Connecting Rivers, Landscapes, People

# Lake Murphy
# Environmental Water Management Plan

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

Department of Environment,
Land, Water & Planning

## Acknowledgement of Country

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

## Document control

### Document History and Status

| Version | Date Issued | Prepared By | Reviewed By | Date Approved |
|---|---|---|---|---|
| Version 1 | 28 April 2014 | Pam Beattie, RMCG | Bree Bisset and Louissa Rogers | 16 March 2015 |
| Version 2 | 23 March 2015 | Faith Deans, GHD | Genevieve Smith and Michelle Maher | - |
| Version 3 | 14 April 2015 | Genevieve Smith and Michelle Maher | Emer Campbell | 23 April 2015 |
| Version 4 | 24 April 2015 | Genevieve Smith and Michelle Maher | Suzanne Witteveen, DELWP | 17 May 2015 |
| Version 5 | 4 June 2015 | Genevieve Smith | Emer Campbell | FINAL |

### Distribution

| Version | Date | Quantity | Issued To |
|---|---|---|---|
| Version 1 | 28 April 2014 | Internal | Bree Bisset and Louissa Rogers |
| Version 2 | 23 March 2015 | Internal | Genevieve Smith and Michelle Maher |
| Version 3 | 14 April 2015 | Internal | Emer Campbell |
| Version 4 | 24 April 2015 | External | Suzanne Witteveen, DELWP |
| Version 5 | 30 June 2015 | External | Suzanne Witteveen and Susan Watson, DELWP |

### Document Management

| | |
|---|---|
| **Printed:** | 30 June 2015 |
| **Last saved:** | 30 June 2015 03:15 PM |
| **File name:** | Lake Murphy EWMP Draft.docx |
| **Authors:** | Various Authors, refer to document control |
| **Name of organisation:** | North Central CMA |
| **Name of document:** | Lake Murphy Environmental Water Management Plan |
| **Document version:** | 5 |
| **SharePoint link:** | NCCMA-63-39956 |

For further information on any of the information contained within this document contact:

North Central Catchment Management Authority
PO Box 18
Huntly Vic 3551
T: 03 5448 7124 F: 03 5448 7148
E: info@nccma.vic.gov.au
www.nccma.vic.gov.au

**Front cover image:** Brolga (*Grus rubicunda*) at Lake Murphy in January 2015 (North Central CMA)



Please cite this document as: North Central CMA, 2015. *Lake Murphy Environmental Water Management Plan*. North Central Catchment Management Authority, Huntly, Victoria.

## Executive Summary

The Lake Murphy Environmental Water Management Plan (EWMP) sets out the long-term objectives for the priority environmental values of Lake Murphy, in the Wandella Creek sub-catchment of the Loddon River Basin. The EWMP is an important part of the Victorian Environmental Water Planning Framework. It provides the five to ten year management intentions, based on scientific information and stakeholder consultation, that 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 Lake Murphy 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 Lake Murphy EWMP. A summary of the main conclusions to facilitate appropriate environmental water management into the future are summarised below.

**Hydrology and system operations**

A key threat to the long-term health of Lake Murphy is the alterations to the watering regime that have occurred as a result of increased regulation and modification throughout the landscape. The natural water supply for Lake Murphy originated from floods in the Loddon River and Wandella Creek. The natural hydrological cycle of Lake Murphy would have consisted of flooding in winter and spring, with drawdown due to evaporation occurring over the summer months. The presence of dead Black Box trees in the bed of the wetland indicates that the wetland would have remained dry for extend periods of time between floods. Periodic flushing would have also enabled the export of salt out of the wetland assisting in the maintenance of salinity levels.

Historically, Lake Murphy was used as a freshwater irrigation storage, which enabled flushing of water through the wetland and increased its permanency. Water was diverted from the Loddon River and pumped from Lake Murphy until the early 1900s when this practice ceased and Lake Murphy became a terminal system. As a consequence of limited through-flow and the significant increase in district saline groundwater levels, Lake Murphy began to accumulate salt. Over the past ten to 15 years, environmental water has regularly been allocated to Lake Murphy from the Murray Flora and Fauna Bulk Entitlement to provide conditions for waterbird feeding and breeding.

**Water dependent values**

Lake Murphy is considered to be a wetland of regional significance and is classed under State Wildlife Reserve. It has a high conservation status due to its size, habitat diversity, prevalence of native vegetation and provides valuable habitat for aquatic fauna, e.g. it is highly productive for waterbirds which use the wetland for habitat and feeding.

**Ecological condition and threats**

Lake Murphy has received natural flooding and environmental water in nine of the last 19 years since 1995. The water regime in recent years has not met the hydrological requirements of Lake Murphy's ecological values, and the condition of the wetland has deteriorated. It is therefore essential that Lake Murphy receive environmental water in a way that restores the hydrology of the system and enables the values and services provided by the wetland to be maintained.

The additional pressure posed by a lack of water may cause irreversible damage, for example, there is a risk that the viability of the seedbank within the wetland system may decline over time in response to minimal flooding opportunities. Environmental water is therefore needed to stimulate a wetland vegetation response

and enable life history processes to be completed for flora species, which can then support the fauna communities (such as waterbirds) within the wetland.

**Management objectives**

A long-term management goal has been defined for Lake Murphy:

> **Lake Murphy long term management goal**
>
> Maintain Lake Murphy as a temporary freshwater marsh able to support a diversity of vegetation communities that provide high quality feeding and breeding habitat for a diversity of waterbirds and frogs.

The ecological objectives and hydrological objectives that sit under the long-term management goal for Lake Murphy were informed by North Central CMA (2010) and Rakali Ecological Associates (2014a) and where refined during the development of this EWMP.

**Managing risks to achieving objectives**

The threats to achieving the ecological objectives that are external to environmental water have been identified by this EWMP. These include introduced species (i.e. foxes, invasive plants) as well as water quality issues.

**Environmental water delivery infrastructure**

It is recommended that a supply point (existing or proposed new delivery point) is retained to continue the supply of environmental water to Lake Murphy. Additional works to improve the ability to deliver environmental water to Lake Murphy include replacement of existing drop-bar outfall structure, however assessment of the emergent vegetation maintained by the current leaking drop board structure will need to be assessed.

**Demonstrating outcomes**

Monitoring is required to allow adaptive management of annual environmental watering (intervention monitoring). It is also required to enable the CMA and VEWH to demonstrate the long term outcomes of the implementation of the Lake Murphy EWMP. As the State is currently developing the Wetlands Monitoring Assessment Program (WetMAP), the Lake Murphy EWMP recommends a suite of intervention and long-term monitoring activities that will meet the monitoring requirements.

**Consultation**

Key stakeholders, including DELWP, VEWH, Parks Victoria and Goulburn Murray Water (GMW) have been engaged during the development of this EWMP. The community involved in the consultation phase of the Lake Murphy EWMP also played a crucial role in advising the North Central CMA on its management of environmental water at the wetland.

**Knowledge gaps**

The management actions in the Lake Murphy EWMP are based on the best available information. A number of knowledge gaps have been identified during the development of the EWMP, particularly around the ecological response from environmental watering.

# CONTENTS


**Executive Summary** ..... **3**
**Contents** ..... **5**
**TABLES** 6
**FIGURES** 6
**1. Introduction** ..... **7**
**1.1. Purpose and Scope** ..... **8**
**1.2. Development Process** ..... **8**
**2. Site overview** ..... **10**
**2.1. Site location** ..... **10**
**2.2. Catchment setting** ..... **10**
**2.3. Land status and management** ..... **12**
**2.4. Wetland characteristics** ..... **14**
**2.5. Environmental water sources** ..... **15**
**2.6. Related agreements, legislation, policy, plans and activities** ..... **17**
**3. Hydrology and system operations** ..... **19**
**3.1. Wetland hydrology, water management and delivery** ..... **19**
3.1.1. Pre-regulation 19
3.1.2. Post-regulation 19
**3.2. Groundwater/surface water interactions** ..... **21**
**3.3. Water Quality** ..... **22**
**3.4. Environmental watering** ..... **23**
**4. Values** ..... **25**
**4.1. Environmental values** ..... **25**
4.1.1. Listings 25
4.1.2. Water-dependent fauna 25
4.1.3. Terrestrial fauna 27
4.1.4. Vegetation communities and flora 27
4.1.5. Wetland depletion and rarity 29
4.1.6. Ecosystem functions 30
**4.2. Social values** ..... **31**
4.2.1. Cultural heritage 31
4.2.2. Recreation 31
**4.3. Economic values** ..... **31**
**4.4. Conceptualisation of the site** ..... **31**
**4.5. Significance** ..... **32**
**5. Ecological condition** ..... **33**
**5.1. Context** ..... **33**
**5.2. Current condition** ..... **33**
**5.3. Condition trajectory – do nothing scenario** ..... **34**
**6. Management objectives** ..... **36**
**6.1. Management goal** ..... **36**
**6.2. Ecological objectives** ..... **36**
**6.3. Lake Murphy Environmental Water Requirements** ..... **39**
**6.4. Watering regime** ..... **41**
**7. Risk assessment** ..... **43**
**8. Environmental water delivery infrastructure** ..... **46**
**8.1. Infrastructures and operational constraints** ..... **46**
**8.2. Irrigation modernisation** ..... **46**
**8.3. Infrastructure recommendations** ..... **47**
**9. Complementary actions** ..... **48**
**10. Demonstrating outcomes** ..... **49**
**10.1. Long-term monitoring** ..... **49**
**10.2. Intervention monitoring** ..... **50**
**11. Consultation** ..... **53**
**12. Knowledge gaps and recommendations** ..... **54**
**13. References** ..... **55**
**14. Abbreviations and acronyms** ..... **58**
**Appendix 1: Community Consultation** ..... **59**
**Appendix 2: Species List** ..... **64**
**Appendix 3: SWET model output** ..... **71**
**Appendix 4: Ecological Vegetation Class Mapping** ..... **73**

