryptic species).<br>- Integration with other monitoring undertaken including BirdLife Australia and Field and Game surveys. | Monthly during watering events or as required for specific species (recommended to utilise WetMAP methods in development) |
| 4 | Waterbird breeding | Is environmental water management resulting in:<br>- Waterbirds breeding? Which species?<br>- Significant breeding events (i.e. high numbers or threatened species)?<br>Did top-ups delivered for waterbird breeding result in:<br>- Fledging of juveniles? | | |
| Process objectives | | | | |
| 5 | Pyramid Creek connection | Is the release of water into Pyramid Creek improving food webs in Pyramid Creek? | Upstream and downstream return point monitoring for:<br>- Stream metabolism- continuous dissolved oxygen, temperature, flow etc.<br>- monthly/ bi-monthly dissolved organic carbon sampling<br>- macroinvertebrate sampling.<br>Monitoring likely to be funded under different programs (i.e. non environmental water related projects) include biofilms, plant growth, fish species richness and abundance (methods to be determined). | Prior to, during and immediately after through flows are provided to Pyramid Creek. |
| Other (i.e. risk based) | | | | |
| N/A | Water quality | Is there a need to flush water through the wetland to improve water quality? | - Spot water quality monitoring | Ad-hoc/ throughout watering event |

| Objective no. | Monitoring focus | Monitoring question/s | Method | When |
|---|---|---|---|---|
| N/A | European fox | Are foxes impacting on fledging success of waterbirds (particularly threatened species)? | - Visual monitoring (including spotlighting)<br>- Use of monitoring cameras in key areas of the wetlands (i.e. near nests) | During significant nesting events through to fledging |
| N/A | Rabbit, pig and/ or deer | Are rabbits, pigs and/ or deer impacting on:<br>- Native plant recruitment (particularly targeted vegetation)?<br>- Cultural heritage? | - Visual monitoring (including spotlighting)<br>- Use of monitoring cameras in key areas of the wetlands | Post environmental watering and during critical recruitment periods |
| N/A | Groundwater | Are ground water levels:<br>- Elevated (prior to water delivery)?<br>- Rising in response to environmental water management? | - Monitoring of groundwater bores | Monthly or bi-monthly during watering events. Quarterly thereafter. |

## 10.Knowledge gaps and recommendations

The Johnson Swamp EWMP has been developed using the best available information. However, a number of information and knowledge gaps exist which may impact on recommendations and/or information presented in the EWMP. The priority status of these are summarised in Table 27.

**Table 27. Knowledge gaps and recommendations**

| Knowledge Gap | Objective[1] | Risk[1] | Recommendation | Who | Priority |
|---|---|---|---|---|---|
| Relationship between environmental water management and extent and density of cumbungi and common reed | 1.2, 1.3 | 1.2 | Monitoring to understand if environmental water management is retarding the growth and reducing the extent of cumbungi (as per objective) of the wetland area. Undertake further work to determine best active management method (i.e. slashing, burning, spraying etc.) to complement delivery of environmental water (if required) and any secondary impacts of vegetation reduction on waterbird habitat | North Central CMA | High |
| Relative contribution of carbon and nutrients from Johnson Swamp to Pyramid Creek | 5 | 1.5, 1.6, 2.12 | Undertake extensive monitoring (see Section 9) to understand if contribution of nutrients and carbon to Pyramid Creek provides enough of a benefit to warrant continued through flows. | Internally, or by consultant on behalf of North Central CMA | High |
| Feasibility of facilitating dual way delivery and drainage of both the west and east sides of Johnson Swamp | 2.4 | 2.12, 2.13 | Investigate if dual way structures (new structure on east side and retrofit on west side) are possible due to head difference between wetland and the normal operation level of Pyramid Creek. | Internally, or by consultant on behalf of North Central CMA (part of the *Works and Measures Program*) | High |
| Continued ability for Johnson Swamp to cater for a range of feeding and breeding waterbird species under proposed changed duration and timing | 1.4, 1.5 | N/A | Compare abundance, diversity, feeding guilds and breeding activity under an early summer vs. late summer/ autumn dry timing. Determine if any feeding guilds or species are absent or no longer breeding under changed regime and investigate if there is sufficient habitat elsewhere in region to support these species (i.e. migratory waders). | North Central CMA | High |
| A comprehensive understanding of surface water-groundwater interactions | All | 2.10 | Continued monitoring and evaluation of groundwater and surface water data is recommended to ensure no detrimental impacts from implementation of the watering regime. | North Central CMA | High |
| An understanding of the use of wetland/ farmland habitat by Australasian bittern and Australian little bittern population | 2.4, 2.5 | N/A | Research or community driven consensus/ surveillance program required to monitor population. This will assist with aligning the water regime to the species movement patterns (i.e. from rice fields onto wetlands) | North Central CMA in partnership with other CMAs, Matt Herring through the *Bitterns in Rice Fields Project,* research body or community groups | Moderate |

| Knowledge Gap | Objective[1] | Risk[1] | Recommendation | Who | Priority |
|---|---|---|---|---|---|
| An understanding of the status of the region's brolga population | 1.4, 1.5 | 2.5 | Research or community driven consensus/ surveillance program required to track/ monitor population to understand fledging success, survival and fecundity. | Internally, by consultant on behalf of North Central CMA/ research body or community group | Low |
| Key:<br>[1]As per the ecological objectives identified in Table 19 and risks identified in Table 23. | | | | | |

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## 12.Abbreviations and acronyms

| | |
|---|---|
| BE | Bulk Entitlement |
| BOM | Bureau of Meteorology |
| Bonn | The Convention on the  Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention or CMS) |
| CAMBA | China-Australia Migratory Bird Agreement |
| MEWAG | Central Murray Wetland Complex Environmental Water Advisory Group |
| CEWH | Commonwealth Environmental Water Holder |
| CMA | Catchment Management Authority |
| DEDJTR | Department of Economic Development, Jobs, Transport and Resources |
| DELWP | Department of Environment, Land, Water and Planning |
| DEPI | Department of Environment and Primary Industries (separated into two departments in 2015: DELWP Victoria and DEDTJR Victoria) |
| DPI | Department of Primary Industries (Now DEDJTR) |
| DSE | Department of Sustainability and Environment (Now DELWP Victoria in 2015) |
| EPBC | *Environment Protection and Biodiversity Conservation Act 1999* (Cth) |
| EVC | Ecological Vegetation Class |
| EWMP | Environmental Water Management Plan |
| EWP | Environmental Watering Plan |
| FFG | *Flora and Fauna Guarantee Act 1988* (Vic) |
| FSL | Full Supply Level |
| GL | Gigalitre (one billion litres) |
| GIS | Geographical Information System |
| GMW | Goulburn Murray Water |
| HRWS | High Reliability Water Share |
| IWC | Index of Wetland Condition |
| JAMBA | Japan-Australia Migratory Bird Agreement |
| LRWS | Low Reliability Water Share |
| MDBA | Murray-Darling Basin Authority (formerly Murray-Darling Basin Commission, MDBC) |
| ML | Megalitre (one million litres) |
| ML/d | Megalitres per day |
| ROKAMBA | Republic of Korea-Australia Migratory Bird Agreement |
| RWS | Regional Waterway Strategy |
| SWP | Seasonal Watering Proposal |
| VEWH | Victorian Environmental Water Holder |
| VWMS | Victorian Waterway Management Strategy |

## Appendix 1: Consultation

| Barapa Barapa site visit<br>14 July 2016- Johnson Swamp, Victoria |
|---|

**Method:**

A Barapa Barapa site visit was held at Johnson Swamp on the afternoon of 14 July 2016 with guest speakers Damien Cook (Rakali Ecological Consulting) and Colin Pardoe (archaeologist) present. The field trip included a brief discussion on the EWMP process and water management at Johnson Swamp, followed by a walk to discuss the EWMP detail, view places of cultural heritage and areas recently targeted for species enrichment planting. Participants were asked to complete a simple questionnaire which queried their understanding of the wetland's condition, their connection to the site and opinion on current and future management. Key notes applicable to the EWMP as well as additional comments provided outside the field trip are summarised below. In addition, notes gathered during a Barapa Barapa site visit at Johnson Swamp conducted on the 5 May 2016 as part of the Kerang Wetlands Ramsar Action Plan have also been incorporated into the below summary. Additional participants include Ester Kirby and Sharnie Hamilton (North Central CMA, 2016b).

**Attendees:**

| Name | Representative |
|---|---|
| Ron Galway | Barapa Barapa representative |
| Neville Whyman | Barapa Barapa representative |
| Joy Galway | Barapa Barapa representative |
| Robert (Ducky) Charles | Barapa Barapa representative |
| Debbie Webster | Barapa Barapa representative, North Central CMA CCC member |
| Dr. Colin Pardoe | Bio-anthropologist/ archaeologist specialising in aboriginal archaeology |
| Damien Cook | Rakali Ecological Consulting |
| Dan Huttan | Forestry NSW |
| Anna Parker | North Central CMA |
| Chris Corr | North Central CMA |
| Robyn McKay | North Central CMA |
| Bambi Less | North Central CMA indigenous facilitator |
| Bree Bisset | Field trip facilitator, North Central CMA |

**Summary:**

Connection and cultural resources:

- Johnson Swamp looks and feels healthy and provides great cultural resources. There is plenty of food, medicinal plants, mussels, eggs, and fish. A healthy wetland creates a healthy culture and therefore healthy people.
- There are a number of recorded sites around Johnson Swamp. On the 14 July 2016 field trip, several earth mounds were viewed including one that had been compromised by a track. The presence of quartz, turtle and fish bones at one mound indicated its use for food preparation.
- The wetland feels like a good place to visit, and would be a great place for camping and social gatherings, as well as providing food and fishing.
- The wetland provided a good spiritual feeling for participants. The cultural heritage and feeling of place indicates that their ancestors were here.
- The wetland would be a good place to come back to for its economic and cultural resources, and cultural connections.
- Participants expressed the following thoughts:
    - 'I'll have a great sleep tonight, after being out in the fresh air", Aunty Joy Galway
    - "It's lovely to see the little red gums coming up…" Aunty Joy Galway
    - 'A cultural landscape and should be considered sensitive'.

Wetland condition:

- The overall condition of Johnson Swamp was thought to be good.
- Some of the plant growth was considered stress due to the drawdown, but thought to improve with time.
- The birds were noted to be in good numbers during both site visits with plenty of swans. Kangaroos were also observed as well as a number of turtle nests.
- Erosion was noted at a few places at the wetland and rabbits and foxes were observed.
- The caged revegetated areas looked excellent, with the planted species growing prolifically inside the cage and not as much outside.
- A variety of vegetation was noted.

Management:

- Management of Johnson Swamp was considered to be good with the importance of maintaining an appropriate watering regime highlighted. Water timing was considered they key component in continued successful water management.
- Weeds, pigs, foxes and rabbits were considered a threat with more work required to control these species and enhance the value of the wetland.
- Species enrichment planting by Damien Cook and Uncle Ducky Charles was looked upon favourably. It was recommended that more revegetation of aquatic plants such as water ribbons and riverine swamp wallaby grass be undertaken. In addition it was recommended that more trees be replanted to replace those that have died. It was highlighted that more appropriate placement of revegetation is required.
- Water was considered to be will managed by the CMA participants noted their desire to be more actively involved in future management.

Other notes:

- Emphasis on inviting the general community onto country and to meetings to understand what is happening.
- Climate change likely to impact Johnson Swamp. Recommended that revegetation and water timing be adapted to adjust to climate change.
- Road access could be improved, particularly during wet weather.

| Community and Stakeholder Workshop |
|---|
| 20 July 2016- Goulburn Murray Water, Kerang (10 am – 2 pm) |

**Method:**

A community and stakeholder workshop was held at Goulburn Murray Water Office Kerang on the 20 July 2016. Key notes applicable to the EWMP as well as additional comments provided outside the workshop are summarised below.

**Attendees:**

| Name | Representative |
|---|---|
| Charlie Gillingham | Meeting chair, North Central CMA Board member |
| Ken Hooper | Community |
| Greg Maxwell | Community |
| Carol Maxwell | Community |
| Graeme Hill | Community |
| Colin Myers | Community |
| Craig McIntosh | Community |
| Neville Goulding | Gannawarra Shire |
| Mark Daley | Field and Game Australian |
| Erin Ashcroft | VEWH |
| Simon Starr | Birdlife Australia |
| Rob Loats | North Central CMA Community Consultative Committee member |
| Daryl Snowdon | Field and Game Australia |
| Ross Stanton | GMW |
| Tavi Manescu | Game Management Authority |
| Murray Thorson | Parks Victoria |
| Minda Murray | DELWP |
| Darren White | North Central CMA |
| Bree Bisset | Meeting facilitator, North Central CMA |

**Summary:**

History:

- Johnson Swamp is the last of four former black box wetlands on the Pyramid Creek. The first was Flannery's Swamp (now totally drained), then Rowlands Swamp (now lost but once noted for magpie geese), then Hird Swamp and Johnson Swamp. Originally these swamps would have filled when the Pyramid Creek flooded, normally in winter and spring.
- Bullock and Hope creeks may have provided a considerable volume of water to Pyramid Creek and subsequently to Johnson Swamp prior to regulation.
- Prior to dredging Pyramid Creek was very shallow and could be walked across. The creek had to be operated at a very high level to supply Kangaroo Lake irrigators and as such Hird and Johnson Swamp were maintained at constantly high levels for 8 months of the year (mid-August to mid-May). This constant level killed the black box trees and established a permanent water regime that supported cumbungi, eel weed, milfoils etc. In spite of this they were still very productive wetlands and were prime duck hunting areas in the region.
- In 1963 the Victorian Government instigated an inquiry into the use of natural streams and lakes as irrigation carriers. It was decided to excavate the Pyramid Creek from Kow Swamp to Kerang Weir, increasing the hydraulic efficient and volume of water able to be delivered downstream. Dredging was supposed to occur along the eastern boundary of both Johnson and Hird swamps; however both wetlands were dredged through the centre, creating two isolated wetland sections. This disconnected the wetlands from inflows.
- In response to dredging, Victorian Field and Game Association (now Field and Game Australia) gave evidence for the need to save the swamps, rebutting Fisheries and Wildlife submission. A Committee accepted the Field and Game evidence and directions were made to preserve Johnson and Hird swamps. This saw the installation of pumps (first in Victoria and possibly Australia) at both wetlands and the implementation of a fill regime from the 1st of September

each year to maintain both wetlands at full supply level. Under this arrangement, Field and Game made annual requisitions to treasury for the necessary funding to operate the pumps and pay for the water costs.

- Originally there was an agreement with Field and Game and State Rivers that water be provided in all years alternating between Hird Swamp and Johnson Swamp, however this agreement was never signed off due to the creation of GMW.
- Annual watering continued up until the late 1960s/ early 1970s when a failure to requisition treasury left all costs to be borne by the Field and Game budget. Consequently pumping was undertaken less frequently and the habitat began to change. In the late 1970s/ early 1980s Johnson Swamp received no water and was completely dried. Hundreds of dead carp were noted on the fringes, cumbungi exploded and hunting opportunities were lost.
- Field and Game began lobbying Fisheries and Wildlife to provide water to the wetlands. This resulted in a Field and Game delegation to the Minister for Water and Conservation (Hon Bill Borthwick) requesting immediate action to be undertaken. The director of Fisheries and Wildlife argued that pumping to the wetlands "was only cosmetic conservation" and should not occur. However the Minister noted that Fisheries and Wildlife were not carrying out the government's directions and that the issue be immediately rectified. The pumps were started within 48 hours and the health of the wetlands began to improve again. However this reprieve was only temporary and the ad-hoc and sporadic management continued into the early 1980s.
- Fisheries and Wildlife constructed the islands on the bed of Johnson Swamp in the 1980s.
- Management shifted to Parks Victoria in the 1980s. Field and Game worked with Parks Victoria during this time to achieve joint outcomes for the environment and hunters. This resulted in periods of excellent conditions and abundant birdlife. A hunter recalls observing a blue-billed duck with a clutch of ducklings while hunting.
- Water management has since shifted to the North Central CMA with a focus on biodiversity outcomes. Although this has resulted in a substantial improvement in condition, it has also been somewhat of a sore point for Field and Game. Evidence given to the Parliamentary Committee in 1963-65 when the Government accepted the Committee's recommendation what "that in the interests of preserving the wildlife and recreational attributes in the Central and Upper Section of the Torrumbarry system, the following measures be taken (which included pumping)." Field and Game ensured that Hird and Johnson swamps were not lost during the irrigation upgrades and have invested a large amount of time and money into management (i.e. built islands at Hird Swamp, planted trees, undertake fox drives and clean ups).