Appendix 5: Lake Murphy contours and capacity table ..... 75
Appendix 6: Criteria and assessment indicators for Lake Murphy's ecosystem function ..... 78

## TABLES

Table 1. History of technical work undertaken for Lake Murphy ..... 9
Table 2. Agencies and stakeholders with a responsibility or interest in the management of Lake Murphy ..... 13
Table 3. Wetland characteristics of Lake Murphy ..... 15
Table 4. Potential environmental water sources for Lake Murphy ..... 16
Table 5. EPA Environmental quality guidelines and spot measurements at Lake Murphy when inundated ..... 23
Table 6. Lake Murphy wetting/drying calendar (North Central CMA 2014) ..... 24
Table 7. Significance of Lake Murphy and its associated species ..... 25
Table 8. Significant water dependent fauna species (birds) recorded at Lake Murphy ..... 26
Table 9. Most recent bird breeding events at Lake Murphy ..... 27
Table 10. Conservation status of EVCs at Lake Murphy (DEPI 2014e) ..... 27
Table 11. Listed water dependent flora recorded at Lake Murphy ..... 28
Table 12. Area, depletion and rarity of wetland classifications in the region ..... 29
Table 13. Ecosystem function of Lake Murphy from a local and regional scale ..... 30
Table 14. IWC biota sub-index scores for Lake Murphy ..... 33
Table 15. Ecological objectives and their justifications for Lake Murphy ..... 37
Table 16. Hydrological requirements for ecological values at Lake Murphy ..... 40
Table 17. Risk Matrix ..... 43
Table 18. Possible risks and mitigation measures associated with environmental water delivery to Lake Murphy ..... 44
Table 19. Complementary actions to enhance the outcomes of environmental water ..... 48
Table 20. Required long-term condition monitoring for Lake Murphy ..... 49
Table 21. Required intervention monitoring activities for Lake Murphy ..... 50
Table 22. Knowledge gaps and recommendations ..... 54
Table 23. Lake Murphy holding capacity table ..... 76

## FIGURES

Figure 1: Planning framework for decisions about environmental water management in Victoria ..... 7
Figure 3. Location of Lake Murphy ..... 10
Figure 4. Lake Murphy cross section (adapted from Northern Land Solutions 2014) ..... 11
Figure 5. Terrain of the lower Loddon River catchment ..... 12
Figure 6. Local landscape and water delivery infrastructure around Lake Murphy ..... 20
Figure 7. Hydrograph showing the changing groundwater levels at Lake Murphy (DEPI 2014d) ..... 22
Figure 8. Schematic of wetland areas to be targeted (not to scale) ..... 32
Figure 9. Lake Murphy GMW infrastructure ..... 46

# 1. Introduction

Management of environmental water is planned and implemented through a framework of key activities. Figure 1 illustrates the strategies, scientific reports and operational documents required for environmental water management in Victoria (VEWH 2013). 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). The NCWS is guided by the *Victorian Waterway Management Strategy 2013 (*VWMS) and the *North Central Regional Catchment Strategy 2013* (RCS) (North Central CMA 2014a).

Lake Murphy sits within the lower Loddon Program Area and is an identified priority wetland in the Waterway Strategy. For Lake Murphy the long term resource condition target is to:

- Provide a water regime that supports a diversity of waterbirds, flora and fauna typical of a temporary freshwater marsh.

The achievement of the NCWS resource condition target is reliant on a number of management activities including potential future environmental water delivery and pest plant and animal control works.

The North Central CMA is being funded through the Department of Environment, Land, Water and Planning (DELWP) 'Victorian Basin Plan Environmental Water Management Plan (EWMP) Program' to prepare an EWMP for Lake Murphy. Once completed, annual seasonal watering proposals for the Lake Murphy will be informed by the NCWS EWMP.

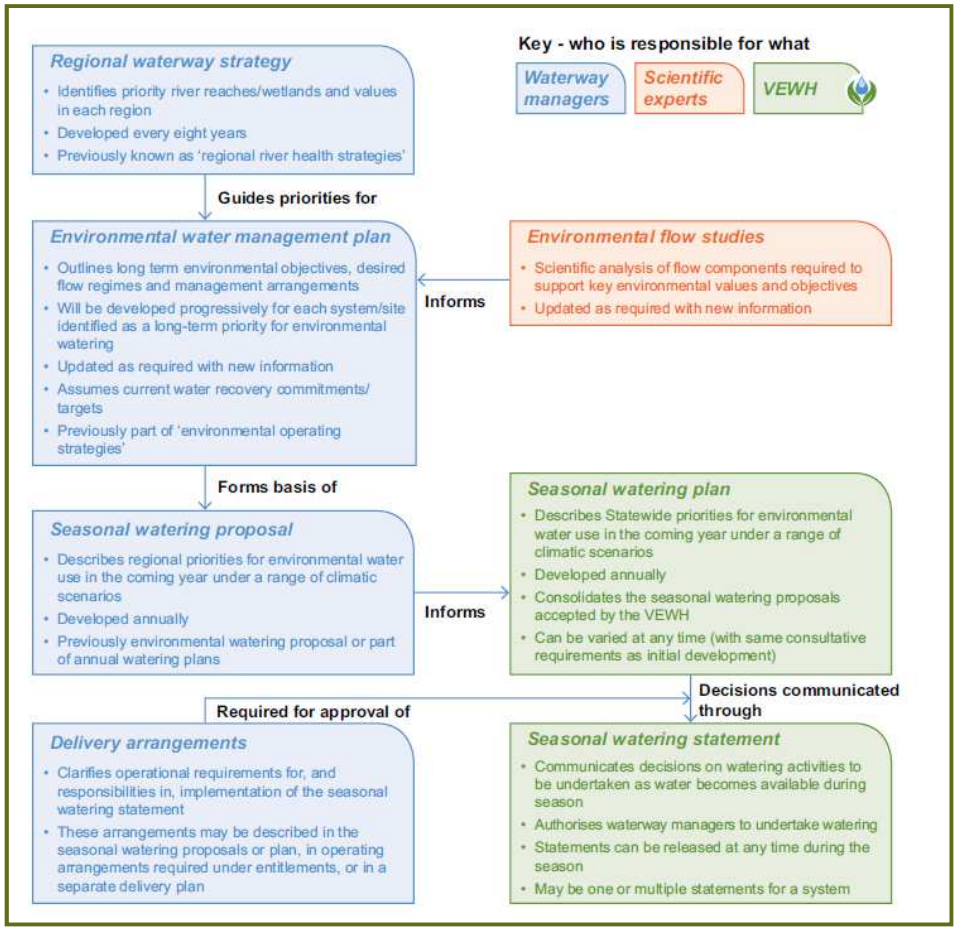



**Figure 1: Planning framework for decisions about environmental water management in Victoria.**

## 1.1. Purpose and scope

The Lake Murphy EWMP is a ten year management plan that describes the ecological values present, the long-term goal for the wetland and priority ecological objectives and required watering regime to achieve these objectives.

It is based on both scientific information and stakeholder consultation and will be used by the North Central CMA when making annual environmental watering decisions, as well as Department of Environment, Land, Water and Planning (DELWP) and the Victorian Environmental Water Holder (VEWH) for both short and longer-term environmental water planning (Department of Environment and Primary Industries [DEPI] 2014a).

The key purposes of the EWMP are to:

- Identify the long-term objectives and water requirements for the river, identified as a high priority by the North Central CMA
- Provide a vehicle for community consultation, including for the long-term objectives and water requirements of the river
- Inform the development of seasonal watering proposals and seasonal watering plans
- Inform Long-term Watering Plans that will be developed by the State under the Basin Plan Chapter 8 (DEPI 2014a).

## 1.2. Development Process

Lake Murphy has an Environmental Watering Plan that was prepared by the North Central CMA under the Goulburn Murray Water Connections Project (formerly the Northern Victoria Irrigation Renewal Project). The development of the EWP was to establish a volume of mitigation water that Goulburn Murray Water Connections Project was required to set aside for Lake Murphy. The development process for the EWP established ecological objectives and a watering regime for Lake Murphy. The Lake Murphy EWMP is based on work undertaken for, and presented in, the *Lake Murphy Environmental Watering Plan 2010* (EWP), and was developed in collaboration with key stakeholders including DELWP, Parks Victoria, VEWH and Goulburn Murray Water (GMW). A number of tasks were undertaken to develop the EWMP including:

- **Scoping and collating information:** Key information e.g. monitoring data and analysis completed at Lake Muphy to date has been included in the EWMP. Key inofrmation from the EWP has been incorporated into this EWMP and updated.
- **Water dependent values:** environmental values have been described including(water dependent fauna, Ecological Vegetation Classes (EVCs) and flora). Social values (cultural heritage, recreation and economic) have also been described.
- **Ecological condition and threats:** the current condition and water related threats have been described.
- **Management objectives:** a key output of the EWMP is defining the key ecological objectives and associated hydrological objectives. The ecological objectives and water regime from the Lake Murphy EWP (North Central CMA 2010) have been reviewed to incorporate any new information. The water regime has also been updated to include critical tolerances under wet, average and dry climate scenarios.
- **Managing risks:** the risks to achieving the ecological objectives for Lake Murphy have been assessed. Management actions to mitigate the risk have been recommended and residual risk assessed.
- **Environmental water delivery infrastructure:** identification of current constraints in delivering the environmental water regime.
- **Demonstrating outcomes:** key monitoring priorities have been identified for the implementation of this EWMP.

- **Consultation:** key stakeholder and community members were engaged to assist with developing a picture of the history, values, threats, condition and management outcomes required at Lake Murphy. The outcomes of this workshop are summarised in Appendix 1.
- **Knowledge gaps and recommendations:** an action list with timeframes has been developed whilst developing the EWMP, including a review of this EWMP in five years' time.

The history of technical works undertaken to date are shown in Table 1.

**Table 1. History of technical work undertaken for Lake Murphy**

| Name | Author | Date | Summary |
|---|---|---|---|
| Lake Murphy Environmental Watering Plan | North Central CMA | July 2010 | This document was prepared for the GMW Connections Project (previously named the Northern Victoria Irrigation Renewal Project, NVIRP). It documents the approach to mitigating the potential impacts from the automation of the Torrumbarry 17/2 channel that was previously an outfall into Lake Murphy. |
| Seasonal Watering Proposal for the Central Murray Wetland Complex 2014-15 | North Central CMA | April 2014 | The Seasonal Watering Proposal (SWP) outlines the North Central CMA's proposed priorities for use of managed environmental water, including the Water Holdings, in the Central Murray Wetland Complex during 2014-15. This includes Lake Murphy. |
| Lake Murphy Bathymetry Survey | Northern Land Solutions | March 2014 | Bathymetric survey which provides detail on minimum depth, full supply level, area at full supply level and volume. |
| Lake Murphy Aquatic vegetation investigation | North Central CMA | January 2015 | Aquatic vegetation survey and mapping on Lake Murphy. |

# 2. Site overview

## 2.1. Site location

Lake Murphy is a 172 hectare intermittent wetland situated approximately eight kilometres south-west of Kerang Victoria (Figure 2).

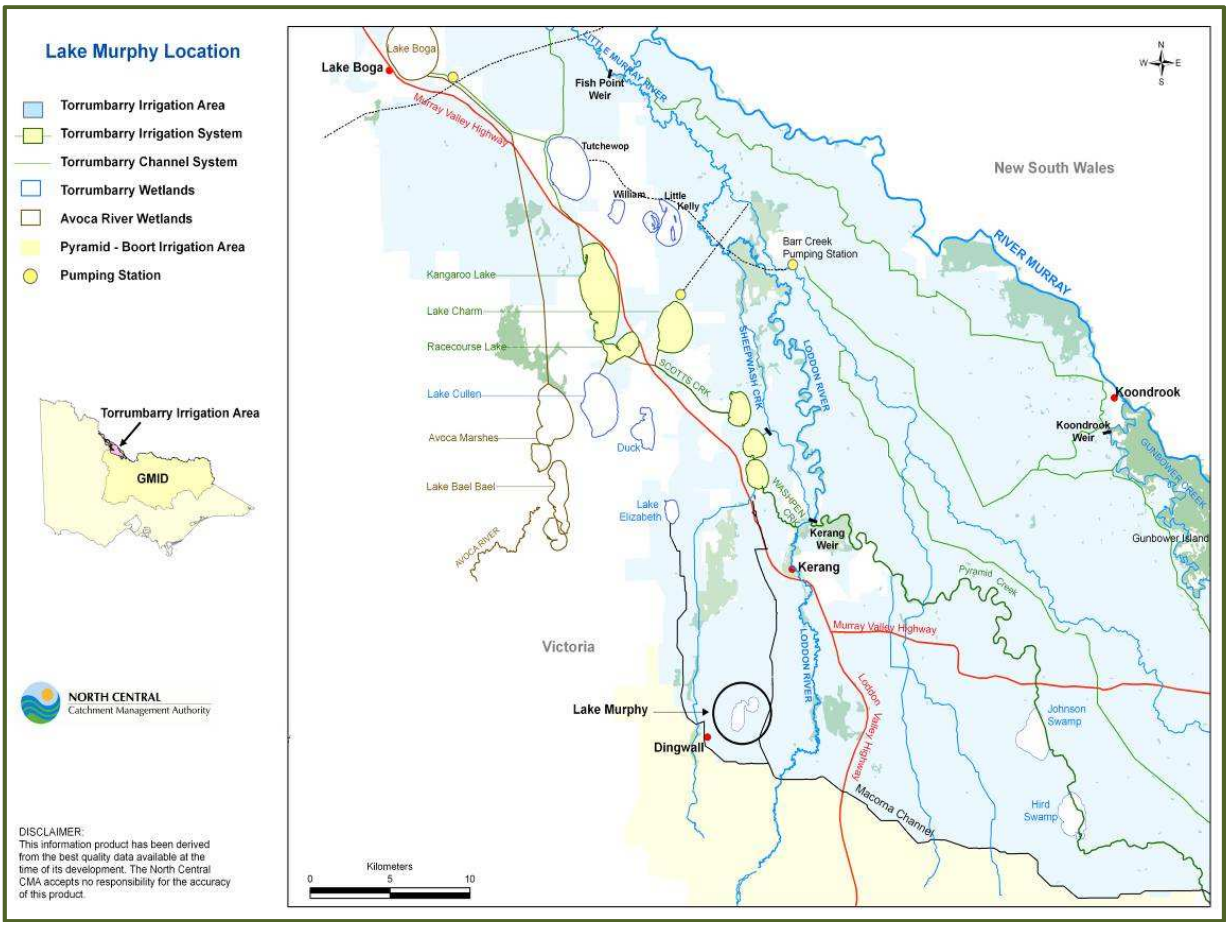



**Figure 2. Location of Lake Murphy**

## 2.2. Catchment setting

*Climate*

Climate data were obtained from the Bureau of Meteorology (BOM) for the Kerang meteorological station. Rainfall in the Kerang region averages 377 mm/year, with May to October being significantly wetter than November to April (Macumber 2002). Maximum average temperatures range from 31.6°C in January to 14.6°C in July, with minimum temperatures rarely falling below zero degrees (BOM 2014). Evaporation rates from the 'Kerang Model Farm' shows pan evaporation (Class A Pan) rates of approximately 1,384.1 mm ranging from 32.8 mm in June to up to 233.3 mm in January between 1991 and 2013 (data supplied by R & E Jones, 2013).

*Hydro-physical characteristics*

Lake Murphy is located within the Wandella Creek sub-catchment of the Loddon River basin. It is situated within Victorian Riverina bioregion; an area that is characterised by a flat to gently undulating landscape on recent unconsolidated sediments, with evidence of former stream channels and broad floodplain areas (DEPI 2014b). The local catchment area of Lake Murphy is approximately 1,600 hectares and is surrounded by an extensive agricultural landscape consisting primarily of broad-acre dryland cropping and grazing (Davies et al. 2005).

The wetland's capacity is 1658 ML at the full supply level (FSL) of 78.0 m AHD (Northern Land Solutions 2014, Appendix 5). Although Lake Murphy is a single lake, the presence of a narrow, slightly elevated section separates the wetland into two, referred to as Lake Murphy East and Lake Murphy West. Both of these areas can currently be influenced by environmental water. When filled the eastern section reaches a depth of approximately 0.2 metres depth before water begins entering the larger western section of the wetland. Figure 3 shows the topography of Lake Murphy.

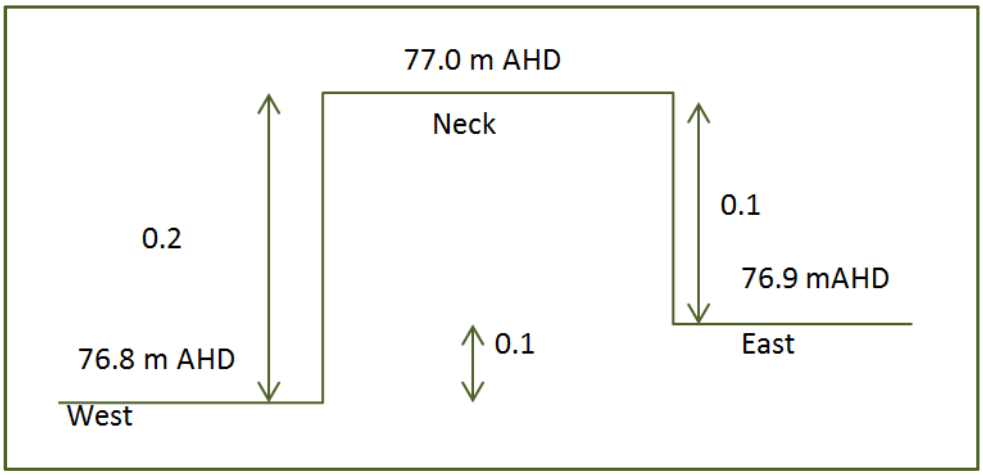



**Figure 3. Lake Murphy cross section (adapted from Northern Land Solutions 2014)**

Minor surface drainage flows can enter the wetland from small depressions along the western and southern boundary however the majority of inflows are now received via the Torrumbarry 17/2 Channel (North Central CMA 2010; SKM 1997). Figure 4 shows the natural topography and major wetlands in the lower Loddon River, downstream of Wandella Creek breakaway to Kerang Weir.