<u>Social, recreational and economic values:</u>

- Johnson Swamp is one of many wetlands that are favoured by hunters.
- The wetland is a State Game Reserve during the declared hunting period. It was closed during the 2016 season for hunting which led to a significant loss of hunting opportunities and income for Gannawarra Shire, its regional towns and their local businesses. Although improved biodiversity should be celebrated, the concentration of rare and threatened non-game species should not create the exclusion of use that occurred during 2016. This concentration of such species can be alleviated by implementing system-based watering as opposed to isolated wetland watering which creates single oasis of thriving biodiversity.
- Sustainable hunting is considered a valuable economic driver within Gannawarra Shire, particularly when other key sectors (i.e. agriculture) are facing challenges. It is therefore of critical importance that any future management does not eliminate the use of Johnson Swamp as a State Game Reserve.
- Management of wetlands such as Johnson Swamp cannot exclude usage, particularly in regard to the high value that Johnson Swamp delivers through hunting during the prescribed season, as well as breeding and feeding opportunities throughout the entire inundation period.
- The best hunter opportunities come from filling a wetland in early autumn, particularly when it has been dry prior. Winter-spring filling is likely to continue to result in wetland closures as it

triggers breeding and encourages threatened species to seek drought refuge at key wetlands. Autumn watering will still attract the high waterbird numbers but is unlikely to trigger breeding that early in the season when hunting is permitted. It may however extend the potential breeding and rearing cycle for waterbirds and inhibit the spread of cumbungi.

Ecological values and watering regime:

- Waterbirds are considered one of the key ecological values. The wetland has historically supported ‘100,000s’ of ibis during wet periods.
- Painted snipe (one of the most threatened waterbirds in Australia) has not been recorded at Johnson Swamp but is likely to utilise the habitat present. The species has been recorded at neighbouring Hird Swamp which supports similar vegetation.
- Presence of bittern at Johnson Swamp this year may have been caused by less rice opportunities for the species. In 2015-16 less rice was sown in New South Wales (due to increase in almonds and cotton) and there was a shift in the use of varieties with shorter growing times that are sown dry.
- Brolga chicks were sighted at Johnson Swamp in 2015-16.
- Autumn watering is considered a good compromise and will likely assist with avoiding threaten species breeding over the summer period. Species such as ibis could be a as they will continue to breed if water is supplied. This needs to be incorporated into annual management.
- Environmental water management of Johnson Swamp should include a holistic rotational approach with the other key wetlands in the area Central Murray and Boort Wetlands.

Threats and threat management:

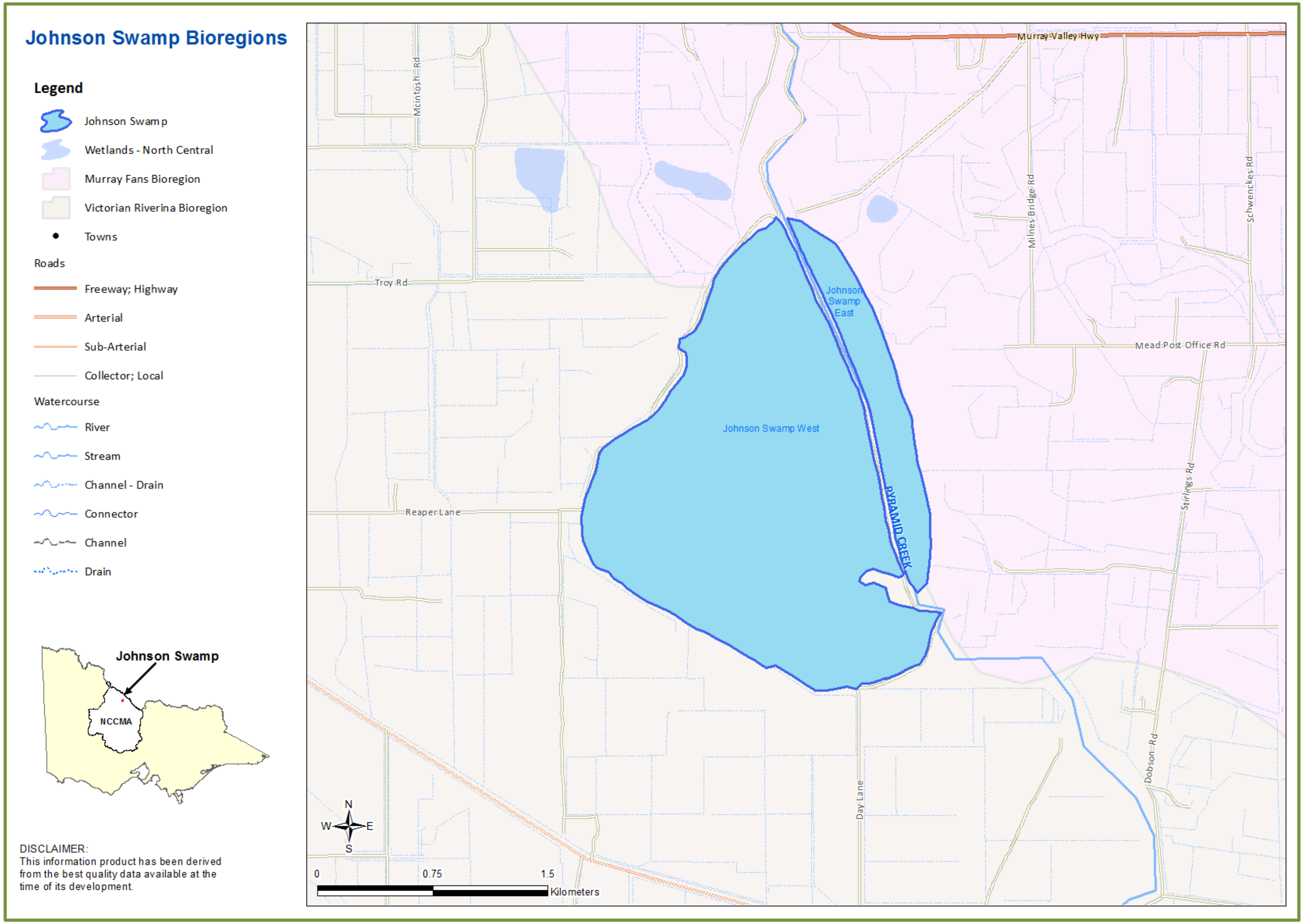
- The over germination of cumbungi is one of the major factors to consider when watering over the summer period. Summer water should still occur occasionally to provide summer refuge for fauna; however dry periods are required in between events to kill new growth. Wetlands are generally robust and can withstand flooding at any time of year and should be managed as such.
- Fire is considered an ineffective tool for management of cumbungi, and may actually increase proliferation of the species. This was observed in areas that were impacted by fire in 1992.
- Aerial spraying of cumbungi occurred historically at Johnson Swamp but stopped due to presence of an adjacent organic farm.
- Ripping of cumbungi is an effective method for control on private property, however unlikely to be utilised on public land due to damage to cultural heritage.
- Herbicides provide the best control method for cumbungi however many are not appropriate for use at wetlands, therefore slashing and drowning is considered the preferred option.
- Cumbungi extent could be monitored using drones and Landsat images.
- Lignum is starting to takeover centre of wetland which historically was clear open water.
- The new synesthetic baiting techniques for foxes are less effective than traditional methods. Predator saturation is effective and should be considered when waterbirds are breeding. Greater action is required to control pest animals.
- Old man Saltbush is coming back post 2010-11 floods.
- Release of pigs for hunting occurs in the area. They are present at Johnson Swamp, although more frequent sighted at Hird Swamp. They travel between the two wetlands via the riparian vegetation of Pyramid Creek.
- A dead deer was recently found at Hird Swamp. Deer are increasingly becoming an issue, however classified as a game species, not a pest.

Complementary management:

- There is no point undertaking revegetation if plants don’t survive. Need to consider which plants are best suited to the environment (i.e. deep rotted plants may not survive if groundwater levels to high) and undertake appropriate preparation and follow up (including weeding and watering) to ensure money is not wasted.

- Planting of river red gums should be undertaken with caution as the species can form dense thickets. This can prevent sunlight from reaching understory native plants and may reduce the habitat available for open water foraging species such as brolga. Planting should only occur in small areas with stem densities below 40 per hectare to prevent the formation of a monocultre. If required drowning of seedlings or mechanical/ chemical removal should be undertaken. Alternative species that could be planted in the riparian zone include black box, eremophilas, sugarwood and moonah (particularly good for insects). With time Black box will provide the hollows needed for fauna. This process can be accelerated by termites which are more likely to be active in the riparian zone.
- Consider moving outlet structure to Pyramid Creek to a more northerly position to facilitate more natural through flow.

## Appendix 2: Johnson Swamp Bioregions



## Appendix 3: Central Murray EWAG membership (as at 1 July 2016)

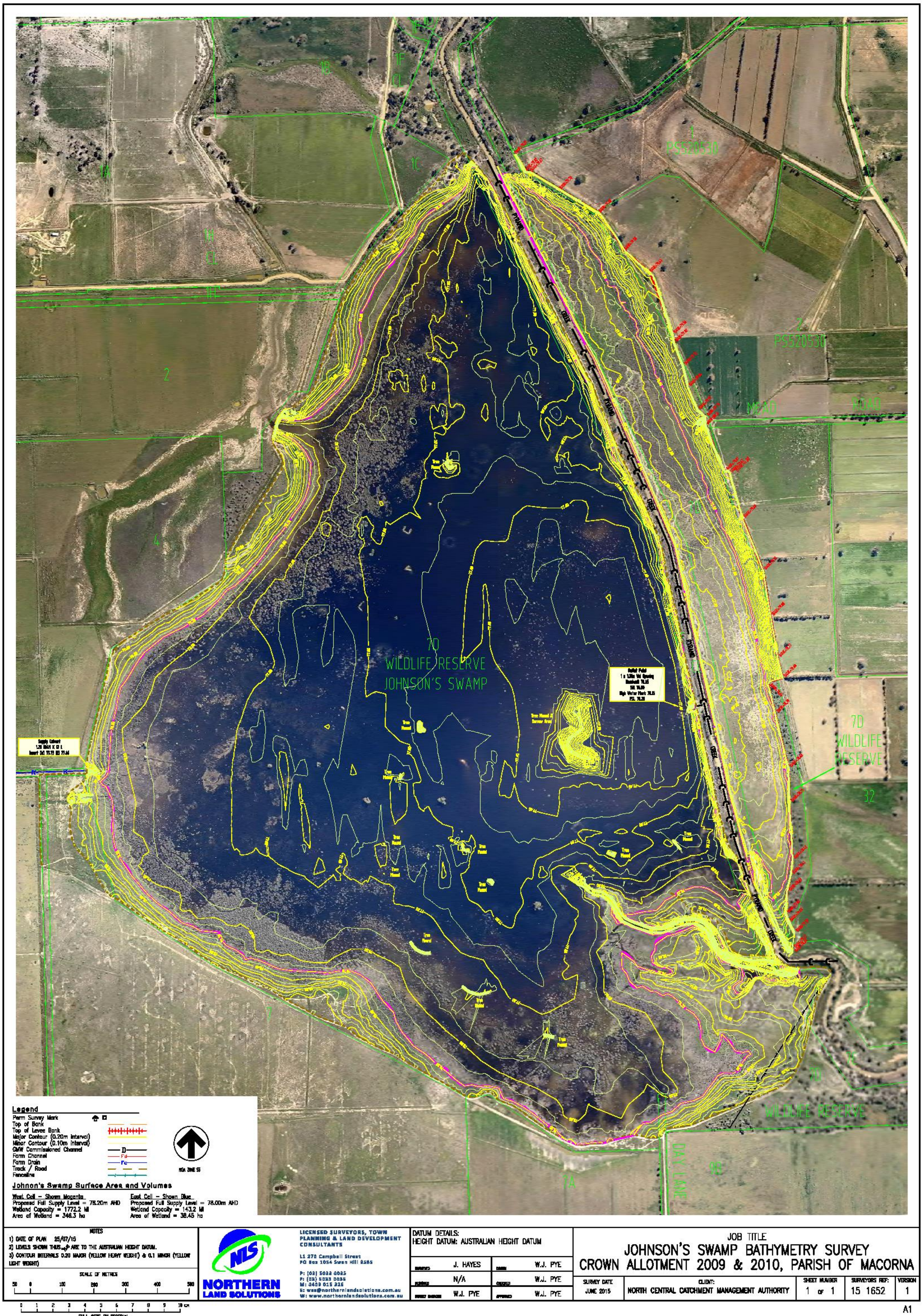
| Name of Member | Organisation/representation |
|---|---|
| Active members | |
| Amy Russell | North Central CMA staff member |
| Andrea Keleher/ Mick Dedini | Department of Land, Water and Planning |
| Benjamin Hall | Community |
| Betty Waterson | Community |
| Bree Bisset | North Central CMA staff member |
| Charlie Gillingham | North Central CMA Board |
| Darren White | North Central CMA staff member |
| Dianne Bowles | North Central CMA Board/ MEWAG Chair |
| Erin Ashcroft | Victorian Environmental Water Holder |
| Geoff Rollinson | Gannawarra Shire Council |
| Harry Pugh | Community |
| Helen Tresize | Community |
| Keith Stockwell/ Simon Starr | BirdLife Australia |
| Ken and Jill Hooper | Community/ private wetland landholder |
| Khane Mason/ Ross Stanton | Goulburn Murray Water |
| Leeza Wishart/ Murray Thorson | Parks Victoria |
| Mark Daley | Field and Game Australia |
| Rob Loats | North Central CMA Community Consultative Committee |
| Samuel Steel | Swan Hill Rural City Council |
| Stan Archard | Community |
| Tuesday Browell | Community |
| Corresponding members | |
| Bruce McBeath | Community |
| Kerry Webber | Commonwealth Environment Water Holder |
| Mark Jones/ Simon Toop/ Tavi Manescu | Game Management Authority |