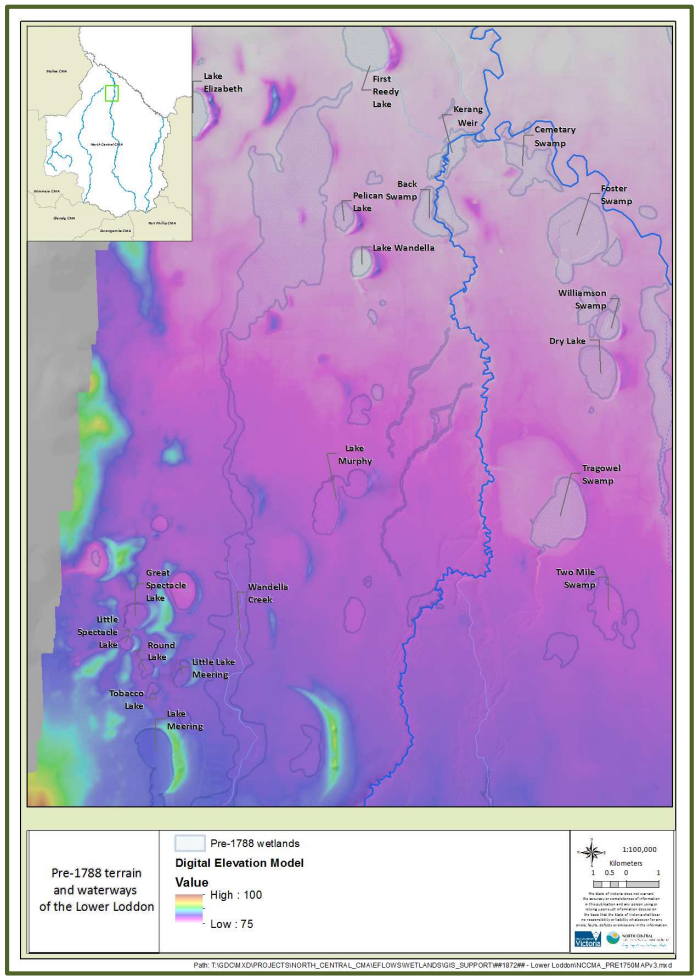



**Figure 4. Terrain of the lower Loddon River catchment**

## 2.3. Land status and management

*Land use*

Land use in the catchment surrounding Lake Murphy is agriculture and the wetland sits within the Torrumbarry Irrigation Area (TIA). Major agricultural activities include sheep and cattle grazing and broadacre dryland cropping (North Central CMA 2010).

*Land tenure*

Lake Murphy is a State Wildlife Reserve established under the *Crown Land (Reserves) Act 1978* on land reserved for the purpose of managing wildlife and preserving its habitat. Parks Victoria manages the day-to-day use of Lake Murphy under the *Wildlife Act 1975* on behalf of the Secretary of DELWP. Lake Murphy is further classified as a State Game Reserve. These reserves are primarily managed to conserve and protect species, communities or habitats of indigenous animals and plants while permitting recreational use (including hunting in season as specified by the land manager), and educational purposes (DSE 2009; VEAC 2008). Goulburn Murray Water (GMW) is the local water corporation and storage operator, while North Central CMA is the regional environmental water manager. Table 2 provides a list of stakeholders and their involvement in the management of Lake Murphy.

**Table 2. Agencies and stakeholders with a responsibility or interest in the management of Lake Murphy**

| Agency / Group | Responsibility / involvement |
|---|---|
| Department of Environment, Land, Water and Planning (DELWP) | • Manage the water allocation and entitlements framework<br>• Develop state policy on water resource management and waterway management approved by the Minister for Environment, Climate Change and Water<br>• Develop state policy for the management of environmental water in regulated and unregulated systems<br>• Act on behalf of the Minister for Environment, Climate Change and Water 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>• Provides approval of EWMPs and endorsement of 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 state-wide Seasonal Watering Plan<br>• Provides final endorsement of SWPs<br>• Approves delivery of environmental water (Seasonal Watering Statement) and funds environmental water related monitoring. |
| Commonwealth Environmental Water Holder (CEWH) | • 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) | • Implementation of 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>• Integration of Basin wide water resource management<br>• Manager of The Living Murray water entitlements |
| North Central Catchment Authority (North Central CMA) | • Waterway Manager<br>• Identify regional priorities for environmental water management in regional Waterway Strategies<br>• In consultation with the community assess water regime requirements of priority rivers and wetlands 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) 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 for 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 |

| Agency / Group | Responsibility / involvement |
|---|---|
| | • Ensure the provision of passing flows and compliance with management of diversion limits in unregulated and groundwater systems<br>• Provides endorsement of SWP and facilitates on-ground delivery. |
| Parks Victoria | • Land manager<br>• Implement the relevant components of EWMPs.<br>• Operate, maintain and replace, as agreed, the infrastructure required for delivery of environmental water, where the infrastructure is not part of the GMW irrigation delivery system.<br>• Where agreed, participate in the periodic review of relevant EWMPs and provides endorsement of 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 | |
| Gannawarra Shire Council | • Local council for area that includes Lake Murphy<br>• Responsible for regulation of local development through planning schemes and on-ground works. |
| Traditional Owners Wamba Wamba, Barapa Barapa and Wadi Wadi Peoples Native Title Claimants (VC00/5) and Barapa Barapa Nation Aboriginal Corporation | • Traditional owners of the area encompassing Lake Murphy<br>• Consulted in the development of this EWMP. |
| Field And Game Australia | • A voluntary organisation formed by hunters to promote responsible firearm ownership and ethical hunting |
| Local community | • Recreational users of Lake Murphy, including passive recreational pursuits such as walking, bird watching, camping and yabbying<br>• Consulted in the development of this EWMP. |
| Local landholders | • Management of private land surrounding Lake Murphy.<br>• Involved in consultation for the Lake Murphy EWMP. |
| Central Murray Environmental Water Advisory Group (Central Murray EWAG) | • The Central Murray EWAG consists of key stakeholders and community representatives who provide advice to the North Central CMA on the best use of environmental water for the wetlands located on the Murray River floodplain extending from Echuca through to Swan Hill. Current membership is provided in Appendix 1. |

## 2.4. Wetland characteristics

Victoria's wetland classification and inventory was updated in 2013 and replaces the system developed by Corrick and Norman. The updated classification is based on the Australian National Aquatic Ecosystem (ANAE) Classification Framework (the Framework) with data on wetlands and their classification attributes converted into spatial Geographic Information System (GIS) layers.

The Framework structure produces 37 wetland categories that were adopted to distinguish naturally-occurring from human-made wetlands in the first level of the classification hierarchy. Aquatic ecosystem habitats: palustrine, lacustrine and estuarine distinguish wetlands in the second level of the classification hierarchy and wetland attributes: water regime, salinity, landscape context, soils and wetland vegetation distinguish wetlands in the third level of the hierarchy (DEPI 2014b).

Under Corrick and Norman, Lake Murphy was classified as a shallow freshwater marsh (1750 pre-European Classification), however regulation as part of the irrigation supply system resulted in the classification shifting to a deep freshwater marsh (1994 Classification) dominated by reed vegetation and dead Black Box (DSE 2009; Lugg et al. 1989). Based on the new classification system, Lake Murphy is a naturally occurring temporary freshwater marsh[1] (DEPI 2014b). An overview of the wetland characteristics is provided in Table 3.

**Table 3. Wetland characteristics of Lake Murphy**

| Characteristics | Description |
|---|---|
| Name | Lake Murphy |
| Mapping ID | Corrick: 7626 587335<br>*Victorian Wetland ID:* 43205 |
| Area (ha) | 172.40 ha at FSL (78.0 m AHD) (NLS 2014) |
| Bioregion | Victoria Riverina |
| Conservation status | Bioregionally Important Wetland, National Land and Water Resources Audit (NLWRA): *Directory of Important Wetlands in Australia*. |
| Land status | Wildlife Reserve (126 ha), under the *Wildlife Act 1975* |
| Land manager | Parks Victoria |
| Surrounding land use | Broadacre dryland cropping and grazing (Davies et al. 2005). |
| Water supply | Historical:<br>• Floodwater from the Loddon River and Wandella Creek.<br>• Local catchment area of approximately 1,600 ha<br>• Has historically received outfalls from the 17/2 channel system from rainfall rejection events occurring after heavy rains, and surplus flows.<br>Current:<br>• Via the GMW 3/17/2 channel located to the north of the wetland.<br>• Some drainage water from nearby farming properties (North Central CMA 2010). |
| 1788 wetland category (Corrick and Norman) | Shallow freshwater marsh |
| 1994 wetland category (Corrick and Norman) | *Category:* Deep freshwater marsh<br>*Sub-category:* Dead Timber |
| 2013 Victorian wetland classification (DEPI 2014b) | *Wetland Type*: Temporary freshwater marsh[1] |
| Wetland capacity | 1658 ML at FSL (not accounting for evaporation or seepage) |
| Wetland depth at capacity | 1.3 m at FSL, refer to Appendix 5 |

## 2.5. Environmental water sources

Three environmental water sources are potentially available for use at Lake Murphy, as shown in Table 4 and described below. 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.

[1] Under the 2013 Victorian wetland classification layer, the wetland type for Lake Murphy is 'unknown'. However, based on the criteria for each wetland type, Lake Murphy has been classified by the North Central CMA as a temporary freshwater marsh.

Allocations are made to high-reliability water shares before low-reliability shares (DEPI 2014c). It is important to note that water availability will vary from season to season, according to climatic conditions, volumes held in storage and carryover entitlements.

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

The Victorian River Murray Flora and Fauna Bulk Entitlement provides 27,600 ML HRWS in the Murray System. It is held by the VEWH for the purpose of providing for flora and fauna needs. It has been used in a range of wetlands including Gunbower Forest (Living Murray icon site) and the Kerang Ramsar wetlands. It can also be traded on the water market on an annual basis. Although it has historically been used in Lake Murphy, the use of this water is not guaranteed and is at the discretion of the VEWH (VEWH 2012).

*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 31 January 2015, the Commonwealth environmental water holdings totaled 3,397 ML for the Loddon River catchment. The use of this water for wetlands in the North Central CMA region is not guaranteed and is at the discretion of the CEWH (CEWH 2015).

*Temporary water allocation donations*

Individuals with water shares can donate water to their local catchment management authority 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 Lake Murphy**

| 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) | 29,783 ML<br>3,993 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<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 | Victorian Environmental Water Holder |
| Commonwealth Environmental Water Holdings – Loddon Catchment | 2,870 ML<br>527 ML | HRWS<br>LRWS | Managed in line with the Murray Darling Basin Plan | Commonwealth Environmental Water Holder |
| Temporary water donations | Variable | N/A | Agreement is required with private donator | VEWH/ CMA |

*Other sources*

The GMW Connections Project sought to upgrade ageing irrigation infrastructure across the Goulburn Murray Irrigation District (GMID) and to save water lost through leakage, seepage, evaporation and system inefficiencies (North Central CMA 2010). Lake Murphy was identified as a priority wetland that could be impacted by the reduction in channel outfalls associated with increased efficiencies (SKM 2008). While the Lake Murphy Environmental Watering Plan 2010 concluded that Lake Murphy was not impacted by a reduction in channel outfalls, an upgrade to existing infrastructure would stop leakage that is critical to

maintaining the character of the wetland. No mitigation water has been calculated for Lake Murphy at present, but this may become necessary if further modernisation of irrigation infrastructure occurs.

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

There are a range of international treaties, conventions and initiatives, as well as Commonwealth and Victorian legislation, policies and strategies that direct management of wetlands within Northern Victoria. Those with particular relevance to Lake Murphy and the management of its environmental and cultural values are listed below. For the functions and major elements of each refer to Appendix 2.

International treaties, conventions and initiatives:

- Japan Australia Migratory Birds Agreement (JAMBA) 1974 - 12 of the species listed under this agreement have been recorded at Lake Murphy.
- China Australia Migratory Birds Agreement (CAMBA) 1986 - 14 of the species listed under this agreement have been recorded at Lake Murphy.
- Republic of Korea Australia Migratory Birds Agreement (ROKAMBA) 2002 - 12 of the species listed under this agreement have been recorded at Lake Murphy.
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) 1979 – 13 of the species listed under this convention have been recorded at Lake Murphy.

Commonwealth legislation and policy:

- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Part IIA) - Lake Murphy is known to support places of cultural significance.
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) - four migratory species and one flora species listed under this Act have been recorded at Lake Murphy.
- *Water Act 2007* – to provide for the protection of ecological values at Lake Murphy through appropriate management of Murray-Darling Basin water resources.

Victorian legislation:

- *Aboriginal Heritage Act 2006* - Lake Murphy is known to support places of cultural significance. As per the *Aboriginal Heritage Act 2006* a Cultural Heritage Management Plan is required if areas of cultural heritage sensitivity are likely to be impacted or if the activity itself is considered high impact (i.e. significant ground disturbance).
- *Catchment and Land Protection Act 1994* - governs the management of land surrounding Lake Murphy e.g. pest plant and animal control.
- *Water Act 1989* - provides a formal means for the integrated management of water in Victoria.
- *Wildlife Act 1975* - Parks Victoria manages Lake Murphy in accordance with this Act.
- *Flora and Fauna Guarantee Act 1988* (FFG Act) - nine fauna species and three flora species listed under this Act have been recorded at Lake Murphy.

Victorian policy and strategies:

- Victorian Waterway Management Strategy (VWMS) - 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 2013).

- Victorian threatened flora and fauna species (DEPI advisory lists) – seven flora species on the DEPI advisory lists have been recorded at Lake Murphy.

Regional strategies and plans:

- North Central Regional Catchment Strategy (RSC) (North Central CMA 2012) – this strategy (2013-2019) 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 Kamarooka Wetland Complex is identified as a key priority asset in the RCS and to is a range of on-ground activities focusing on the development of environmental water infrastructure to improve wetland health.
- North Central Waterway Strategy (NCWS) (North Central CMA 2014) – this regional strategy is an action out of the VWMS 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. Lake Murphy is a priority wetland for this eight year planning period.
- Lake Murphy Environmental Watering Plan (EWP) (North Central CMA 2010) – was developed as part of the GMW Connections Project. It documents the approach to mitigating the potential impacts of the automation of the Torrumbarry 17/2 channel that outfalls into Lake Murphy. The EWP defines the water required to protect the environmental values (established a management goal with ecological and hydrological objectives that sit uder the overall goal).

# 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 & Gosselink 2000). Duration, frequency and seasonality (timing) are the main components of the hydrological regime for wetlands and rivers.

## 3.1. Wetland hydrology, water management and delivery

### 3.1.1. Pre-regulation

Prior to European influence, the natural water supply for Lake Murphy would have originated from floods in the Loddon River and Wandella Creek. In large flood events, the wetland would have overflowed in a north-westerly direction towards Wandella Forest. It is estimated that Lake Murphy historically received up to 30% of the Loddon River floodwater (SKM 1997). Today Wandella Creek becomes active when flows in the Loddon River reach 350 ML/day (RMCG 2012).

The natural hydrological cycle of Lake Murphy would have consisted of flooding in winter and spring, with drawdown due to evaporation occurring over the summer months. The presence of Black Box trees (now dead) in the bed of the wetland indicates that the wetland would have remained dry for extended periods of time between floods, allowing this species to grow. However, the small diameter of the Black Box stumps within the wetland is a reflection of the regular inundation of the wetland coupled with naturally higher salinity levels which are unfavourable to this species (SKM 1997). Periodic flushing would have also enabled the export of salt out of the wetland assisting in the maintenance of salinity levels (SKM 1997). This natural wetting and drying cycle would have supported a diversity of aquatic and terrestrial flora and fauna communities (Australian Ecosystems 2012).

### 3.1.2. Post-regulation

*Historic use of Lake Murphy*

Historically, Lake Murphy was used as a freshwater irrigation storage, which enabled flushing of water through the wetland and increased its permanency. Water was diverted from the Loddon River and pumped from Lake Murphy then into a 'trust' channel, through Wandella Forest to Lake Elizabeth. In the early 1900s this practice ceased and Lake Murphy became a terminal system. As a consequence of limited through-flow and the significant increase in district saline groundwater levels, Lake Murphy began to accumulate salt.

*Irrigation outfalls and modernisation*

Lake Murphy historically received outfalls from GMW's 17/2 channel system (located in the north east corner, Figure 5) from rainfall rejection events occurring after heavy rains and surplus flows until sometime in the 1990s (no later than 1998) (North Central CMA 2010). Although not recorded, these may have been as high as 10-12 ML/day (Turner G, 1997, personal communication [DPI] in SKM 1997). Anecdotal information suggests that prior to the 1990s water bailiffs would intentionally outfall water prior to the opening of the duck season. The periodic flushing and flooding conditions would have provided suitable open water and mudflat habitat for waterbirds (O'Brien 2009).

Outfall data for Lake Murphy has been recorded by GMW since 1998 and records indicate no outfalls to the wetland have occurred from 1998 to 2008. This is a result of increased channel efficiency, lower water allocations and the perceived adverse impacts of outfalls on wetlands (e.g. increasing salinity) (North Central CMA 2010). However, substantial leakage through and around the outfall structure has been observed during the irrigation season (not recorded or quantified) and this water has supported a small area of Cumbungi at the inlet channel (North Central CMA 2010). It has also influenced local groundwater levels (Section 3.2).

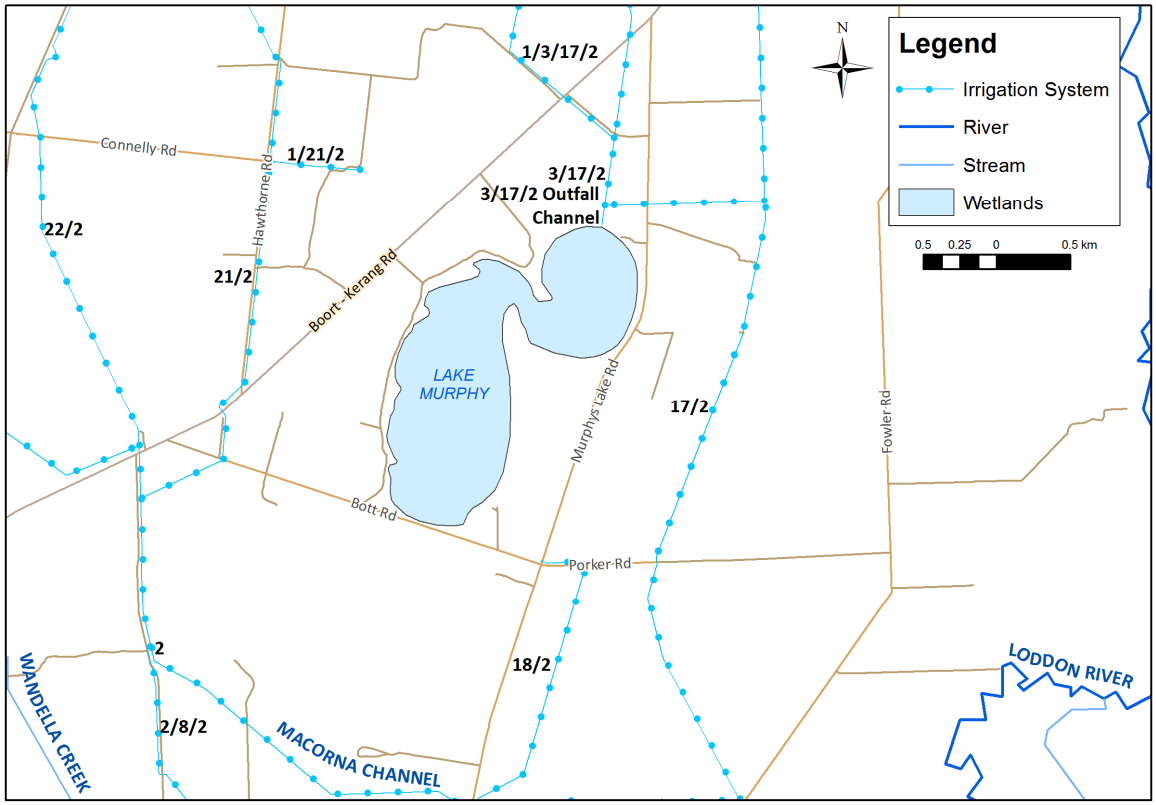



**Figure 5. Local landscape and water delivery infrastructure around Lake Murphy**

*Current water regime*

The wetland is no longer actively managed for distribution or storage of floodwater and due to floodplain changes it is now a terminal system. Since 1996, environmental water has been allocated to Lake Murphy (five events) from the Murray Flora and Fauna Bulk Entitlement to provide conditions for waterbird feeding and breeding (refer to Section 3.4).