## Appendix 4: Johnson Swamp capacity table and bathymetry

| JOHNSON SWAMP WEST | | | | |
|---|---|---|---|---|
| Water Level (WL) Range AHD WL from: | AHD WL to: | Capacity (ML) | Accumulative capacity (ML) | Surface Area (ha) |
| 76.70 | 76.70 | 0.0 | 0.0 | 0.0 |
| 76.70 | 76.75 | 0.0 | 0.0 | 0.0 |
| 76.75 | 76.80 | 0.0 | 0.0 | 0.0 |
| 76.80 | 76.85 | 0.0 | 0.0 | 0.0 |
| 76.85 | 76.90 | 0.0 | 0.0 | 0.1 |
| 76.90 | 76.95 | 0.2 | 0.2 | 0.6 |
| 76.95 | 77.00 | 0.4 | 0.6 | 1.0 |
| 77.00 | 77.05 | 0.7 | 1.3 | 1.7 |
| 77.05 | 77.10 | 1.0 | 2.3 | 2.2 |
| 77.10 | 77.15 | 1.2 | 3.5 | 2.7 |
| 77.15 | 77.20 | 1.5 | 5.0 | 3.3 |
| 77.20 | 77.25 | 2.1 | 7.0 | 5.2 |
| 77.25 | 77.30 | 4.6 | 11.6 | 17.9 |
| 77.30 | 77.35 | 13.8 | 25.4 | 35.5 |
| 77.35 | 77.40 | 20.6 | 46.1 | 47.2 |
| 77.40 | 77.45 | 26.7 | 72.7 | 59.8 |
| 77.45 | 77.50 | 35.4 | 108.2 | 83.1 |
| 77.50 | 77.55 | 47.9 | 156.1 | 108.3 |
| 77.55 | 77.60 | 60.1 | 216.2 | 133.4 |
| 77.60 | 77.65 | 72.2 | 288.4 | 155.7 |
| 77.65 | 77.70 | 83.8 | 372.2 | 181.3 |
| 77.70 | 77.75 | 96.5 | 468.7 | 204.1 |
| 77.75 | 77.80 | 107.0 | 575.6 | 223.4 |
| 77.80 | 77.85 | 118.3 | 693.9 | 249.3 |
| 77.85 | 77.90 | 131.4 | 825.3 | 280.1 |
| 77.90 | 77.95 | 143.5 | 968.8 | 293.9 |
| 77.95 | 78.00 | 150.3 | 1119.1 | 307.2 |
| 78.00 | 78.05 | 156.5 | 1275.6 | 317.6 |
| 78.05 | 78.10 | 161.0 | 1436.6 | 326.5 |
| 78.10 | 78.15 | 165.5 | 1602.1 | 335.5 |
| 78.15 | 78.20 | 170.1 | 1772.2 | 346.3 |
| 78.20 | 78.25 | 174.2 | 1946.5 | 350.6 |
| 78.25 | 78.30 | 176.3 | 2122.8 | 354.7 |
| 78.30 | 78.35 | 178.4 | 2301.2 | 358.8 |
| 78.35 | 78.40 | 180.4 | 2481.6 | 362.8 |
| 78.40 | 78.45 | 182.8 | 2664.4 | 367.7 |
| 78.45 | 78.50 | 184.9 | 2849.3 | 371.8 |
| 78.50 | 78.55 | 186.7 | 3036.0 | 375.0 |
| 78.55 | 78.60 | 188.2 | 3224.2 | 378.0 |
| 78.60 | 78.65 | 190.0 | 3414.2 | 381.6 |
| 78.65 | 78.70 | 191.5 | 3605.8 | 384.4 |
| 78.70 | 78.75 | 192.9 | 3798.6 | 387.0 |
| 78.75 | 78.80 | 194.2 | 3992.8 | 390.3 |
| 78.80 | 78.85 | 195.7 | 4188.5 | 392.6 |
| 78.85 | 78.90 | 196.8 | 4385.3 | 394.5 |
| **Key:**<br>**Blue=** designated FSL | | | | |

| JOHNSON SWAMP EAST | | | | |
|---|---|---|---|---|
| **Water Level (WL) Range AHD WL from:** | **AHD WL to:** | **Capacity (ML)** | **Accumulative capacity (ML)** | **Surface Area (ha)** |
| 77.15 | 77.20 | 0.1 | 0.2 | 0.4 |
| 77.20 | 77.25 | 0.3 | 0.5 | 0.8 |
| 77.25 | 77.30 | 0.6 | 1.1 | 1.4 |
| 77.30 | 77.35 | 0.9 | 2.0 | 2.3 |
| 77.35 | 77.40 | 1.7 | 3.6 | 5.3 |
| 77.40 | 77.45 | 3.4 | 7.0 | 8.1 |
| 77.45 | 77.50 | 4.7 | 11.7 | 10.9 |
| 77.50 | 77.55 | 6.3 | 18.0 | 14.2 |
| 77.55 | 77.60 | 7.9 | 26.0 | 17.6 |
| 77.60 | 77.65 | 9.6 | 35.6 | 20.9 |
| 77.65 | 77.70 | 11.3 | 46.8 | 24.1 |
| 77.70 | 77.75 | 12.9 | 59.7 | 27.5 |
| 77.75 | 77.80 | 14.4 | 74.2 | 30.1 |
| 77.80 | 77.85 | 15.7 | 89.8 | 32.5 |
| 77.85 | 77.90 | 16.8 | 106.6 | 34.6 |
| 77.90 | 77.95 | 17.8 | 124.4 | 36.5 |
| 77.95 | 78.00 | 18.8 | 143.2 | 38.5 |
| 78.00 | 78.05 | 19.7 | 162.9 | 40.2 |
| 78.05 | 78.10 | 20.4 | 183.3 | 41.4 |
| 78.10 | 78.15 | 21.0 | 204.3 | 42.4 |
| 78.15 | 78.20 | 21.4 | 225.6 | 43.1 |
| 78.20 | 78.25 | 21.7 | 247.3 | 43.8 |
| 78.25 | 78.30 | 22.0 | 269.4 | 44.4 |
| 78.30 | 78.35 | 22.3 | 291.7 | 44.9 |
| 78.35 | 78.40 | 22.6 | 314.3 | 45.5 |
| 78.40 | 78.45 | 22.9 | 337.2 | 46.0 |
| 78.45 | 78.50 | 23.1 | 360.3 | 46.5 |
| 78.50 | 78.55 | 23.4 | 383.6 | 46.9 |
| 78.55 | 78.60 | 23.6 | 407.2 | 47.4 |
| 78.60 | 78.65 | 23.8 | 431.0 | 47.8 |
| 78.65 | 78.70 | 24.0 | 455.0 | 48.2 |
| 78.70 | 78.75 | 24.2 | 479.3 | 48.7 |
| 78.75 | 78.80 | 24.5 | 503.7 | 49.1 |
| 78.80 | 78.85 | 24.7 | 528.4 | 49.7 |
| 78.85 | 78.90 | 25.0 | 553.4 | 50.5 |
| 78.90 | 78.95 | 25.4 | 578.9 | 51.3 |
| 78.95 | 79.00 | 25.8 | 604.7 | 51.9 |
| 79.00 | 79.05 | 26.1 | 630.7 | 52.4 |
| 79.05 | 79.10 | 26.3 | 657.1 | 52.8 |
| 79.10 | 79.15 | 26.5 | 683.6 | 53.2 |
| 79.15 | 79.20 | 26.7 | 710.3 | 53.5 |

**Key:**
**Blue=** designated FSL
Source: NLS 2015


7D
WILDLIFE RESERVE
JOHNSON'S SWAMP
7D
WILDLIFE
RESERVE
32
PS520530
WILDLIFE RESERVE
DAY LANE
7A
9B
Legend
Perm Survey Mark
Top of Bank
Top of Levee Bank
Major Contour (0.20m interval)
Minor Contour (0.10m interval)
GMW Commissioned Channel
Farm Channel
Farm Drain
Track / Road
Fenceline
D
Fd
Fc
MGA ZONE 55
Johnon's Swamp Surface Area and Volumes
West Cell – Shown Magenta
Proposed Full Supply Level = 78.20m AHD
Wetland Capacity = 1772.2 Ml
Area of Wetland = 346.3 ha
East Cell – Shown Blue
Proposed Full Supply Level = 78.00m AHD
Wetland Capacity = 143.2 Ml
Area of Wetland = 38.45 ha
NOTES
1) DATE OF PLAN 25/07/15
2) LEVELS SHOWN THUS ARE TO THE AUSTRALIAN HEIGHT DATUM.
3) CONTOUR INTERVALS 0.20 MAJOR (YELLOW HEAVY WEIGHT) & 0.1 MINOR (YELLOW LIGHT WEIGHT)
SCALE OF METRES
50 0 100 200 300 400 500
0 1 2 3 4 5 6 7 8 9 10 cm
FULL SIZE ON ORIGINAL
NORTHERN LAND SOLUTIONS
LICENSED SURVEYORS, TOWN PLANNING & LAND DEVELOPMENT CONSULTANTS
L1 278 Campbell Street
PO Box 1054 Swan Hill 3585
P: (03) 5032 0025
F: (03) 5033 0036
M: 0409 015 326
E: wes@northernlandsolutions.com.au
W: www.northernlandsolutions.com.au
DATUM DETAILS:
HEIGHT DATUM: AUSTRALIAN HEIGHT DATUM
J. HAYES
W.J. PYE
N/A
W.J. PYE
W.J. PYE
W.J. PYE
JOB TITLE
JOHNSON'S SWAMP BATHYMETRY SURVEY
CROWN ALLOTMENT 2009 & 2010, PARISH OF MACORNA
SURVEY DATE
JUNE 2015
CLIENT:
NORTH CENTRAL CATCHMENT MANAGEMENT AUTHORITY
SHEET NUMBER
1 OF 1
SURVEYORS REF:
15 1652
VERSION
1
A1

## Appendix 5: Fauna species list

| Common Name | Scientific Name | Last record | Data Source |
|---|---|---|---|
| **Terrestrial birds** | | | |
| Australasian Pipit | *Anthus novaeseelandiae* | 2013 | BirdLife Australia 2016a |
| Australian Hobby | *Falco longipennis* | 2016 | Ermaea eBird 2016 |
| Australian Magpie^ | *Cracticus tibicen* | 2016 | Rakali 2015 |
| Australian Owlet nightjar | *Aegotheles cristatus* | 2016 | Rakali 2015 |
| Australian Raven^ | *Corvus coronoides* | 2016 | Rakali 2015 |
| Barn Owl | - | 2016 | Rakali 2015 |
| Black Falcon | *Falco subniger* | 2005 | Ermaea eBird 2016 |
| Black Kite^ | *Milvus migrans* | 2016 | Ermaea eBird 2016 |
| **Black-eared Cuckoo** | ***Chalcites osculans*** | **2005** | **BirdLife Australia 2016a** |
| Black-faced Cuckoo-shrike^ | *Coracina novaehollandiae* | 2016 | Ermaea eBird 2016 |
| Black-faced Woodswallow^ | *Artamus cinereus* | 2006 | BirdLife Australia 2016a |
| Black-shouldered Kite | *Elanus axillaris* | 2016 | Rakali 2015 |
| Brown Falcon^ | *Falco berigora* | 2016 | Rakali 2015 |
| Brown Goshawk | *Accipiter fasciatus* | 2016 | Rakali 2015 |
| **Brown Quail^** | ***Coturnix ypsilophora*** | **2016** | **Rakali 2015** |
| Brown Songlark | *Cincloramphus cruralis* | 2016 | Ermaea eBird 2016 |
| Brown Treecreeper | *Climacteris picumnus* | 2016 | Ermaea eBird 2016 |
| **Brown Treecreeper** | ***Climacteris picumnus victoriae*** | **2000** | **VBA 2016** |
| Chestnut-rumped Thornbill | *Acanthiza uropygialis* | 2016 | Rakali 2015 |
| Collared Sparrowhawk | *Accipiter cirrocephalus* | U | VBA 2016 |
| Common Bronzewing | *Phaps chalcoptera* | 2015 | Ermaea eBird 2016 |
| Crested Pigeon | *Ocyphaps lophotes* | 2016 | Rakali 2015 |
| Crested Shrike-tit^ | *Falcunculus frontatus* | 2001 | BirdLife Australia 2016a |
| Dusky Woodswallow^ | *Artamus cyanopterus* | 2016 | Ermaea eBird 2016 |
| Eastern Rosella^ | *Platycercus eximius* | 2016 | Rakali 2015 |
| Fairy Martin^ | *Petrochelidon ariel* | 2016 | Ermaea eBird 2016 |
| Flame Robin | *Petroica phoenicea* | 2012 | Ermaea eBird 2016 |
| Galah | *Eolophus roseicapilla* | 2016 | Rakali 2015 |
| Golden-headed Cisticola | *Cisticola exilis* | 2016 | Rakali 2015 |
| Grey Shrike-thrush^ | *Colluricincla harmonica* | 2016 | Ermaea eBird 2016 |
| Grey-crowned Babbler^ | *Pomatostomus temporalis* | 2001 | BirdLife Australia 2016a |
| Horsfield’s Bushlark | *Mirafra javanica* | 2014 | Rakali 2014a |
| Horsfield's Bronze-Cuckoo^ | *Chalcites basalis* | 2015 | Rakali 2015 |
| Little Eagle | *Hieraaetus morphnoides* | 2015 | Ermaea eBird 2016 |
| Little Grassbird^ | *Megalurus gramineus* | 2016 | Rakali 2015 |
| Little Raven | *Corvus mellori* | 2016 | Rakali 2015 |
| Long-billed Corella | *Cacatua tenuirostris* | 2016 | Rakali 2015 |
| Magpie-lark^ | *Grallina cyanoleuca* | 2016 | Rakali 2015 |
| Noisy Miner | *Manorina melanocephala* | 2016 | Rakali 2015 |
| Peregrine Falcon | *Falco peregrinus* | 2016 | Rakali 2015 |
| Pied Butcherbird | *Cracticus nigrogularis* | 2016 | Rakali 2015 |
| Rainbow Bee-eater^ | *Merops ornatus* | 2001 | BirdLife Australia 2016a |
| Red-browed Finch | *Neochmia temporalis* | 2016 | Ermaea eBird 2016 |
| Red-capped Robin | *Petroica goodenovii* | 2015 | Ermaea eBird 2016 |
| Red-rumped Parrot^ | *Psephotus haematonotus* | 2016 | Rakali 2015 |
| Rock Dove | *Columba livia* | 2016 | Ermaea eBird 2016 |
| Rufous Songlark | *Cincloramphus mathewsi* | 2011 | Ermaea eBird 2016 |
| Rufous Whistler | *Pachycephala rufiventris* | 1999 | BirdLife Australia 2016a |
| Silvereye | *Zosterops lateralis* | 2016 | Ermaea eBird 2016 |
| Southern Whiteface | *Aphelocephala leucopsis* | 2016 | Ermaea eBird 2016 |
| Striated Pardalote | *Pardalotus striatus* | 2014 | Rakali 2014a |
| Stubble Quail^ | *Coturnix pectoralis* | 2005 | Ermaea eBird 2016 |
| Superb Fairy-wren^ | *Malurus cyaneus* | 2016 | Rakali 2015 |
| Tree Martin^ | *Petrochelidon nigricans* | 2016 | Rakali 2015 |
| Variegated Fairy-wren | *Malurus lamberti* | 2015 | Ermaea eBird 2016 |
| Wedge-tailed Eagle | *Aquila audax* | 2016 | Rakali 2015 |
| Weebill | *Smicrornis brevirostris* | 2016 | Rakali 2015 |