Lake Murphy is now disconnected from the floodplain through irrigation channels and levees throughout the landscape which have significantly reduced natural floodwaters entering the wetland (SKM 1997). The water regime is now determined by rainfall, natural inflows, environmental watering and leakage through and around the channel outfall. Spring and summer floods between September 2010 and January 2011 resulted in the wetland filling and retaining water up until April 2013 when it dried completely. An environmental watering event commenced in October 2014, targeting the lignum vegetation community and promoting a range of habitat types important for waterbirds such as open water and mudflats (North Central CMA 2014b).

**Plate 1: Dry phase (March 2009)**

**Plate 2: Wet phase (1985) showing coverage of emergent vegetation**

Plate 3. Wet phase (November 2014) showing limited littoral and aquatic vegetation in Lake Murphy West

Plate 4. Pelicans feeding at Lake Murphy (December 2014)

## 3.2. Groundwater/surface water interactions

*Surface water interactions*

The wetland has a local catchment area of approximately 1,600 ha (SKM 1997). Surface runoff from the surrounding land has not been monitored but it was still considered to be substantial, especially in the wetter periods of the early 1970s to mid-1990s. However, the following 12 years saw the volume of local catchment runoff reduce significantly due below average rainfall and low rainfall intensity combined with the drier catchment. Minor drainage flows enter from small depressions that flow into Lake Murphy West at various points along the western bank (North Central CMA 2010).

Local catchment runoff entering the wetland could have positive environmental benefits. However, this is dependent on the timing of the runoff and the water quality. During wetter periods (i.e. 1980s and mid-1990s), the local drainage inputs had a negative impact on the environmental values of the wetland through increased nutrient and salinity inputs (North Central CMA 2010).

*Groundwater interactions*

The Department of Economic Development, Jobs, Transport and Resources (previous Department of Primary Industries) has monitored surface water at Lake Murphy since 1990 and the groundwater since 1994. In September 1999, additional surface water and groundwater monitoring sites were established to obtain more comprehensive data on the wetland.

The regional groundwater flow is in a general northerly direction. This pattern is complicated from time to time by local seasonal influences from streams, channels and wetlands. The hydraulic gradient is also quite flat across the area (Reid & O'Brien 2009). The hydrograph record (Figure 6) shows a history of dynamic groundwater behaviour with watertable levels in the vicinity of Lake Murphy corresponding well to wetland levels. After the environmental water event in 2005-06 watertables under and surrounding the wetland dropped by between one and two metres.

Groundwater levels have risen since their record low in late 2009 and early 2010, due to the influence of natural flooding between September 2010 and January 2011. Figure 6 shows how quickly water table levels can respond to flooding. In February 2010, the depth to water table was measured at greater than three metres. Following the floods, the water table rose to 0.5m from the surface by November 2011. One year later, the water table had dropped back to around two metres from the surface.

During periods of elevated groundwater levels, the wetland has the potential to be impacted by saline groundwater discharge, or potentially induce salinity in surrounding land. Groundwater around Lake Murphy is generally higher than 50,000 µScm (typically close to the salinity of seawater).

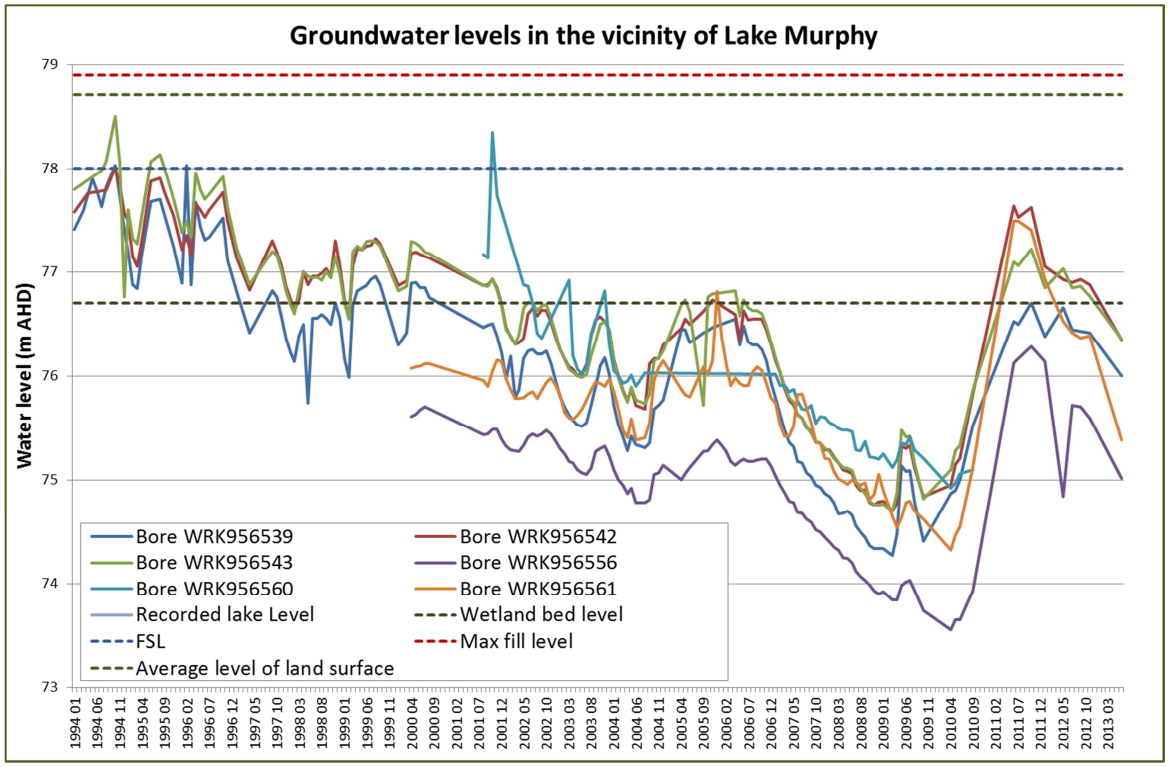



**Figure 6. Hydrograph showing the changing groundwater levels at Lake Murphy (DEPI 2014d)**

The groundwater trends indicate the following:

- Present watertable levels reflect the regional watertable surface (there is no obvious groundwater mound caused by the wetland).
- The watertable depth during wetland dry periods is historically sufficiently low to provide good leaching potential.
- There is presently a low to moderate salinity risk to the wetland area, where groundwater levels have begun to decline again following the recent rises in response to natural flooding. Conversely, if groundwater levels rise again and remain high, the risk of salinity impacts is higher.
- Environmental watering at Lake Murphy needs to take into account the depth to water table trends and be adapted accordingly to maximise ecological outcomes while managing salinity risks
- It is expected that environmental water delivery to Lake Murphy will have some temporary impact on the watertable locally and depending on watertable levels this may pose a salinity risk to adjacent areas. This risk will require careful monitoring and management. The groundwater data for the recent watering event needs to be reviewed.

### 3.3. Water Quality

The following section outlines the most recent water quality monitoring undertaken within Lake Murphy. Due to the variable hydrological nature there are no definitive water quality guidelines for wetlands in Victoria. When discussing water quality parameters of Lake Murphy, the Environmental Protection Authority (EPA) Environmental Water Quality Guidelines for Victorian Lakes (2010) for shallow (<5m) inland lakes and the Australian and New Zealand Environment Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality Volume 1 (2000) will be used as a guide.

Intervention water quality monitoring has been undertaken in response to the environmental watering of Lake Murphy in September 2014. Table 5 provides the results from the spot monitoring undertaken. The results highlight that the pH was higher than the EPA guidelines and dissolved oxygen was within the guidelines of 80-120%. Nutrient spot monitoring was also undertaken in October 2014. Total phosphorous

and Total Nitrogen both exceeded the EPA guidelines (3,700 µG/L and 410 µG/L respectively), however samples were taken during the wetting up phase which mostly likely explains this result. Upon flooding, the soil releases nutrients which promote biological growth, stimulating phytoplankton and zooplankton production (macroinvertebrates) (Boulton and Brock 1999).

**Table 5. EPA Environmental quality guidelines and spot measurements at Lake Murphy when inundated**

| | Temp $^{o}$C | pH | Dissolved oxygen range (% saturation) | Electrical conductivity (µScm$^{-1}$) |
|---|---|---|---|---|
| **EPA Guidelines for shallow inland lakes** | | 6.5-8.5 | 80-120 | NA |
| **Measured at Lake Murphy** | | | | |
| **East 25/02/2015** | 26.8 | 9.2 | 208.1 | 536 |
| **East 5/3/15** | 16 | 8.85 | 94.3 | 605 |
| **East 18/3/15** | 18.8 | 8.54 | 85.6 | 678 |
| **West 25/02/2015** | 26.8 | 9.26 | 182.8 | 798 |
| **West 5/3/15** | 18 | 9.19 | 100.6 | 840 |
| **West 18/3/15** | 19.1 | 9.06 | 85.6 | 909 |

Salinity from the spot monitoring ranged between 536 and 909 µS/cm. Groundwater in the area is highly saline, typically around 50,000 µS/cm. Lake Murphy is a terminal system with no outflows with the majority of water being lost through evaporation. Monitoring of groundwater levels, salinity and nutrient inputs at Lake Murphy are required to assess environmental watering events (refer to Section 10).

### 3.4. Environmental watering

The 17/2 channel and outfall structure provide the only current means to deliver environmental water to Lake Murphy. Constraints to delivery are associated with this infrastructure, which are discussed in detail in Section 8.1.

As a result of infrastructure modernisation and drier weather patterns, Lake Murphy received less outfall water from the irrigation system. Subsequently, environmental water was periodically allocated to the wetland from the mid-1990s, with a longer dry spell during the later years of the Millennium Drought. Lake Murphy received large volumes of natural inflows in 2010-11 and 2011-12 following heavy rainfall throughout the region. The North Central CMA developed an Environmental Watering Plan for Lake Murphy in 2010, and following the watering regime identified in this plan, environmental water was delivered to the wetland in the current watering season (2014-15). The wetting and drying calendar for the last twenty years is presented in Table 6. A daily surface water balance has been modelled in order to identify the hydrological attributes of Lake Murphy. The model used is a simplified version of the Savings at Wetlands from Evapotranspiration daily Time-Series (SWET) (Gippel 2005a, Gippel 2005b, Gippel 2005c). Components are discussed in brief in Appendix 3, the modelling produces a range of volumes required to operate the wetland in accordance with the optimal regime and is used to guide the volumes required for an environmental watering event and documented in the annual seasonal watering proposal.

Environmental water delivered to Lake Murphy is derived from the Murray Flora and Fauna Bulk Entitlement, with the aim to provide habitat and suitable conditions for waterbird feeding and breeding. A daily surface water balance has been modelled in order to identify the hydrological attributes of Lake Murphy. The model used is a simplified version of the Savings at Wetlands from Evapotranspiration daily Time-Series (SWET) (Gippel 2005a, Gippel 2005b, Gippel 2005c). Components are discussed in brief in Appendix 3, the modelling produces a range of volumes required to operate the wetland in accordance with the optimal regime and is used to guide the volumes required for an environmental watering event and documented in the annual seasonal watering proposal.

**Table 6. Lake Murphy wetting/drying calendar (North Central CMA 2014)**

| Year | 93/94 | 94/95 | 95/96 | 96/97 | 97/98 | 98/99 | 99/00 | 00/01 | 01/02 | 02/03 | 03/04 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wetting/drying cycle* | W | D | W | W | W | D | W | D | D | W | D |
| Water source^ | C / S | | E | E | E | - | E | - | - | E | - |
| **Year** | **04/05** | **05/06** | **06/07** | **07/08** | **08/09** | **09/10** | **10/11** | **11/12** | **12/13** | **13/14** | **14/15** |
| Wetting/drying cycle* | W | W | D | D | D | D | W | W | W-D | D | W** |
| Water source^ | E | E | - | - | - | - | F | - | - | - | E |

*W – Water present, D – Wetland dry

^ Environmental water allocation / Flood inundation / Channel outfall / Surplus flows

# 4. Values

## 4.1. Environmental values

### 4.1.1. Listings

Lake Murphy is considered to be a wetland of regional significance (North Central CMA 2010) especially for waterbird use and breeding, as well as conservation of native plants (Lugg et al. 1989). It is classed under State Wildlife Reserve, Utilities and Survey. Table 7 outlines the legislation, agreements, conventions and listings that are relevant to Lake Murphy based on the species known to use the site. As shown, management of the wetland falls within four international listings, one national listing and two Victorian State listings.

**Table 7. Significance of Lake Murphy 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 | ✓ |
| Victorian advisory lists | State | ✓ |

### 4.1.2. Water-dependent fauna

Deliveries of environmental water and flooding in recent years has enhanced the conservation value of the wetland and provided valuable habitat for aquatic fauna, including waterbirds and macroinvertebrates (North Central CMA 2010; Reid & O'Brien 2009; SKM 1997). Lake Murphy has proven to be extremely productive for waterbirds with surveys in 2011 noting in excess of 5,700 birds using the wetland for habitat and feeding (Dedini 2015).

The wetland provides habitat types that support various waterbird feeding guilds including dabbling ducks, deep-water foragers, fish eaters (which includes frogs, yabbies), large waders, grazing waterfowl and shoreline foragers. Sixty-two waterbird species have been recorded at Lake Murphy, including 28 species protected by international agreements, state legislation and Victorian advisory listings. The wetland provides important habitat for the endangered Freckled Duck (*Stictonetta naevosa*), Blue-billed Duck (*Oxyura australis*), Intermediate Egret (*Ardea intermedia*) and Little Egret (*Egretta garzetta nigripes*) (Table 8 and Appendix 1). Post flood monitoring in 2011 recorded high numbers of the vulnerable Hardhead (*Aytha australis*).

**Table 8. Significant water dependent fauna species (birds) recorded at Lake Murphy**

| Common name | Scientific name | Last Record | EPBC Status | FFG Status | Victorian Status | International Status |
|---|---|---|---|---|---|---|
| Australasian Shoveler | *Anas rhynchotis* | 2015 | | | VU | |
| Bar-tailed Godwit | *Limosa lapponica* | 1989 | | | VU | C/J/R/B |
| Black-tailed Godwit | *Limosa limosa* | 2006 | | | VU | C/J/R/B |
| Blue-billed Duck | *Oxyura australis* | 2015 | | L | EN | |
| Brolga | *Grus rubicunda* | 2015 | | L | VU | |
| Caspian Tern | *Hydroprogne caspia* | 2006 | | L | NT | C/J |
| Common Greenshank | *Tringa nebularia* | 2006 | | | VU | C/J/R/B |
| Curlew Sandpiper | *Calidris ferruginea* | 2005 | | | EN | C/J/R/B |
| Double-banded Plover | *Charadrius bicinctus* | 2006 | | | | B |
| Eastern Great Egret | *Ardea modesta* | 2015 | | L | VU | C/J |
| Freckled Duck | *Stictonetta naevosa* | 2015 | | L | EN | |
| Glossy Ibis | *Plegadis falcinellus* | 2014 | | | NT | C/B |
| Hardhead | *Aythya australis* | 2015 | | | VU | |
| Intermediate Egret | *Ardea intermedia* | 2012 | | L | EN | |
| Little Egret | *Egretta garzetta nigripes* | 1994 | | L | EN | |
| Little Stint | *Calidris minuta* | 2006 | | | | R |
| Long-toed Stint | *Calidris subminuta* | 2006 | | | NT | C/J |
| Marsh Sandpiper | *Tringa stagnatilis* | 2006 | | | VU | C/J/R/B |
| Musk Duck | *Biziura lobata* | 2015 | | | VU | |
| Pectoral Sandpiper | *Calidris melanotos* | 2006 | | | NT | J/R/B |
| Pied Cormorant | *Phalacrocorax varius* | 2015 | | | NT | |
| Red-necked Stint | *Calidris ruficollis* | 2006 | | | | C/J/R |
| Royal Spoonbill | *Platalea regia* | 2015 | | | NT | |
| Ruff | *Philomachus pugnax* | 2006 | | | | C/J/R/B |
| Sharp-tailed Sandpiper | *Calidris acuminata* | 2014 | | | | C/J/R |
| Whiskered Tern | *Chlidonias hybridus javanicus* | 2014 | | | NT | |
| White-bellied Sea-Eagle | *Haliaeetus leucogaster* | 2015 | | L | VU | C |
| Wood Sandpiper | *Tringa glareola* | 2006 | | | VU | C/J/R/B |

Key:

EPBC – M = migratory species list FFG Status – L = Listed as threatened

DSE Status: VU = vulnerable, EN = endangered, NT = near threatened

International Status: C = CAMBA, J = JAMBA, R = ROKAMBA, B = Bonn Convention\

Source: Australian Ecosystems 2012; DELWP 2015a; Dedini 2015.

Lake Murphy has supported a number of breeding populations of waterbirds when inundated, such as the Pacific Black Duck (*Anas superciliosa*), Purple Swamphen (*Porphyrio porphyrio*), and Black Swan (*Cygnus atratus*). It is particularly important breeding habitat for waterfowl, including coots and ducks (North Central CMA 2010). Four species have been recorded nesting or breeding at the wetland, shown in Table 9.

**Table 9. Most recent bird breeding events at Lake Murphy**

| Common name | Scientific name | Source | Last Record |
|---|---|---|---|
| Australian Shelduck | *Tadorna tadornoides* | Dedini 2015 | 2014 |
| Black Swan | *Cygnus atratus* | Dedini 2015 | 2013 |
| Grey Teal | *Anas gracilis* | Dedini 2015 | 2014 |
| Pacific Black Duck | *Anas superciliosa* | Dedini 2015 | 2014 |

Lake Murphy is also known to support three amphibians, including the Plains Froglet (*Crinia parinsignifera*) and Spotted Marsh Frog (*Limnodynastes tasmaniensis*). Further survey effort may detect other water-dependent species.

### 4.1.3. Terrestrial fauna

In addition to supporting numerous water-dependent species, Lake Murphy also supports 44 species of terrestrial birds, including the vulnerable Black Falcon (*Falco niger*), and one reptile was historically recorded, the Marbled Gecko (*Christinus marmoratus*). These species are likely to depend on the wetland due to large scale land clearing of woodland habitat within the Kerang region.

### 4.1.4. Vegetation communities and flora

The variable hydrological history of Lake Murphy in recent decades has resulted in substantial changes to the composition, diversity and distribution of native vegetation. Recent surveys during a dry phase identified 5 Ecological Vegetation Classes (EVCs), with a further 4 aquatic EVC aggregates/complexes recorded after inundation (North Central CMA 2015; Rakali Ecological Consulting 2014a). The distribution of these EVCs is depicted in Appendix 4.

The current EVCs and bioregional conservation status for Lake Murphy are presented in Table 10.

**Table 10. Conservation status of EVCs at Lake Murphy (DEPI 2014e)**

| EVC no. | EVC name | Bioregional Conservation Status |
|---|---|---|
| 813 | Intermittent Swampy Woodland | Depleted |
| 823 | Lignum Swampy Woodland | Vulnerable |
| 537 | Brackish Aquatic Herbland | - |
| 829 | Chenopod Grassland | Endangered |
| 98 | Semi-arid Chenopod Woodland | Endangered |
| 821 | Tall Marsh | Depleted |
| 718 | Freshwater Lake Aggregate | Vulnerable |
| 949 | Dwarf Floating Aquatic Herbland | - |
| - | Brackish Lakebed Herbland/Intermittent Swampy Woodland Complex | - |

Note: not all EVCs have a Bioregional Conservation Status. In addition, EVC complexes are not attributed with an EVC number.