| Common Name | Scientific Name | Last record | Data Source |
|---|---|---|---|
| Welcome Swallow^ | *Hirundo neoxena* | 2016 | Rakali 2015 |
| Whistling Kite | *Haliastur sphenurus* | 2016 | DELWP 2016a |
| White-backed Swallow | *Cheramoeca leucosterna* | 2016 | Rakali 2015 |
| White-breasted Woodswallow^ | *Artamus leucorynchus* | 2016 | Rakali 2015 |
| White-browed Woodswallow | *Artamus superciliosus* | 2016 | Ermaea eBird 2016 |
| White-fronted Chat^ | *Epthianura albifrons* | 2016 | DELWP 2016a |
| White-plumed Honeyeater | *Lichenostomus penicillatus* | 2016 | Rakali 2015 |
| **White-throated needletail** | ***Hirundapus caudacutus*** | **2016** | **Rakali 2015** |
| White-winged Fairy-wren | *Malurus leucopterus* | 2016 | Rakali 2015 |
| White-winged Triller | *Lalage sueurii* | 2003 | BirdLife Australia 2016a |
| Willie Wagtail^ | *Rhipidura leucophrys* | 2016 | Rakali 2015 |
| Yellow-rumped Thornbill^ | *Acanthiza chrysorrhoa* | 2016 | Rakali 2015 |
| Zebra Finch^ | *Taeniopygia guttata* | 2016 | Rakali 2015 |
| **Fish** | | | |
| Australian Smelt | *Retropinna semoni* | 1989 | VBA 2016 |
| **Amphibians** | | | |
| Barking Marsh Frog | *Limnodynastes fletcheri* | 2016 | Rakali 2015 |
| Common Froglet | *Crinia signifera* | 2015 | Rakali 2015 |
| **Growling Grass Frog** | ***Litoria raniformis*** | **1982** | **VBA 2016** |
| Peron's Tree Frog | *Litoria peroni* | 2016 | Rakali 2015 |
| Plains Froglet | *Crinia parinsignifera* | 2015 | Rakali 2015 |
| Pobbleblonk | *Limnodynastes dumerili* | 2016 | Rakali 2015 |
| Spotted Marsh Frog | *Limnodynastes tasmaniensis* | 2016 | Rakali 2015 |
| **Mammals** | | | |
| Common Brushtail Possum | *Trichosurus vulpecula* | 1982 | VBA 2016 |
| Eastern Grey Kangaroo | *Macropus giganteus* | 2015 | Rakali 2015 |
| Swamp Wallaby | *Wallabia bicolor* | 2015 | Rakali 2015 |
| Water Rat | *Hydromys chrysogaster* | 1982 | VBA 2016 |
| White-striped Freetail Bat | *Tadarida australis* | 1982 | VBA 2016 |
| **Reptiles** | | | |
| Boulenger's Skink | *Morethia boulengeri* | 2015 | Rakali 2015 |
| **Carpet Python** | ***Morelia spilota metcalfei*** | **2001** | **VBA 2016** |
| **Eastern long-necked turtle** | ***Chelodina longicollis*** | **2015** | **Rakali 2015** |
| Tiger Snake | *Notechis scutatus* | 2015 | Rakali 2015 |
| **Waterbirds** | | | |
| **Australasian Bittern^** | ***Botaurus poiciloptilus*** | **2016** | **Rakali 2015** |
| Australasian Darter | *Anhinga novaehollandiae* | 2016 | DELWP 2016a |
| Australasian Grebe | *Tachybaptus novaehollandiae* | 2016 | DELWP 2016a |
| Australian Reed-Warbler | *Acrocephalus australis* | 2016 | Rakali 2015 |
| **Australasian Shoveler** | ***Anas rhynchotis*** | **2016** | **DELWP 2016a** |
| **Australian Little Bittern^** | ***Ixobrychus dubius*** | **2016** | **Rakali 2015** |
| Australian Pelican | *Pelecanus conspicillatus* | 2016 | DELWP 2016a |
| Australian Shelduck^ | *Tadorna tadornoides* | 2016 | DELWP 2016a |
| Australian Spotted Crake | *Porzana fluminea* | 2016 | Rakali 2015 |
| Australian White Ibis | *Threskiornis moluca* | 2016 | DELWP 2016a |
| Australian Wood Duck^ | *Chenonetta jubata* | 2016 | DELWP 2016a |
| **Balions Crake** | ***Porzana pusilla palustris*** | **2015** | **Rakali 2015** |
| Black Swan^ | *Cygnus atratus* | 2016 | DELWP 2016a |
| Black-fronted Dotterel | *Elseyornis melanops* | 2016 | DELWP 2016a |
| Black-tailed Native-hen | *Tribonyx ventralis* | 2016 | DELWP 2016a |
| Black-winged Stilt | *Himantopus himantopus* | 2016 | DELWP 2016a |
| **Blue-billed Duck** | ***Oxyura australis*** | **2016** | **DELWP 2016a** |
| **Brolga^** | ***Grus rubicunda*** | **2016** | **DELWP 2016a** |
| Buff-banded Rail | *Gallirallus philippensis* | 2016 | Rakali 2015 |
| **Cattle Egret** | ***Ardea ibis*** | **2002** | **VBA 2016** |
| **Common Greenshank** | ***Tringa nebularia*** | **2006** | **BirdLife Australia 2016a** |
| Chestnut Teal | *Anas castanea* | 2016 | DELWP 2016a |
| Dusky Moorhen | *Gallinula tenebrosa* | 2016 | Rakali 2015 |
| **Eastern Great Egret** | ***Ardea modesta*** | **2016** | **Rakali 2015** |
| Eurasian Coot | *Fulica atra* | 2016 | DELWP 2016a |

| Common Name | Scientific Name | Last record | Data Source |
|---|---|---|---|
| **Freckled Duck** | ***Stictonetta naevosa*** | **2016** | **DELWP 2016a** |
| **Glossy Ibis** | ***Plegadis falcinellus*** | **2016** | **DELWP 2016a** |
| Great Cormorant | *Phalacrocorax carbo* | 2016 | DELWP 2016a |
| Great Crested Grebe^ | *Podiceps cristatus* | 2016 | DELWP 2016a |
| Great Egret | *Ardea alba* | 2016 | DELWP 2016a |
| Grey Teal^ | *Anas gracilis* | 2016 | DELWP 2016a |
| **Hardhead** | ***Aythya australis*** | **2016** | **DELWP 2016a** |
| Hoary-headed Grebe | *Poliocephalus poliocephalus* | 2016 | DELWP 2016a |
| **Intermediate Egret** | ***Ardea intermedia*** | **2014** | **Rakali 2014b** |
| **Latham's Snipe** | ***Gallinago hardwickii*** | **2016** | **DELWP 2016a** |
| Lewin's Rail | *Lewinia pectoralis* | 2016 | Ermaea eBird 2016 |
| Little Black Cormorant | *Phalacrocorax sulcirostris* | 2016 | DELWP 2016a |
| Little Pied Cormorant | *Microcarbo melanoleucos* | 2016 | DELWP 2016a |
| **Marsh Sandpiper** | ***Tringa stagnatilis*** | **2016** | **Rakali 2015** |
| Masked Lapwing^ | *Vanellus miles* | 2016 | DELWP 2016a |
| **Musk Duck** | ***Biziura lobata*** | **2016** | **Rakali 2015** |
| Nankeen Kestrel | *Falco cenchroides* | 2016 | Rakali 2015 |
| **Nankeen Night Heron** | ***Nycticorax caledonicus*** | **2016** | **Rakali 2015** |
| Pacific Black Duck^ | *Anas superciliosa* | 2016 | DELWP 2016a |
| **Pied Cormorant** | ***Phalacrocorax varius*** | **2014** | **Rakali 2014b** |
| Pink-eared Duck | *Malacorhynchus membranaceus* | 2016 | DELWP 2016a |
| Purple Swamphen | *Porphyrio porphyrio* | 2016 | DELWP 2016a |
| Red-kneed Dotterel^ | *Erythrogonys cinctus* | 2016 | DELWP 2016a |
| Red-necked advocet | *Recurvirostra novaehollandiae* | 2016 | DELWP 2016a |
| **Red-necked Stint** | ***Calidris ruficollis*** | **2006** | **BirdLife Australia 2016a** |
| **Royal Spoonbill** | ***Platalea regia*** | **2016** | **DELWP 2016a** |
| Sacred Kingfisher | *Todiramphus sanctus* | 2014 | Rakali 2014a |
| **Sharp-tailed Sandpiper** | ***Calidris acuminata*** | **2016** | **DELWP 2016a** |
| Silver Gull | *Chroicocephalus novaehollandiae* | 2016 | DELWP 2016a |
| Spotless Crake | *Porzana tabuensis* | 2016 | Rakali 2015 |
| Straw-necked Ibis | *Threskiornis spinicollis* | 2016 | DELWP 2016a |
| Swamp Harrier | *Circus approximans* | 2016 | DELWP 2016a |
| **Whiskered Tern** | ***Chlidonias hybrida*** | **2016** | **Rakali 2015** |
| **White-bellied Sea-Eagle** | ***Haliaeetus leucogaster*** | **2016** | **DELWP 2016a** |
| White-faced Heron | *Egretta novaehollandiae* | 2016 | DELWP 2016a |
| White-necked Heron^ | *Ardea pacifica* | 2016 | DELWP 2016a |
| **White-winged Black Tern** | ***Chlidonias leucopterus*** | **2005** | **Ermaea eBird 2016** |
| **Wood Sandpiper** | ***Tringa glareola*** | **2006** | **BirdLife Australia 2016a** |
| Yellow-billed Spoonbill | *Platalea flavipes* | 2016 | DELWP 2016a |
| Marsh Harrier | | 2016 | DELWP 2016a |
| **Introduced species** | | | |
| Brown Hare | *Lepus capenis* | 2015 | Rakali 2015 |
| Common Starling^ | *Sturnus vulgaris* | 2016 | Rakali 2015 |
| Deer | *Cervus spp.* | 2015 | Anecdotal |
| Eastern Gambusia | *Gambusia holbrooki* | 1989 | VBA 2016 |
| Common Carp | *Cyprinus carpio* | 1975 | VBA 2016 |
| European Goldfinch | *Carduelis carduelis* | 2012 | Ermaea eBird 2016 |
| European Rabbit | *Oryctolagus cuniculus* | 2015 | Rakali 2015 |
| Goldfish | *Carassius auratus* | 1981 | VBA 2016 |
| House Sparrow^ | *Passer domesticus* | 2016 | Rakali 2015 |
| Feral pig | *Sus scrofa* | 2015 | Anecdotal |
| Red Fox | *Vulpes vulpes* | 2015 | Rakali 2015 |
| Redfin | *Perca fluviatilis* | 1975 | VBA 2016 |
| Sheep | *Ovis aries* | 2015 | Rakali 2015 |
| Tench | *fam. Cyprinidae gen. Tinca* | 1975 | VBA 2016 |
| **Key:**<br>**^**= breeding recorded<br>**Bold**= significant species | | | |

## Appendix 6: Flora species list

| Common Name | Scientific Name | Type | year of record | Data Source |
|---|---|---|---|---|
| **Native flora** | | | | |
| Annual Cudweed | *Euchiton sphaericus* | D/ MF | 2015 | Rakali 2015 |
| Berry Saltbush | *Atriplex semibaccata* | T | 2015 | Rakali 2015 |
| Black Box | *Eucalyptus largiflorens* | AM/ GD | 2015 | Rakali 2015 |
| **Black Roly-poly** | ***Sclerolaena muricata*** | **T** | **2015** | **Rakali 2015** |
| Blackseed Glasswort | *Tecticornia pergranulata subsp. pergranulata* | GD | 2015 | Rakali 2015 |
| Blunt Pondweed | *Potamogeton ochreatus* | OA | 2015 | Rakali 2015 |
| **Branching Groundsel** | ***Senecio cunninghamii var. cunninghamii*** | **AM** | **2015** | **Rakali 2015** |
| Bristly Wallaby-grass | *Rytidosperma setaceum var. setaceum* | T | 2015 | Rakali 2015 |
| Broad-leaf Cumbungi | *Typha orientalis* | AM | 2015 | Rakali 2015 |
| **Brown Beetle-grass** | ***Leptochloa fusca subsp. fusca*** | **AM** | **2015** | **Rakali 2015** |
| Bulrush | *Typha spp.* | AM | 2015 | Rakali 2015 |
| Clove-strip | *Ludwigia peploides subsp. montevidensis* | AM | 2015 | Rakali 2015 |
| Coarse Water-milfoil | *Myriophyllum caput-medusae* | AM | 2015 | Rakali 2015 |
| Common Blown-grass | *Lachnagrostis filifolia s.l* | AM/ MF | 2015 | Rakali 2015 |
| Common Cotula | *Cotula australis* | T | 2014 | Rakali 2014a |
| Common Nardoo | *Marsilea drummondii* | AM | 2015 | Rakali 2015 |
| Common Reed | *Phragmites australis* | AM | 2015 | Rakali 2015 |
| Common Sneezeweed | *Centipeda cunninghamii* | - | 1986 | VBA 2016 |
| Common Spike-sedge | *Eleocharis acuta* | AM | 2015 | Rakali 2015 |
| Common Swamp Wallaby-grass | *Amphibromus nervosus* | AM | 2015 | Rakali 2015 |
| Common Wallaby-grass | *Rytidosperma caespitosum* | T | 2015 | Rakali 2015 |
| Corky Saltbush | *Atriplex lindleyi subsp. inflata* | T | 2015 | Rakali 2015 |
| Cotton Fireweed | *Senecio quadridentatus* | T | 2015 | Rakali 2015 |
| Cottony Saltbush | *Chenopodium curvispicatum* | - | 1997 | VBA 2016 |
| Couch | *Cynodon dactylon* | - | 1986 | VBA 2016 |
| Creeping Monkey-flower | *Mimulus repens* | AM /MF | 2015 | Rakali 2015 |
| Curly Pondweed | *Potamogeton crispus* | OA | 2015 | Rakali 2015 |
| Dense Crassula | *Crassula colorata* | T | 2015 | Rakali 2015 |
| Drooping Cassinia | *Cassinia arcuata* | T | 2015 | Rakali 2015 |
| Eel Grass | *Vallisneria americana var. americana* | OA | 2015 | Rakali 2015 |
| Eumong | *Acacia stenophylla#* | AM/ GD | 2015 | Rakali 2015 |
| Fennel Pondweed | *Potamogeton pectinatus* | OA | 2015 | Rakali 2015 |
| Finger Rush | *Juncus subsecundus* | D | 2014 | Rakali 2014a |
| Flat Spurge | *Euphorbia drummondii* | T | 2015 | Rakali 2015 |
| **Floodplain Fireweed** | ***Senecio campylocarpus*** | **D** | **2015** | **Rakali 2015** |
| Forde Poa | *Poa fordeana* | AM | 2015 | Rakali 2015 |
| Furrowed Pondweed+ | *Potamogeton sulcatus* | OA | 2015 | Rakali 2015 |
| Fuzzy New Holland Daisy | *Vittadinia cuneata* | T | 2015 | Rakali 2015 |
| Giant Rush | *Juncus ingens* | AM | 2015 | Rakali 2015 |
| Gold Rush | *Juncus flavidus* | AM | 2015 | Rakali 2015 |
| Grassland Wood-sorrel | *Oxalis perennans* | D/ T | 2015 | Rakali 2015 |
| Grey Roly-poly | *Sclerolaena muricata var. villosa* | T | 2015 | Rakali 2015 |
| Hairy Willow-herb | *Epilobium hirtigerum* | AM/ D/ T | 2015 | Rakali 2015 |
| Hedge Saltbush# | *Rhagodia spinescens* | T | 2015 | Rakali 2015 |
| Hornwort+ | *Ceratophyllum demersum* | OA | 2015 | Rakali 2015 |
| Indian Cudweed | *Gnaphalium polycaulon* | MF | 2015 | Rakali 2015 |
| Jersey Cudweed | *Helichrysum luteoalbum* | T | 2015 | Rakali 2015 |
| Joint-leaf Rush | *Juncus holoschoenus* | AM | 2015 | Rakali 2015 |
| Lesser Joyweed | *Alternanthera denticulata* | AM/ MF | 2015 | Rakali 2015 |
| Lesser Sea-spurrey | *Spergularia marina s.s.* | MF/ T | 2015 | Rakali 2015 |
| Mousetail | *Myosurus australis* | MF | 2015 | Rakali 2015 |

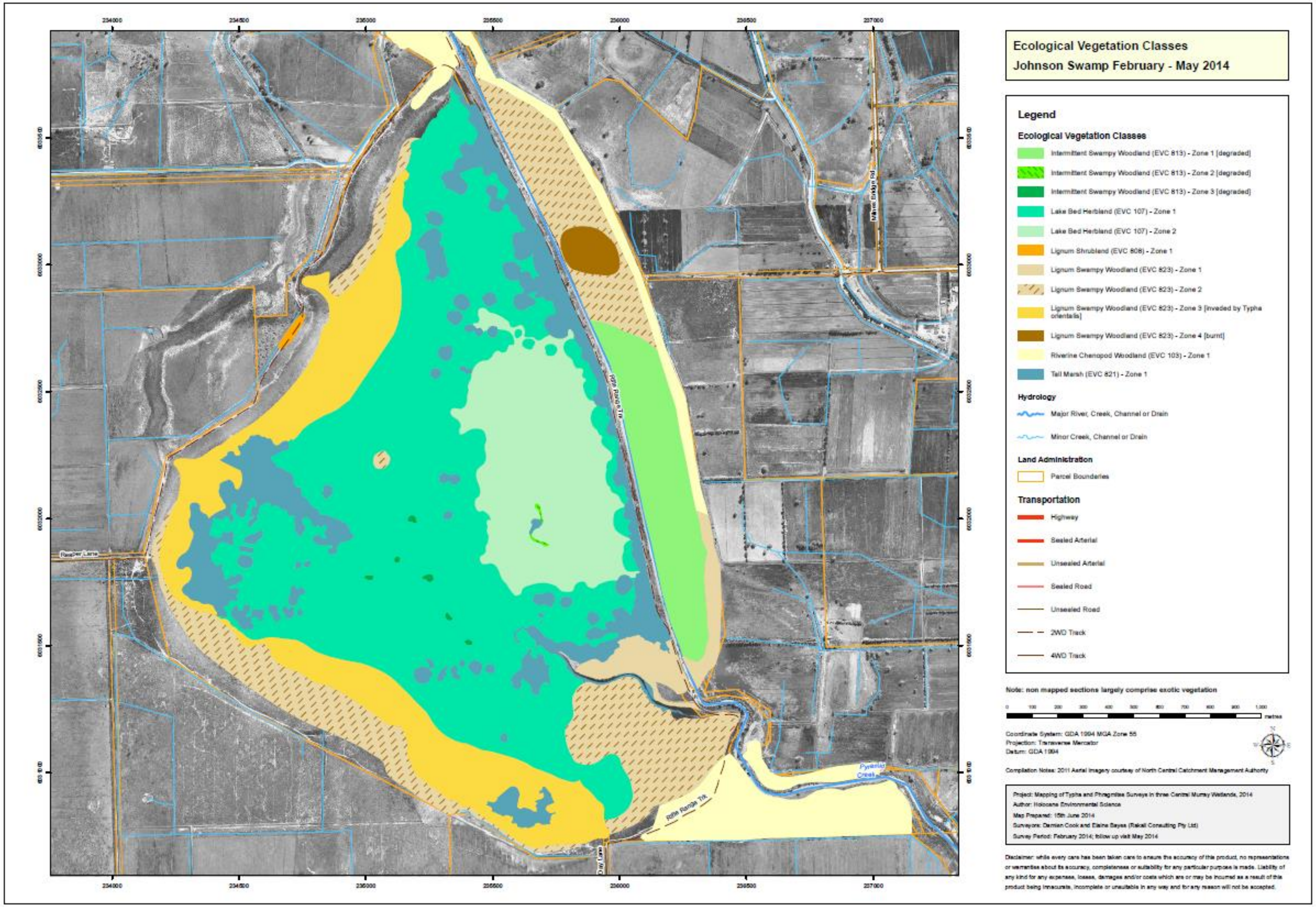
| Common Name | Scientific Name | Type | year of record | Data Source |
|---|---|---|---|---|
| Narrow-leaf Cumbungi | *Typha domingensis* | - | 1997 | VBA 2016 |
| Narrow-leaf Dock | *Rumex tenax* | AM | 2015 | Rakali 2015 |
| Narrow-leaf Nardoo | *Marsilea costulifera* | AM | 2015 | Rakali 2015 |
| Nitre Goosefoot | *Chenopodium nitrariaceum* | AM | 2015 | Rakali 2015 |
| Nitre-bush | *Nitraria billardierei* | T | 2015 | Rakali 2015 |
| Nodding Saltbush | *Einadia nutans subsp. nutans* | T | 2015 | Rakali 2015 |
| Northern Water-ribbons+ | *Triglochin multifructa* | AM | 2015 | Rakali 2015 |
| Old-man Saltbush | *Atriplex nummularia subsp. Nummularia* | T | 2012 | Australian Ecosystems 2012 |
| Oval Purse | *Hornungia procumbens* | - | 2014 | Rakali 2014a |
| Pacific Azolla | *Azolla filiculoides* | OA | 2015 | Rakali 2015 |
| Pale Beauty-heads | *Calocephalus sonderi* | MF | 2015 | Rakali 2015 |
| Pale Goodenia | *Goodenia glauca* | AM/ D | 2015 | Rakali 2015 |
| Pale Knotweed | *Persicaria lapathifolia* | MF | 2015 | Rakali 2015 |
| Plump Spear-grass | *Austrostipa aristiglumis* | T | 2015 | Rakali 2015 |
| Prickly Saltwort | *Salsola tragus subsp. tragus* | T | 2015 | Rakali 2015 |
| Red Pondweed+ | *Potamogeton cheesemanii* | AM | 2015 | Rakali 2015 |
| Red Water-milfoil | *Myriophyllum verrucosum* | AM | 2015 | Rakali 2015 |
| **Ridged Water-milfoil+** | ***Myriophyllum porcatum*** | **AM** | **2015** | **Rakali 2015** |
| Rigid Panic | *Walwhalleya proluta* | AM/ D | 2015 | Rakali 2015 |
| River Buttercup+ | *Ranunculus inundatus* | AM | 2015 | Rakali 2015 |
| River Club-sedge | *Schoenoplectus tabernaemontani* | - | 1997 | VBA 2016 |
| River Red-gum | *Eucalyptus camaldulensis* | AM/ GD | 2015 | Rakali 2015 |
| **River Swamp Wallaby-grass+** | ***Amphibromus fluitans*** | **AM** | **2015** | **Rakali 2015** |
| Robust Water-milfoil | *Myriophyllum papillosum* | AM | 2015 | Rakali 2015 |
| Rosinweed | *Cressa australis* | AM/ MF | 2015 | Rakali 2015 |
| Ruby Salt-bush | *Enchylaena tomentosa var. tomentosa* | T | 2015 | Rakali 2015 |
| Salt Club-sedge | *Bolboschoenus caldwellii* | AM | 2015 | Rakali 2015 |
| **Salt Paperbark** | ***Melaleuca halmaturorum subsp. halmaturorum*** | **AM** | **2012** | **Australian Ecosystems 2012** |
| Short-fruit Nardoo | *Marsilea hirsuta* | AM | 2015 | Rakali 2015 |
| Short-leaf Bluebush | *Maireana brevifolia* | T | 2015 | Rakali 2015 |
| Slender Dock | *Rumex brownii* | D/ T | 2014 | Rakali 2014a |
| Slender Groundsel | *Senecio glossanthus s.l.* | MF | 2015 | Rakali 2015 |
| Slender Knotweed | *Persicaria decipiens* | AM | 2015 | Rakali 2015 |
| Slender-fruit Saltbush | *Atriplex leptocarpa* | AM/ T | 2015 | Rakali 2015 |
| Small Loosestrife | *Lythrum hyssopifolia* | AM/ D/ MF | 2015 | Rakali 2015 |
| Small Mud-mat+ | *Glossostigma elatinoides* | AM | 2015 | Rakali 2015 |
| Smooth Heliotrope | *Heliotropium curassavicum* | MF | 2015 | Rakali 2015 |
| Smooth Willow-herb | *Epilobium billardierianum subsp. billardierianum* | MF/ T | 2015 | Rakali 2015 |
| Southern Cane-grass | *Eragrostis infecunda* | - | 1986 | VBA 2016 |
| Southern Liquorice | *Glycyrrhiza acanthocarpa* | MF | 2015 | Rakali 2015 |
| Spear Grass | *Austrostipa spp.* | T | 2015 | Rakali 2015 |
| Spider-grass | *Enteropogon acicularis* | AM/ D/ T | 2015 | Rakali 2015 |
| Spiny Mud-grass+ | *Pseudoraphis spinescens* | AM | 2015 | Rakali 2015 |
| Sprawling Saltbush# | *Atriplex suberecta* | MF | 2015 | Rakali 2015 |
| Spreading Crassula | *Crassula decumbens var. decumbens* | D/ T | 2014 | Rakali 2014a |
| Star Fruit+ | *Damasonium minus* | AM | 2015 | Rakali 2015 |
| **Stiff Groundsel+** | ***Senecio behrianus*** | **AM** | **2015** | **Rakali 2015** |
| Stonewort | *Characeae spp.* | OA | 2015 | Rakali 2015 |
| Swamp Lily+ | *Ottelia ovalifolia subsp. ovalifolia* | OA | 2015 | Rakali 2015 |
| Tall Fireweed | *Senecio runcinifolius* | AM | 2015 | Rakali 2015 |
| Tangled Lignum | *Duma florulenta* | AM | 2015 | Rakali 2015 |
| Thin Duckweed | *Landoltia punctata* | OA | 2015 | Rakali 2015 |
| Tiny Star | *Hypoxis glabella var. glabella* | T | 2015 | Rakali 2015 |

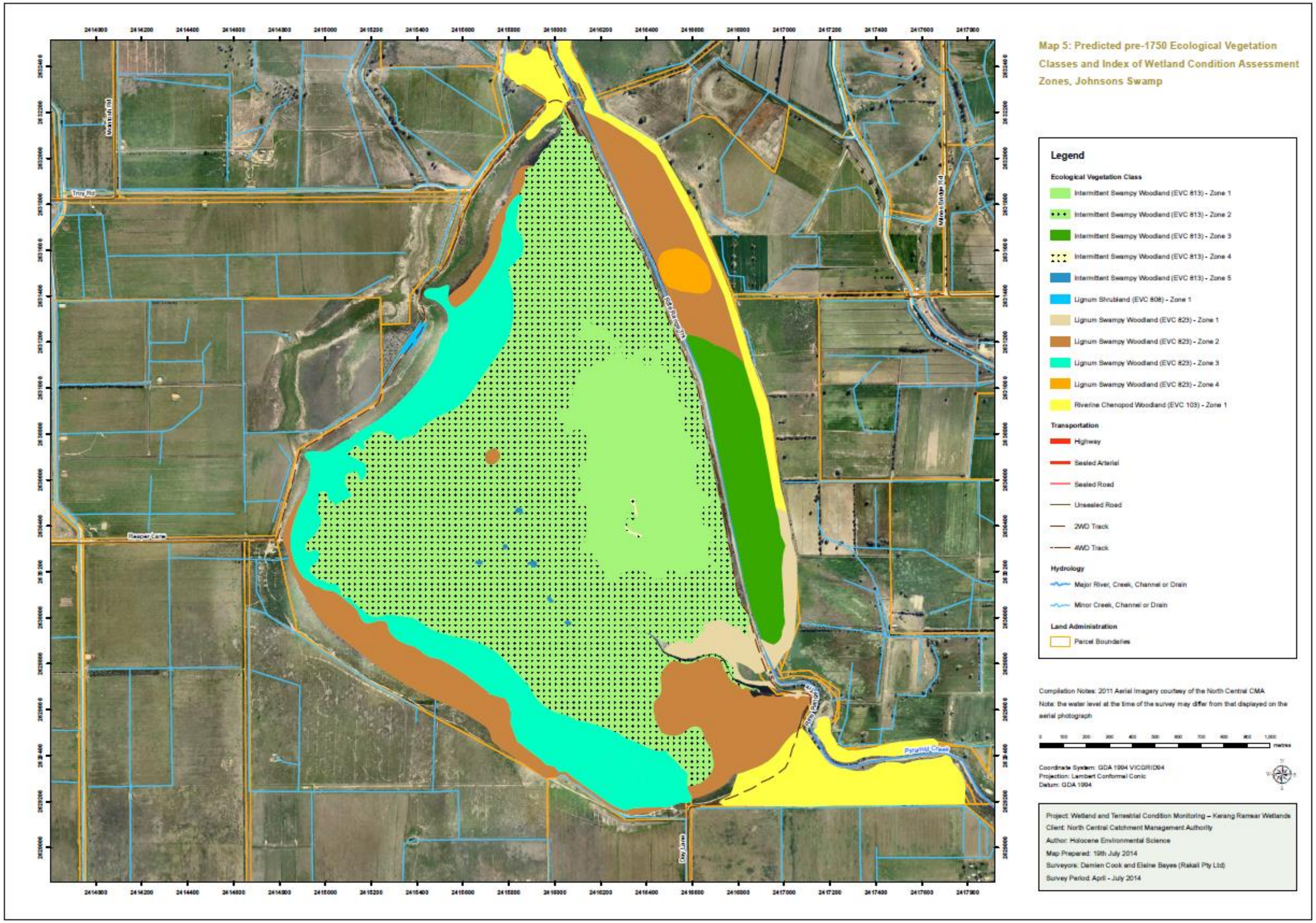
| Common Name | Scientific Name | Type | year of record | Data Source |
|---|---|---|---|---|
| Tussock Rush | *Juncus aridicola* | AM | 2014 | Rakali 2014a |
| Umbrella Wattle | *Acacia oswaldii* | T | 2012 | Australian Ecosystems 2012 |
| Upright Water-milfoil+ | *Myriophyllum crispatum* | AM | 2015 | Rakali 2015 |
| Variable Flat-sedge | *Cyperus difformis* | AM | 2015 | Rakali 2015 |
| **Water Nymph+** | ***Najas tenuifolia*** | **OA** | **2015** | **Rakali 2015** |
| Water Pepper | *Persicaria hydropiper* | MF | 2014 | Rakali 2014a |
| Water Ribbons | *Cycnogeton spp.* | - | 1997 | VBA 2016 |
| Waterwort | *Elatine gratioloides* | AM | 2015 | Rakali 2015 |
| **Wavy Marshwort+** | ***Nymphoides crenata*** | **AM** | **2015** | **Rakali 2015** |
| Weeping Pittosporum | *Pittosporum angustifolium* | T | 2012 | Australian Ecosystems 2012 |
| Willow Wattle | *Acacia salicina* | GD | 2012 | Australian Ecosystems 2012 |
| **Winged Water-starwort** | ***Callitriche umbonata*** | **AM** | **2015** | **Rakali 2015** |
| Yellow Bladderwort+ | *Utricularia australis* | OA | 2015 | Rakali 2015 |
| **Introduced flora** | | | | |
| African Box-thorn | *Lycium ferocissimum* | T | 2015 | Rakali 2015 |
| Annual Meadow-grass | *Poa annua* | T | 2012 | Australian Ecosystems 2012 |
| Aster-weed | *Aster subulatus* | AM/ MF | 2015 | Rakali 2015 |
| Barley-grass | *Hordeum murinum s.l.* | T | 2015 | Rakali 2015 |
| Bathurst Burr | *Xanthium spinosum* | MF | 2015 | Rakali 2015 |
| Berry Seablite | *Suaeda baccifera* | D/ MF | 2015 | Rakali 2015 |
| Black Nightshade | *Solanum nigrum s.l.* | T | 2015 | Rakali 2015 |
| Burr Medic | *Medicago polymorpha* | T | 2015 | Rakali 2015 |
| Cape weed | *Arctotheca calendula* | T | 1986 | VBA 2016 |
| Celery Buttercup | *Ranunculus sceleratus subsp. sceleratus* | AM | 2015 | Rakali 2015 |
| Clustered Dock | *Rumex conglomeratus* | - | 1986 | VBA 2016 |
| Common Ice-plant | *Mesembryanthemum crystallinum* | D/ T | 2012 | Australian Ecosystems 2012 |
| Common Peppercress | *Lepidium africanum* | T | 2015 | Rakali 2015 |
| Common Sow-thistle | *Sonchus oleraceus* | T | 2015 | Rakali 2015 |
| Curled Dock | *Rumex crispus* | AM | 2015 | Rakali 2015 |
| Drain Flat-sedge | *Cyperus eragrostis* | AM | 2015 | Rakali 2015 |
| Ferny Cotula | *Cotula bipinnata* | D | 2015 | Rakali 2015 |
| Flaxleaf Fleabane | *Conyza bonariensis* | T | 2015 | Rakali 2015 |
| Great Brome | *Bromus diandrus* | T | 2015 | Rakali 2015 |
| Ground Cherry | *Physalis ixocarpa* | T | 2015 | Rakali 2015 |
| Hastate Orache | *Atriplex prostrata* | MF | 2015 | Rakali 2015 |
| Hogweed | *Polygonum aviculare s.s.* | T | 2015 | Rakali 2015 |
| Large Annual Buttercup | *Ranunculus trilobus* | MF | 2015 | Rakali 2015 |
| London Rocket | *Sisymbrium irio* | T | 2012 | Australian Ecosystems 2012 |
| Malta Thistle | *Centaurea melitensis* | T | 2012 | Australian Ecosystems 2012 |
| Marsh Bitter-cress | *Rorippa palustris* | AM /MF | 2015 | Rakali 2015 |
| Musky Heron's-bill | *Erodium moschatum* | - | 1986 | VBA 2016 |
| Oat | *Avena spp.* | T | 2015 | Rakali 2015 |
| Ox-tongue | *Helminthotheca echioides* | T | 2015 | Rakali 2015 |
| Paradoxical Canary-grass | *Phalaris paradoxa* | AM/ MF | 2015 | Rakali 2015 |
| Paterson's Curse | *Echium plantagineum* | T | 2014 | Rakali 2014a |
| Prickly Lettuce | *Lactuca serriola* | T | 2015 | Rakali 2015 |
| Prostrate Knotweed | *Polygonum aviculare s.l.* | T | 2014 | Rakali 2014b |
| Red Brome | *Bromus rubens* | T | 2015 | Rakali 2015 |
| Red Sand-spurrey | *Spergularia rubra s.s.* | T | 2015 | Rakali 2015 |
| Ribwort | *Plantago laceolata* | T | 2015 | Rakali 2015 |
| River Oak | *Casuarina cunninghamiana subsp. cunninghamiana* | AM | 2012 | Australian Ecosystems 2012 |
| Rough Sow-thistle | *Sonchus asper s.s.* | T | 2015 | Rakali 2015 |
| Scorzonera | *Scorzonera laciniata* | T | 2015 | Rakali 2015 |
| Sea Barley-grass | *Hordeum marinum* | T | 2015 | Rakali 2015 |
| Small Ice-plant | *Mesembryanthemum nodiflorum* | D/ T | 2015 | Rakali 2015 |
| Small Nettle | *Urtica urens* | T | 2012 | Australian Ecosystems 2012 |
| Small-flower Mallow | *Malva parviflora* | T | 2015 | Rakali 2015 |
| Smooth Mustard | *Sisymbrium erysimoides* | T | 2015 | Rakali 2015 |

| Common Name | Scientific Name | Type | year of record | Data Source |
|---|---|---|---|---|
| Soft Brome | *Bromus hordeaceus subsp. hordeaceus* | T | 2015 | Rakali 2015 |
| Soursob | *Oxalis pes-caprae* | T | 2015 | Rakali 2015 |
| Sowbane | *Chenopodium murale* | AM/ T | 2015 | Rakali 2015 |
| Spear Thistle | *Cirsium vulgare* | T | 2015 | Rakali 2015 |
| Spiny Rush | *Juncus acutus subsp. acutus* | - | 1986 | VBA 2016 |
| Squirrel-tail Fescue | *Vulpia bromoides* | T | 2015 | Rakali 2015 |
| Stemless Thistle | *Onopordum acaulon* | T | 2014 | Rakali 2014b |
| Stinkwort | *Dittrichia graveolens* | MF | 2014 | Rakali 2014a |
| Strawberry Clover | *Trifolium fragiferum var. fragiferum* | - | 1986 | VBA 2016 |
| Swamp Yate | *Eucalyptus occidentalis* | AM | 2012 | Australian Ecosystems 2012 |
| Sweet Melilot | *Melilotus indicus* | T | 2015 | Rakali 2015 |
| Toowoomba Canary-grass | *Phalaris aquatica* | AM/ T | 2015 | Rakali 2015 |
| Variegated Thistle | *Silybum marianum* | T | 2015 | Rakali 2015 |
| Wall Fescue | *Vulpia muralis* | T | 2015 | Rakali 2015 |
| Wandering Speedwell | *Veronica peregrina* | AM | 2015 | Rakali 2015 |
| Water Buttons | *Cotula coronopifolia* | AM | 2015 | Rakali 2015 |
| Water Couch | *Paspalum distichum* | AM | 2015 | Rakali 2015 |
| Water Crassula | *Crassula natans var. minus* | AM | 2015 | Rakali 2015 |
| Wild Oat | *Avena fatua* | T | 1986 | VBA 2016 |
| Willow | *Salix sp.* | AM/ T | 2015 | Rakali 2015 |
| Willow-leaf Lettuce | *Lactuca saligna* | T | 2015 | Rakali 2015 |
| Wimmera Rye-grass | *Lolium rigidum* | T | 2015 | Rakali 2015 |

**Key:**
Type: T- terrestrial, AM- amphibious, MF-mudflat specialist, D- dampland, GD- groundwater dependent, OA- obligate aquatic
**+**= Planted
**#**= indigenous species that may occur outside of their natural range

## Appendix 7: Ecological Vegetation Classes of Johnson Swamp





Map 5: Predicted pre-1750 Ecological Vegetation Classes and Index of Wetland Condition Assessment Zones, Johnsons Swamp
Legend
Ecological Vegetation Class
Intermittent Swampy Woodland (EVC 813) - Zone 1
Intermittent Swampy Woodland (EVC 813) - Zone 2
Intermittent Swampy Woodland (EVC 813) - Zone 3
Intermittent Swampy Woodland (EVC 813) - Zone 4
Intermittent Swampy Woodland (EVC 813) - Zone 5
Lignum Shrubland (EVC 808) - Zone 1
Lignum Swampy Woodland (EVC 823) - Zone 1
Lignum Swampy Woodland (EVC 823) - Zone 2
Lignum Swampy Woodland (EVC 823) - Zone 3
Lignum Swampy Woodland (EVC 823) - Zone 4
Riverine Chenopod Woodland (EVC 103) - Zone 1
Transportation
Highway
Sealed Arterial
Sealed Road
Unsealed Road
2WD Track
4WD Track
Hydrology
Major River, Creek, Channel or Drain
Minor Creek, Channel or Drain
Land Administration
Parcel Boundaries
Compilation Notes: 2011 Aerial Imagery courtesy of the North Central CMA
Note: the water level at the time of the survey may differ from that displayed on the aerial photograph
metres
Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Project: Wetland and Terrestrial Condition Monitoring – Kerang Ramsar Wetlands
Client: North Central Catchment Management Authority
Author: Holocene Environmental Science
Map Prepared: 19th July 2014
Surveyors: Damien Cook and Elaine Bayes (Rakali Pty Ltd)
Survey Period: April - July 2014

## Appendix 8: Assessments against the Murray Darling Basin Plan

### Schedule 8- Criteria for identifying an Environmental Asset

To be considered a priority for environmental water management, environmental assets (i.e. wetlands and rivers) must meet one or more of the assessment indicators for any of the five criteria specified in schedule 8 of the Basin Plan. The below table summarises each criteria and provides justification for those relevant to Johnson Swamp.

| Item | Criteria | Meets criteria | Justification |
|---|---|---|---|
| *Criterion 1: The water-dependent ecosystem is formally recognised in international agreements or, with environmental watering, is capable of supporting species listed in those agreements* | | | |
| 1 | Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it is: | | |
| | (a) a declared Ramsar wetland; or | ✓ | Johnson Swamp is one of 23 wetland that make up the Kerang Wetlands Ramsar site (KBR 2011). |
| | (b) with environmental watering, capable of supporting a species listed in or under the JAMBA, CAMBA, ROKAMBA or the Bonn Convention. | ✓ | Ten waterbird species listed under one or more international migratory agreements have been recorded at Johnson Swamp. |
| *Criterion 2: The water-dependent ecosystem is natural or near-natural, rare or unique* | | | |
| 2 | Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it: | | |
| | (a) represents a natural or near-natural example of a particular type of water-dependent ecosystem as evidenced by a relative lack of post-1788 human induced hydrologic disturbance or adverse impacts on ecological character; or | × | |
| | (b) represents the only example of a particular type of water-dependent ecosystem in the Murray-Darling Basin; or | × | |
| | (c) represents a rare example of a particular type of water-dependent ecosystem in the Murray-Darling Basin. | × | |
| *Criterion 3: The water-dependent ecosystem provides vital habitat* | | | |
| 3 | Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it: | | |
| | (a) provides vital habitat, including: (i) a refuge for native water-dependent biota during dry spells and drought; or | ✓ | During dry times when Johnson Swamp is provided with environmental water, the wetland serves as an important drought refuge for waterbirds. The wetland has previously supported tens of thousands of waterbirds belonging to over sixty-six species and is therefore considered an important wetland for maintaining biological diversity within the landscape. |
| | (ii) pathways for the dispersal, migration and movements of native water-dependent biota; or | ✓ | During migration, waterbirds rely on a chain of highly productive wetlands to rest and feed, building up sufficient energy to fuel the next phase of their journey. When wet, Johnson Swamp regularly supports at least ten of these migratory species and is considered an important summer feeding ground. |
| | (iii) important feeding, breeding and nursery sites for native water-dependent biota; or | ✓ | Johnson Swamp historically supports large numbers of waterbirds including at least thirteen breeding species. The wetland is particularly important for Australasian bittern supporting at least one percent of the flyway population. In addition the wetland provides extensive mudflat habitat during the drawdown phase, catering to a range of migratory shoreline and wading waterbirds. This habitat component is relatively rare in the Kerang area with a large portion of inundated wetlands maintained as permanent water storages. |
| | (b) is essential for maintaining, and preventing declines of, native water-dependent biota. | ✓ | When inundated, Johnson Swamp supports a range of waterbird species including at least one percent of the flyway population of Australasian bittern and a large portion of the Kerang brolga |

| Item | Criteria | Meets criteria | Justification |
|---|---|---|---|
| | | | population. These species have niche habitat requirements for breeding, in which Johnson Swamp supports. |
| *Criterion 4: Water-dependent ecosystems that support Commonwealth, State or Territory listed threatened species or communities* | | | |
| 4 | Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it: | | |
| | (a) supports a listed threatened ecological community or listed threatened species; or<br>Note: See the definitions of ***listed threatened ecological community*** and ***listed threatened species*** in section 1.07. (Listed under the EPBC Act 1999) | ✓ | Johnson Swamp supports three EPBC listed water dependent flora species, two fauna species and ten migratory waterbird species. |
| | (b) supports water-dependent ecosystems treated as threatened or endangered (however described) under State or Territory law; or | ✓ | Johnson Swamp supports FOUR endangered EVC and three vulnerable EVCs within the Victorian Riverina and Murray Fans bioregions. |
| | (c) supports one or more native water-dependent species treated as threatened or endangered (however described) under State or Territory law. | ✓ | Johnson Swamp supports at least twenty-three water dependent fauna species and at least ten flora species listed under state legislation. |
| *Criterion 5: The water-dependent ecosystem supports, or with environmental watering is capable of supporting, significant biodiversity* | | | |
| 5 | Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it supports, or with environmental watering is capable of supporting, significant biological diversity. This includes a water-dependent ecosystem that: | | |
| | (a) supports, or with environmental watering is capable of supporting, significant numbers of individuals of native water-dependent species; or | ✓ | Johnson Swamp has supported at least one percent of the flyway population of Australasian bittern. |
| | (b) supports, or with environmental watering is capable of supporting, significant levels of native biodiversity at the genus or family taxonomic level, or at the ecological community level. | × | |

### Schedule 9- Criteria for identifying an Ecosystem Function

To be considered a priority for environmental water management, ecosystem functions that require environmental water to sustain them as well as the environmental watering requirements of that function must be identified for all environmental assets (i.e. wetlands and rivers). An environmental asset must meet one or more of the assessment indicators for any of the four criteria specified in schedule 9 of the Basin Plan. The below table summarises each criteria and provides justification for those relevant to Johnson Swamp.

| Item | Criteria | Meets criteria | Description for Johnson Swamp |
|---|---|---|---|
| *Criterion 1: The ecosystem function supports the creation and maintenance of vital habitats and populations* | | | |
| 1 | Assessment indicator: An ecosystem function requires environmental watering to sustain it if it provides vital habitat including: | | |
| | (a) a refugium for native water-dependent biota during dry periods and drought; or | × | |
| | (b) pathways for the dispersal, migration and movement of native water-dependent biota; or | ✓ | As per Criteria 3(ii) of Schedule 8 of the Basin Plan, migrating waterbirds rely on a chain of highly productive wetlands to rest and feed, building up sufficient energy to fuel the next phase of their journey. When wet, Johnson Swamp regularly supports at least ten of these migratory species and is considered an important summer feeding ground. |
| | (c) a diversity of important feeding, breeding and nursery sites for native water-dependent biota; or | ✓ | Johnson Swamp has a diversity of habitat types from reeds, rushes and sedges, lignum, dead and live black box and red gum trees and aquatic and amphibious plants. These habitats provide an array of feeding, breeding and nursery opportunities for a diversity of water-dependent fauna including waterbirds, turtles and frogs. |
| | (d) a diversity of aquatic environments including pools, rifle and run environments; or | × | |
| | (e) a vital habitat that is essential for preventing the decline of native water-dependent biota. | ✓ | Johnson Swamp provides one of only a handful of breeding sites for Australasian bittern, Australian little bittern and brolga in Northern Victoria. These species are noted to be in decline due to habitat loss, low breeding success and high fecundity. The provision of an appropriate water regime will assist with bolstering the population of these species. |
| *Criterion 2: The ecosystem function supports the transportation and dilution of nutrients, organic matter and sediment* | | | |
| 2 | Assessment indicator: An ecosystem function requires environmental watering to sustain it if it provides for the transportation and dilution of nutrients, organic matter and sediment, including: | | |
| | (a) pathways for the dispersal and movement of organic and inorganic sediment, delivery to downstream reaches and to the ocean, and to and from the floodplain; or | ✓ | Johnson Swamp has the potential to be an important component in the dispersal of organic and inorganic sediments and nutrients through connection with the Pyramid Creek. This is currently only possible when large flood events cause Pyramid Creek to overtop. |
| | (b) the dilution of carbon and nutrients from the floodplain to the river systems. | ✓ | |
| *Criterion 3: The ecosystem function provides connections along a watercourse (longitudinal connections)* | | | |
| 3 | Assessment indicator: An ecosystem function requires environmental watering to sustain it if it provides connections along a watercourse or to the ocean, including longitudinal connections: | | |
| | (a) for dispersal and re-colonisation of native water-dependent communities; or | × | |
| | (b) for migration to fulfil requirements of life history stages; or | × | |
| | (c) For in-stream primary production. | × | |

| Item | Criteria | Meets criteria | Description for Johnson Swamp |
|---|---|---|---|
| *Criterion 4: The ecosystem function provides connections across floodplains, adjacent wetlands and billabongs (lateral connections)* | | | |
| 4 | Assessment indicator: An ecosystem function requires environmental watering to sustain it if it provides connections across floodplains, adjacent wetlands and billabongs, including: | | |
| | (a) lateral connections for foraging, migration and re-colonisation of native water-dependent species and communities; or | × | |
| | (b) lateral connections for off-stream primary production. | × | |

## Appendix 9: IWC biota sub-indices assessments

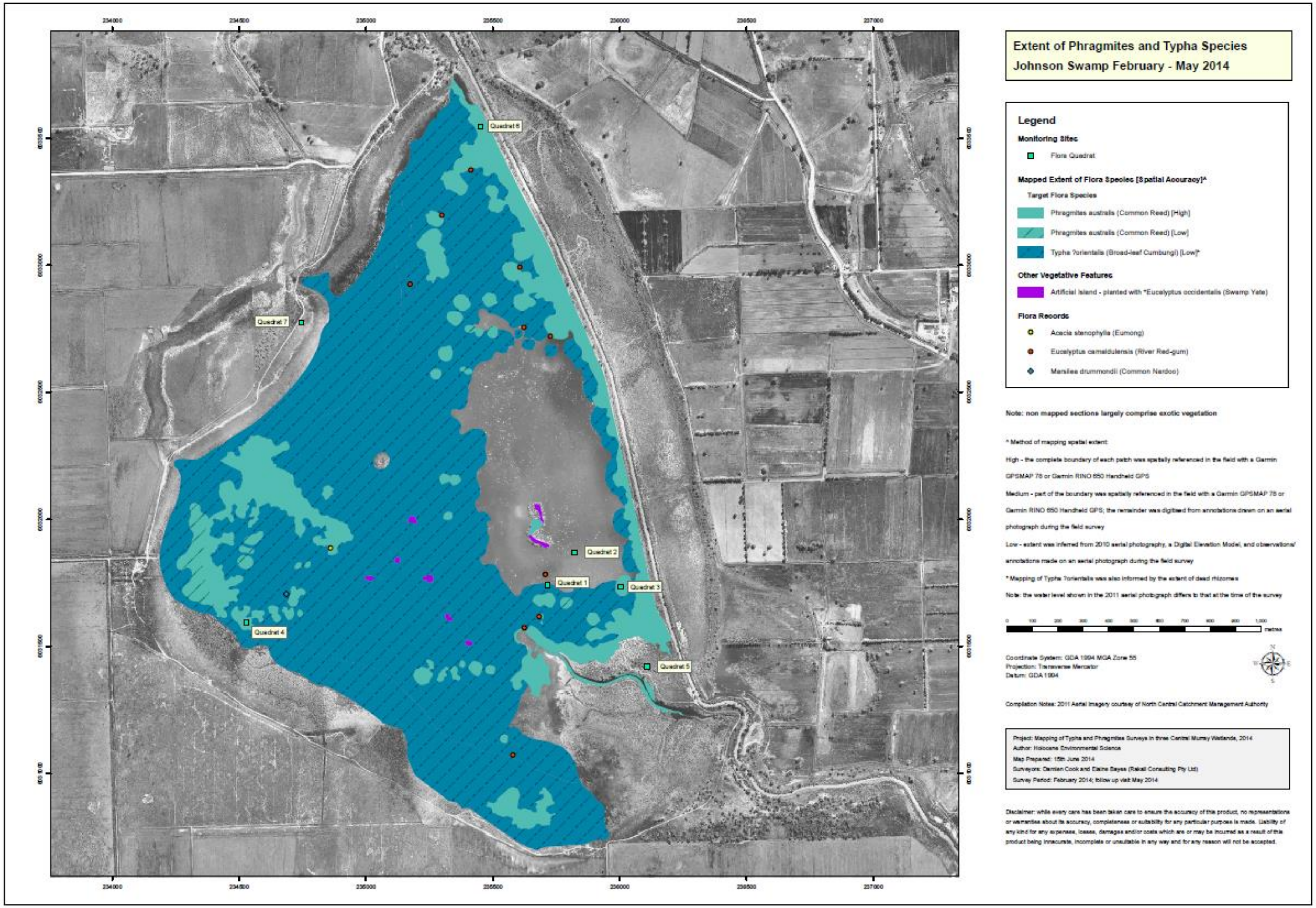
**IWC biota sub-index scores by assessment zone for Johnson Swamp- Standard IWC methodology (pre-1750s benchmark)**

| EVC | EVC no. | Critical lifeforms (F) | weeds (G) | indicator of altered process (H) | vegetation structure and health (I) | EVC score (F+G+H+I/5) | % of wetland area covered by EVC | Result (EVC score x %) |
|---|---|---|---|---|---|---|---|---|
| **2012 (Australian Ecosystem 2012)** | | | | | | | | |
| Intermittent Swampy Woodland | 813 | 9.38 | 3 | 10 | 0 | 4.48 | 63 | 2.8224 |
| Lignum Shrubland | 808 | 15.63 | 18 | 20 | 20 | 14.73 | 2 | 0.2946 |
| Lignum Swampy Woodland | 823 | 15.63 | 12 | 15 | 20 | 6.1 | 33 | 2.01 |
| Riverine Chenopod Woodland | 103 | 10.41 | 10 | 10 | 0 | 12.53 | 2 | 0.2 |
| | | | | | | | **TOTAL** | **5.327** |
| **2014 (Rakali Ecological Consulting 2014)** | | | | | | | | |
| Intermittent Swampy Woodland- Zone 1 | 813 | 9.38 | 15 | 10 | 0 | 6.88 | 11.21 | 0.770611 |
| Intermittent Swampy Woodland- Zone 2 | 813 | 9.38 | 10 | 10 | 0 | 5.88 | 50.77 | 2.98335 |
| Intermittent Swampy Woodland- Zone 3 | 813 | 9.38 | 3 | 10 | 25 | 9.48 | 5.97 | 0.229788 |
| Intermittent Swampy Woodland- Zone 4 | 813 | 0 | 0 | 0 | 0 | 0 | 0.05 | 0.006056 |
| Intermittent Swampy Woodland- Zone 5 | 813 | 3.125 | 10 | 5 | 0 | 3.6 | 0.1 | 0.003741 |
| Lignum Shrubland | 808 | 15.63 | 18 | 20 | 20 | 14.73 | 0.12 | 0.017707 |
| Lignum Swampy Woodland- Zone 1 | 823 | 14.6 | 15 | 20 | 15 | 12.92 | 2.27 | 0.29334 |
| Lignum Swampy Woodland- Zone 2 | 823 | 12.5 | 15 | 10 | 0 | 7.5 | 14.72 | 1.10382 |
| Lignum Swampy Woodland- Zone 3 | 823 | 12.5 | 15 | 10 | 0 | 7.5 | 13.92 | 1.043836 |
| Lignum Swampy Woodland- Zone 4 | 823 | 4.2 | 0 | 5 | 0 | 1.84 | 0.87 | 0.016017 |
| | | | | | | | **TOTAL** | **6.50** |
| **Source: Rakali 2014a** | | | | | | | | |

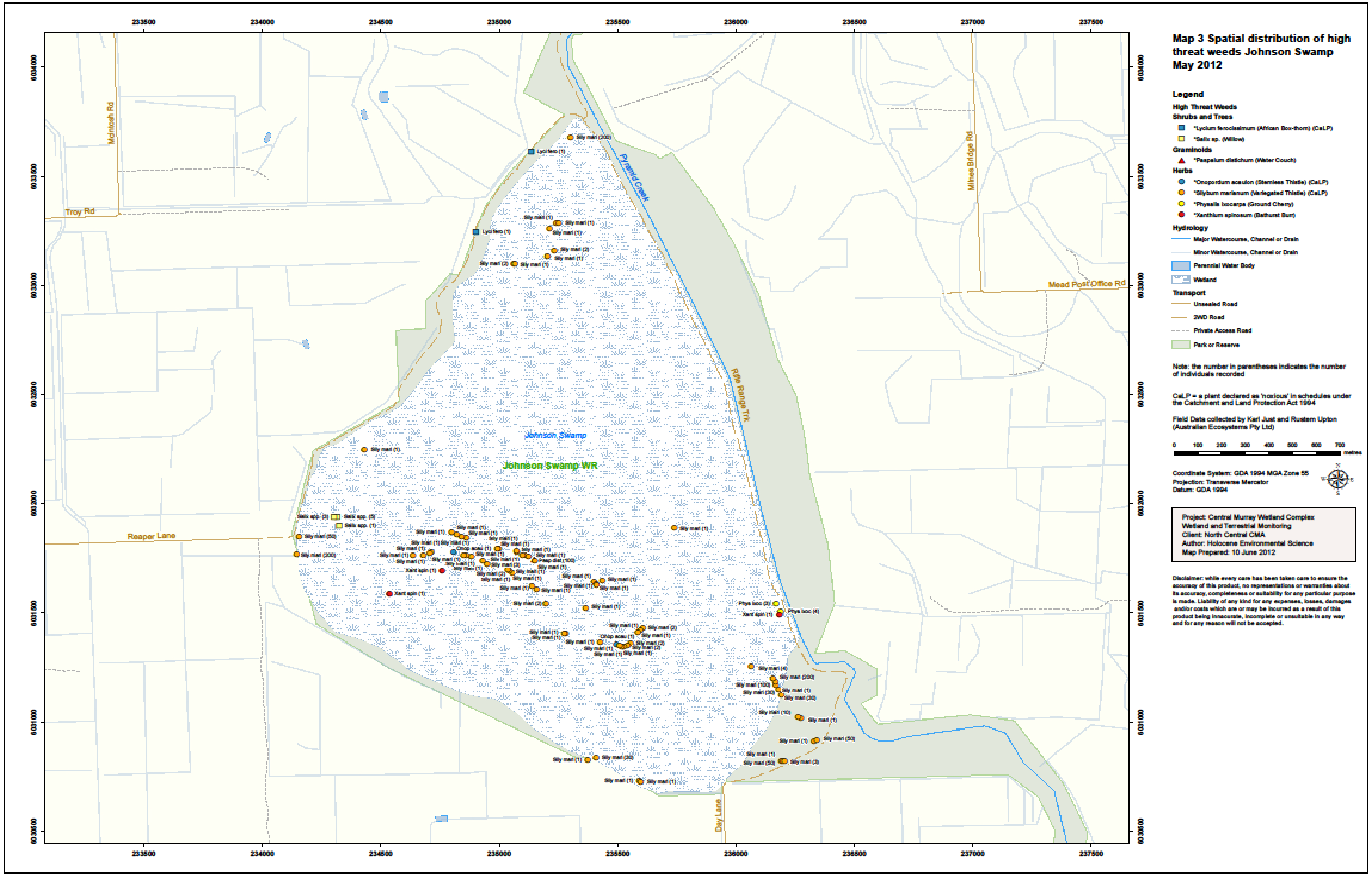
**IWC biota sub-index scores by assessment zone for Johnson Swamp- Non-standard methodology (2014 benchmark)**

| EVC | EVC no. | Critical lifeforms (F) | weeds (G) | indicator of altered process (H) | vegetation structure and health (I) | EVC score (F+G+H+I/5) | % of wetland area covered by EVC | Result (EVC score x %) |
|---|---|---|---|---|---|---|---|---|
| **2014 (Rakali Ecological Consulting 2014)** | | | | | | | | |
| Lake Bed Herbland- Zone 1 | 107 | 4.20 | 15 | N/A | 25 | 11.79 | 39 | 4.61 |
| Lake Bed Herbland- Zone 1 | 107 | 8.30 | 10 | N/A | 25 | 11.55 | 11 | 1.29 |
| Tall Marsh | 821 | 9.38 | 15 | N/A | 25 | 13.17 | 12 | 1.6 |
| Intermittent Swampy Woodland- Zone 1 | 813 | 3.125 | 10 | 5 | 0 | 3.6 | 6 | 0.22 |
| Intermittent Swampy Woodland- Zone 2 | 813 | 12.5 | 10 | 10 | 25 | 11.5 | 0 | 0.01 |
| Intermittent Swampy Woodland- Zone 3 | 813 | 6.25 | 3 | 10 | 0 | 3.85 | 0 | 0 |
| Lignum Shrubland | 808 | 15.63 | 18 | 20 | 20 | 14.73 | 0 | 0.02 |
| Lignum Swampy Woodland- Zone 1 | 823 | 14.60 | 15 | 20 | 15 | 12.92 | 2 | 0.29 |
| Lignum Swampy Woodland- Zone 2 | 823 | 12.50 | 15 | 10 | 0 | 7.50 | 15 | 1.10 |
| Lignum Swampy Woodland- Zone 3 | 823 | 12.50 | 15 | 10 | 0 | 7.50 | 13 | 1.00 |
| Lignum Swampy Woodland- Zone 4 | 823 | 4.20 | 0 | 5 | 0 | 1.84 | 1 | 0.02 |
| | | | | | | | **TOTAL** | **10.2** |
| **Source: Rakali 2014a** | | | | | | | | |

## Appendix 10: Extent of cumbungi and common reed distribution in Johnson Swamp



## Appendix 11: Distribution of high threat weeds at Johnson Swamp



## Appendix 12: Water requirements of key values

| Key values | Species present | | Broad requirements | | |
|---|---|---|---|---|---|
| | Characteristic | significant | Habitat | Breeding | Water requirements |
| **Water dependent fauna** | | | | | |
| Dabbling ducks | Chestnut teal, grey teal[1], Pacific black duck[1], pink-eared duck | Australasian shoveler, freckled duck | • Seasonal to permanent wetlands with fringing vegetation, including soft mud and open water (approximately 30 cm depth)<br>• Feed both in open water, or fringe (including soft mud and fringing vegetation) primarily on insects, macros and plant material including seeds | • stimulated by flooding, rainfall (rising water level) and/or season and breed predominantly between June-Feb with a breeding duration of approximately 3-4 months (exception is pink-eared duck that displays erratic opportunistic breeding seasons in response to food availability)<br>• ideally require flood duration 5-9 months with a moderate rate of water level recession<br>• breed in grassy areas or in tree hollows near wetlands<br>• nest in grassed areas, elevated surfaces (including river red gum and black box trees) or under lignum and rushes<br>• No defined water depth requirement for breeding | • Flood required ideally in winter/ early spring to stimulate breeding<br>• Inundation to be maintained for up to 9 months, however average lag time to breed 2-5 months.<br>• Fringing vegetation and open water required with ample food resources such as insects, macros, crustaceans and plant material) |
| Deep-water foragers | Black swan[1], Eurasian coot | Blue-billed duck, hardhead, musk duck | • Most (with exception of Eurasian coot) exhibit a preference for large, deep and open water with abundant aquatic vegetation<br>• Forage in shallow or deep open water fringed by tall vegetation or at wetland margins with exposed mudflats<br>• diet consisting of aquatic plants, seeds and leaves and some aquatic animals (depending on species) | • Stimulated by flood and/or season and breed predominately between Aug-Jan with a breeding duration of 3-5 months (ideal flood duration is 5-8 months). Black swan breed between April-Oct for a duration of 7-8 months (ideal flood duration of 7-9 months)<br>• Moderate to slow recession in water level required<br>• Depth range of 0.3->3 metres required depending on species<br>• Nest in deeper areas on platforms or in densely vegetated fringes (i.e. cumbungi, sedges, lignum) | • Flood required between April-Jan (depending on species) to stimulate breeding. Some species are purely seasonal breeders (i.e. musk duck and blue-billed duck between Sept-Feb)<br>• Generally maintain inundation for up to 6 months (up to 9 months required for black swan)<br>• Good aquatic vegetation required<br>• Generally higher breeding success after drying periods |
| Fish-eaters | Australian darter, Australasian grebe, Australian pelican, great cormorant, great | Cattle egret, eastern great egret, intermediate egret, nankeen | • Observed at a range of habitat types (including shallow and deep, permanent and temporary)<br>• Forage in open and fringing areas for fish, macros, insects, frogs and some | • Stimulated by flooding and/or season and usually breed between Aug- May with a 3-5 month breeding duration (darters have two breeding season- Sept-Jan and March-August) | • Flood required in winter/spring to stimulate breeding<br>• Sufficient littoral vegetation and open water required to support food sources<br>• Most species have better breeding success |

| Key values | Species present | | Broad requirements | | |
|---|---|---|---|---|---|
| | Characteristic | significant | Habitat | Breeding | Water requirements |
| | crested grebe[1], hoary-headed grebe, little black cormorant, little pied cormorant, silver gull, white-faced heron[1], white-necked heron, sacred kingfisher[1] | nigh heron, pied cormorant, whiskered tern, white-winged black tern | plant material<br>• Roost and nest beside or in wetlands (some in trees and shrubs, others within fringing vegetation)- some exhibit colonial nesting behaviour (i.e. darters, pelican, cormorants, ibis) | • Ideally require flood duration of 5-12 months (egrets require approximately 12 months at depth)<br>• Moderate to slow recession in water level required<br>• Some (i.e. darter, egrets, herons, cormorants) preferentially breed at sites where live river red gums have flooded in excess of four months<br>• Depth not important for some species, however fluctuations have been implicated in reduced breeding or chick survival and deeper floods have greater duration promoting better breeding success. | following a dry period. |
| Grazing waterfowl | Australian shelduck[1], Australian wood duck[1] | N/A | • Observed in a range of habitats although prefer deeper wetlands with open banks and nearby grasslands for grazing<br>• Forages for plant material amongst short grass, herbs, emergent vegetation or on aquatic plants at edge. | • Stimulated by rainfall, season and /or flooding with breeding season usually occurring between July-Dec<br>• Duration of 3-4 months required with total inundation duration of 3-7 months<br>• Require water depth of at least 0.6 metres for shelduck and deep water for wood duck with moderate to slow water recession<br>• Nests typically established in hollows of live trees, near water in densely timbered areas<br>• Wood duck do not exhibit a flooding requirement for breeding | • Flood required in winter/spring to stimulate plant growth and support breeding<br>• Most species have better breeding success following a dry period (considered a higher breeding stimulant for wood duck then flooding). |
| Larger waders | Australian white ibis, straw-necked ibis, yellow-billed spoonbill | Australasian bittern[1], Australian little bittern[1], brolga[1], glossy ibis, royal spoonbill | • Preference for shallow swamps with abundant aquatic flora or wet grasslands/meadows<br>• Forages mainly in shallow water (bittern require <30 cm) or amongst tall emergent vegetation of medium to low density or moist mud<br>• Some roost in trees (above water), tree stumps, shrubs (i.e. lignum, reeds) or on ground or banks<br>• Diet consists of insects, fish, plant material (including crops, rice fields), | • Stimulated by flood and/or season and breed predominately between Oct-May (duration of 2-3 months required with ideal flood duration of 4-12 months depending on species), with the exception of brolga who breed between July-Nov (3-4 month breeding duration with ideal flood duration of 6 months)<br>• Prefer water depth of 0.3-1.5 metre (brolga prefer 0.24-0.72 metres, bittern <0.3 metres)<br>• Moderate to slow flood recession required. For bittern, once the nest is established a rise of >30 cm in water level can drown out nest. | • Flood timing dependent on target species<br>• Inundation to be maintained for approximately 4- 12 months<br>• Many species closely linked to water level-recession before fledging of juveniles may result in lack of food resources of predation |

| Key values | Species present | | Broad requirements | | |
|---|---|---|---|---|---|
| | Characteristic | significant | Habitat | Breeding | Water requirements |
| | | | reptiles and frogs. Brolga consume mostly crops and tubers. | Fairly stable water levels required to support fledging.<br>• Some species (i.e. spoonbills and ibis) will nest in colonies with other colonial nesting birds<br>• Some species closely linked to water depth (i.e. spoonbills, ibis, brolga, bittern)<br>• Brolga nest in shallow areas usually less than 0.3 metres in depth (on ground made out of tussock grass, sedges or cane grass)- nesting occurs approximately 20-60 days post filling.<br>• Bittern nest in densely vegetated areas (i.e. common reed, cumbungi) and build nest in deep cover over shallow water <0.3 metres). Egg incubation period of 23 days, 9 weeks for fledging and to leave nest.<br>• Fledging success of bittern and brolga strongly linked to the duration of inundation post hatching subsequently the availability of food (timed drawdown to support food resources) and shelter.<br>• 6-8 month inter-flooding period linked with increased success of Brolga breeding. | |
| Shoreline foragers | Black-tailed native hen, buff-banded rail, dusky moorhen, Lewin's rail, masked lapwing[1], purple swamphen, spotless crake | Ballion's crake, common greenshank, Latham's snipe, marsh sandpiper, red-necked stint | • Range of habitat types however tend to favour permanent or ephemeral wetlands with dense clumped vegetation (i.e. lignum, cane grass, sparse woodland)<br>• Forage on edges (grassy or mudflat margins) and roosts amongst grass or dense vegetation<br>• Diet consists predominately of invertebrates, insects and occasional seeds and other vegetation matter.<br>• Marsh sandpiper, red-necked stint and common greenshank visit Australian between August and April | • Generally stimulated by flood, rainfall and/or season and breed predominately between July-Dec 1-3 month breeding duration)<br>• Ideally require up to 6 months of inundation with depth of up to approximately 1 metre.<br>• Slow to moderate flood water recession required.<br>• Nest on ground and breed in range of habitat types including grassy banks, sedges, rushes, driftwood, fallen timber etc.<br>• Marsh sandpiper, red-necked stint and common greenshank does not breed in Australia | • Flood required in late winter/spring to stimulate breeding of most species with inundation to be maintained for up to 6 months<br>• Changes in water depth will create foraging opportunities can also result in nest abandonment if to severe. |
| Small waders | Australian spotted crake, | Sharp-tailed sandpiper, wood | • Frequents shallow, open freshwaters, particularly those with dense short | • Stimulated by flood and/or season with breeding occurring predominately between | • Flood required in winter/spring to stimulate breeding |

| Key values | Species present | | Broad requirements | | |
|---|---|---|---|---|---|
| | Characteristic | significant | Habitat | Breeding | Water requirements |
| | black-fronted dotterel, black-winged stilt, red-kneed dotterel[1], red-necked advocet | sandpiper | coverage of grass or other emergent vegetation<br>• Roost in shallow waters or on bare islands or banks near water<br>• Forage primarily in shallow water or saturated mudflats often close to emergent vegetation<br>• Diet comprises of aquatic and terrestrial invertebrates and occasional plant material including seeds<br>• Sharp-tailed and wood sandpipers visit Australia between August and by April | July-Feb (2-3 month breeding duration preferred)<br>•<br>• Flood duration of up to 6 months required with a moderate to slow recession in level<br>• Breed in a range of habitats and nest in a variety of habitats including grassy banks, sedges, floating vegetation, tussocks or on-ground nests<br>• Black-winged stilt and red-kneed dotterels regarded as semi-colonial<br>• Sharp-tailed and wood sandpipers do not breed in Australia | • Inundation to be maintained for up to 6 months<br>• Preference for intermittent wetlands which is shown to benefit breeding success. |
| Amphibians | Common froglet, pobblebonk, barking marsh frog, plains froglet, spotted marsh frog, peron's tree frog | Growling grass frog | • Normally widely distributed species that are highly adapted to a range of habitats, although prefer wetlands with ample fringing vegetation and fallen timber<br>• Most are able to readily colonise any waterbody<br>• Prefer to breed in diverse aquatic vegetation or submerged grasses | • Breed in spring and summer and lay eggs in slow moving/ still water or terrestrial habitat<br>• Tadpole development time of 2-6 months depending on the species<br>• All species appear to be more productive in wetlands with longer hydroperiods (i.e >6 months or permanent conditions)<br>• The timing of inundation dictates which species are able to successfully recruit and also impacts tadpole development time<br>• Growling grass frog required seasonally flooded waterbodies to breed | • Retain pooled water for at least 6 weeks if flooded in spring/summer and 3 months for winter<br>• Some species will burrow when wetlands dry (i.e. Eastern Sign-bearing Froglet) whilst other have a limited burrowing capacity and require more permanent conditions (growling grass frog)<br>• More productive in environments with ample aquatic and fringing vegetation with fallen timber. |
| Reptiles | N/A | Eastern long-necked turtle | • Typically occupy ephemeral or semi-permanent water bodies and avoid competition with other turtles and fish<br>• Will retreat to permanent water during drought or periods of low rainfall<br>• Adapted to overland migration and can move over 5 kilometres (although these events are rare)<br>• Rely on terrestrial environments as habitat corridors<br>• Diet consists primarily of fish, insects, tadpoles, frogs, yabbies and other crustaceans. | • Eggs laid during spring and early summer in an excavation in the bank of a wetland/dam (prefer sandy conditions)<br>• Young catch over incubation period of 3 to 8 months<br>• Eggs are at risk of predation by foxes | • Providing nearby water sources are available ephemeral or semi-permanent waterbodies are preferred. If site is isolated permanent conditions are required.<br>• Can cover themselves in mud or soil in dried up water bodies during dry months. |

| Key values | Species present | | Broad requirements | | |
|---|---|---|---|---|---|
| | **Characteristic** | **significant** | **Habitat** | **Breeding** | **Water requirements** |
| Macro-invertebrates | Predators | N/A | • Feed on other consumers | • Life histories of invertebrates are tied to food availability i.e. macroinvertebrates that eat algae scrapers/ grazers) are most abundant in the summer when algae production is at its highest<br>• Immature macroinvertebrates are most numerous during periods when dissolved oxygen levels are high (i.e. winter) | • Provide a diversity of habitat types and food sources (i.e. aquatic vegetation, fallen timber/ leaf litter, substrates etc.) to support a range of macroinvertebrates across the four key functional feeding groups |
| | Scraper/ grazers | | • Consume algae, bacteria, fungi and associated material from the surface of rocks, sediments, plants etc. | | |
| | Shredders | | • Consume live and dead coarse particulate organic matter (CPOM) including leaf litter, macrophytes and wood | | |
| | Collectors | | • Decompose fine particulate organic matter (FPOM) from the water column using a variety of filters (i.e. body parts, nets or my gathering)<br>• Often associated with sandy or muddy substrates | | |
| **Terrestrial based fauna** | | | | | |
| Woodland/ grassland birds | See Appendix 5 | Australian reed-warbler, black-eared cuckoo, brown quail, brown treecreeper, clamorous reed-warbler, grey-crowned babbler, white-bellied sea eagle, white-throated needletail | • Mainly over grassland and lightly wooded areas<br>• Nest in trees<br>• Some prey on mammals, others probe trees for insects or forage on the ground. | • Nest in trees (i.e. hollows or constructed nests) | • Most species not directly dependent on water however require watering points in the landscape<br>• Brown Treecreeper is dependent on vegetation reliant on flooding. |
| Mammals | Black wallaby, common brushtail possum, Eastern grey kangaroo, white-striped free-tailed bat, swamp Wallaby | N/A | • Varies habitat requirement depending on the species (from grasslands to woodland environments) | • Varies depending on the species | • Most species not directly dependent on water however require watering points in the landscape |
| Reptiles | Boulenger's | Carpet python | • Diet consist predominately of other | • Breed predominately in spring with eggs of | • Most species not directly dependent on |

| Key values | Species present | | Broad requirements | | |
|---|---|---|---|---|---|
| | Characteristic | significant | Habitat | Breeding | Water requirements |
| | skink, tiger snake | | reptiles and small mammals, nesting birds and carrion<br>• Utilise dense vegetation, trees and fallen timber as shelter | carpet python laid during December to January period. Hatchlings appear by late February.<br>• | water however require watering points in the landscape or habitat features dependent on water (i.e. river red gum) |

Key:
Note[1]: Breeding previously noted
Source: Birdlife Australia 2016a; Birdlife Australia 2016b; DELWP 2016a; DELWP 2016b; DELWP 2016c; DELWP 2016d; DELWP 2016e; DELWP 2016f; DELWP 2016g; Rakali 2016; VBA 2016; DELWP 2015a; Rakali 2015; Rakali 2014a; Pickering 2013; Australian Ecosystems 2012; Clemann and Gillespie 2012; Herring 2005; Roberts and Marston 2011; Rogers and Ralph 2011; Garnett and Crowley 2000; Marchant and Higgins 1990.

| EVC | Species present | | Broad requirements | | | | Broad ecological service |
|---|---|---|---|---|---|---|---|
| | Characteristics | Significant | Category | Frequency | Duration | Depth | |
| **Water dependent** | | | | | | | |
| Riverine Chenopod Woodland (EVC 103) | Dominated by black box with a diverse shrubby-grassy understorey rich in annual species. | Salt paperbark (planted) | Episodic | <3 in 10 years | Variable, but usually brief | <0.3 metres | • Trees (both dead and alive), shrub, reeds, rushes and grasses provide habitat (foraging/hunting grounds and nesting material) for waterbirds, reptiles, amphibians and terrestrial fauna (i.e. hollows, dense vegetation, fallen branches, shade and shelter).<br>• Existing plants provide a seed source for further recruitment.<br>• Water dependent species are promoted through wetting and drying cycles resulting in seed germination, nutrient cycling etc. |
| Lignum Shrubland (EVC 808) | Open Shrubland of tangled lignum with a ground layer dominated by grasses and herbs | N/A | Episodic | <3 in 10 years | < 6 months | <.5 metres | |
| Lignum Swampy Woodland (EVC 823) | Tall, mostly dense shrub-layer dominated by tangled lignum and a low overstorey of red gum, black box and eumong. Groundlayer has species promoted by intermittent inundation including water-ribbons, nardoo, milfoils and sedges. | Floodplain fireweed | Intermittent | 3-7 in 10 years | 1-6 months | 0.3-1 metre | |
| Intermittent Swampy Woodland (EVC 813) | Open canopy of mainly dead river red gum and black box trees with an open shrub layer consisting of tangled lignum. Groundlayer normally shallowly inundated supporting sedges and grasses. | Ridged water-milfoil, river swamp wallaby-grass, stiff groundsel, water nymph, wavy Marshwort (planted species), branching groundsel, brown beetle-grass, floodplain fireweed, winged water-starwort | Intermittent | 3-7 in 10 years | 1-6 months | 0.3-1 metre | |
| Aquatic Herbland (EVC 653)/ Lake Bed | Generally treeless area dominated by herbaceous species able to withstand | N/A | Intermittent | 3-7 in 10 years | 1-12 months | >0.3 metres | |

| EVC | Species present | | Broad requirements | | | | Broad ecological service |
|---|---|---|---|---|---|---|---|
| | Characteristics | Significant | Category | Frequency | Duration | Depth | |
| Herbland (EVC 107) | drying periods. Includes pondweed, milfoils, eel grass etc. | | | | | | |
| Tall Marsh (EVC 821) | Typically treeless zone dominated by thick swards of common reed and cumbungi. | N/A | Seasonal | 8-10 in 10 years | 1-8 months | 0.3-1 metres | • Provide shelter and nesting material for many waterbirds including habitat for cryptic species<br>• Assist with capture of sediments and filtering of water<br>• Provides habitat for frog species.<br>• N.B. EVC can become invasive if shallow flooding or waterlogging is provided during summer months. |
| Source: VBA 2016; DELWP 2015b; Rakali 2015; DEPI 2014b; Rakali 2014a; Australian Ecosystems 2012; DSE 2012; Frood 2012; Roberts and Marston 2011; Rogers and Ralph 2011. | | | | | | | |

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