Visible throughout the wetland are numerous dead stags that are so weathered it has become difficult to determine their species; however, anecdotal evidence and ecologists (Rakali Ecological Consulting 2014a) suggest that these were Black Box (*Eucalyptus largiflorens*). It is unusual for such a large, deep wetland that intermittently holds water for prolonged periods to be dominated by Black Box (Rakali Ecological Consulting 2014a). These areas were mapped as an atypical form of Intermittent Swampy Woodland (EVC 813), that forms a complex with Brackish Aquatic Herbland when wet and Brackish Lakebed Herbland when dry.

Prior to the recent watering, emergent species such as Cumbungi (*Typha spp.*) and Common Reed (*Phragmites australis*) were rare (Rakali Ecological Consulting 2014b). However, in the recent watering event, both species have been observed forming small (<1ha) patches to the north of the wetland, particularly near

the channel outfall (North Central CMA 2015). These areas were mapped as Tall Marsh (EVC 821) (Figure and Figure 10).

Freshwater Lake Aggregate forms in small areas when the wetland is inundated, dominated by Rush (*Juncus spp.*), Curled Dock (*Rumex crispus*) and Spiny Flat-sedge (*Cyperus gymnocaulos*). These species are relatively sparse, and in some areas are dominated by dense weed infestations. A very small patch of Dwarf Floating Aquatic Herbland (EVC 949) was identified within the Freshwater Lake Aggregate, dominated by Common Duckweed (*Lemna disperma*).

Lignum Swampy Woodland (EVC 823) remains on sections of the western margins of the wetland. This EVC is characterised by stunted Black Box with an understorey dominated by dense patches of Tangled Lignum and Cane Grass (*Eragrostis australasica*). The ground-layer mostly comprises low chenopods and herbs including Rosinweed (*Cressa australis*) and numerous saltbush species. Terrestrial EVCs include Semi-arid Chenopod Woodland (EVC 98) along the low aeolian dunes on the eastern margins and Chenopod Grassland (EVC 829) on the flatter, higher terraces (Australian Ecosystems 2012). The latest EVC map for Lake Murphy is shown in Appendix 4.

*Native and threatened flora*

The latest survey (Australian Ecosystems 2012) found six flora species of conservation significance at Lake Murphy. An additional two species were previously recorded (Chariot Wheels and Woolly Buttons). Of the 104 native species recorded at Lake Murphy, 56 are considered to be water-dependent. These include threatened species such as Cane Grass (*Eragrostis australasica*) and Spiny Lignum (*Duma horrida subsp. horrida*), as well as the historically recorded and nationally vulnerable Chariot Wheels (*Maireana cheelii*).

Recorded flora species also include 45 terrestrial species, including the poorly-known Black Roly-poly (*Sclerolaena muricata var. muricata*) and rare Mealy Saltbush (*Atriplex pseudocampanulata*). The listed species are shown in Table 11. A full flora species list is available in Appendix 2.

**Table 11. Listed water dependent flora recorded at Lake Murphy**

| Common name | Scientific name | Last Record | EPBC Status | FFG Status | Victorian Status | Source | Comment |
|---|---|---|---|---|---|---|---|
| Black Roly-poly | Sclerolaena muricata var. muricata | 2012 | | | PK | VBA, AE (2012) | EVC 829, EVC 98 |
| Chariot Wheels | Maireana cheelii | 1986 | VU | L | VU | VBA | EVC 829 |
| Goat Head | Malacocera tricornis | 2012 | | | R | AE (2012) | EVC 829 |
| Mealy Saltbush | Atriplex pseudocampanulata | 2012 | | | R | VBA, AE (2012) | EVC 829 |
| Spiny Lignum | Duma horrida subsp. Horrida | 2012 | | | R | North Central CMA (2010), AE (2012) | EVC 829, EVC 823, EVC 98 |
| Swamp Cane Grass | Eragrostis australasica | 2012 | | | VU | North Central CMA (2010), AE (2012) | EVC 823 |
| Yakka Grass | Sporobolus caroli | 2012 | | | R | VBA, AE (2012) | EVC 829 |

Key:
EPBC – VU = vulnerable FFG Status – L = Listed as threatened
DSE Status: VU = vulnerable, PK = poorly known, R = rare
Source: Australian Ecosystems 2012; DELWP 2015a

### 4.1.5. Wetland depletion and rarity

As discussed in Section 2.4, Victoria's wetland classification system was recently updated to align with the ANAE national framework for aquatic ecosystems. The depletion and rarity of both classifications in Victoria, the North Central CMA region, the Loddon Catchment and Victoria Riverina bioregion are discussed below.

*Deep freshwater marsh (Corrick and Norman Classification)*

Under the Corrick and Norman Classification, Lake Murphy's pre-European classification was a shallow freshwater marsh. However, it is currently classified as a deep freshwater marsh (DEPI, 2014e; DEPI, 2014g), one of the most depleted wetland categories within Victoria. Deep freshwater marshes are often drained to facilitate agricultural activities including grazing or cropping, and have subsequently decreased in extent across the landscape (DNRE 1997). Across the state, the greatest decreases in original wetland area have been in the freshwater meadow (43 per cent decrease), shallow freshwater marsh (60 per cent decrease) and deep freshwater marsh (70 per cent decrease) categories (DNRE 1997). Table 12 illustrates the reduction in area of deep freshwater marsh across various defined landscapes and the contribution Lake Murphy makes to this existing area.

*Temporary freshwater marsh (Victorian Wetland Classification)*

As previously mentioned, under the 2013 Victorian Wetland Classification framework, the classification for Lake Murphy is unknown. However, based on the criteria for wetland types, the wetland is considered to represent a temporary freshwater marsh, as it is dominated by non-woody emergent and submergent vegetation, and is between 0.5-2 metres depth (Brooks et al. 2013). Lake Murphy represents less than 0.5% of this classification in all of the Victoria, North Central CMA region, Loddon River catchment and Victoria Riverina bioregion landscapes (Table 12). A comparison of percentage reduction since European settlement could not be undertaken as the system does not include a comprehensive update of the WETLAND_1788 layer to meet the new wetland classification categories.

**Table 12. 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 (%) | Lake Murphy contribution to current area (%) | Current area (ha) | Lake Murphy contribution to current area (%) |
| Victoria | 176,044 | 54,360 | 31 | 0.3 | 224,456 | 0.08 |
| North Central CMA catchment | 10,526 | 4,880 | 46 | 3.5 | 153,024 | 0.11 |
| Loddon River catchment | 8,361 | 3,753 | 44 | 4.5 | 114,083 | 0.15 |
| Victorian Riverina bioregion | 8,784 | 3687 | 42 | 4.6 | 42,589 | 0.40 |

### 4.1.6. Ecosystem functions

'Ecosystem function' is a term used to describe the biological, geochemical and physical processes and components that take place or occur within an ecosystem. These functions relate to the structural components of an ecosystem (e.g. vegetation, water, soil, atmosphere and biota) and how they interact with each other, both at a local (i.e. site specific) and regional (i.e. complex) scale. This include 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.

From a landscape context, Lake Murphy is an individual wetland covering 172 hectares. It is not part of a larger wetland complex. Therefore environmental water management at the site is tailored to the specific water regime needs of the flora and fauna within and immediately surrounding the Lake Murphy wetland. It is, however of high value representing one of the most depleted wetland types in Victoria. It also supports a diversity of threatened flora and fauna species as well as communities important for maintaining biological diversity in the biogeographic region. In particular the wetland's importance at both a state and northern Victorian level, providing habitat and feeding for thousands of waterbirds, including species listed under international migratory bird agreements. Lake Murphy also has an important riparian zone which supports six listed flora species, including the Chariot Wheel (*Maireana cheelii*) listed as vulnerable under the *EPBC Act* 1999. Table 13 broadly shows the ecosystem functions provided by Lake Murphy from a local and regional perspective.

**Table 13. Ecosystem function of Lake Murphy from a local and regional scale**

| Local ecosystem functions | Regional ecosystem functions |
|---|---|
| • **Convert matter to energy for uptake by biota**- this includes substrate surfaces (i.e. rocks, woody debris, gravel) for biofilms and plant matter and interactions between primary producers and consumers such as the breakdown of carbon and nutrients by zooplankton and macroinvertebrates for higher order consumers.<br>• **Provide shade and shelter for biota**- this includes amelioration of extremes in temperature, sunlight exposure and wind as well as protection from predators. The interrelationship of tree, shrub, forb and grass species with compatible geology, soil type, slope aspect, elevation, moisture availability and temperature range characteristics are the main ecosystem components supporting this function.<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>• **Feeding Habitat**- food for growth, shelter and provision of water for consumption. Birds are able to breed in other in other wetland habitats and utilise Lake Murphy for feeding.<br>• **Recruitment** Plants require specific germination and growth conditions (including flood cues, follow up flooding, drying etc.) to ensure successful recruitment. | • **Movement/ dispersal**- movement of individuals is linked to food web functions (see local ecosystem functions) and is a requirement for the life cycle of some species (i.e. migration). It is also assists with maintaining genetic diversity within the landscape and reduces the risk of local species extinction. The movement of mobile species through the landscape further supports the dispersal of seeds/progapules in the landscape providing a source for colonisation.<br>• **Cycle nutrients and store carbon**- important for essential ecological processes such as evapotranspiration, respiration, groundwater and carbon sequestration etc.<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. |
| Note: The above ecosystem services are particularly important for species with low or restricted mobility. | |

The Basin Plan specifies the need to "identify priority environmental assets and priority ecosystem functions, and their environmental watering requirements" (Australian Government 2012, p68). Section 8.50 of the Basin Plan outlines the method for identifying ecosystem functions that require environmental watering and their environmental watering requirements (Schedule 9—Criteria for identifying an ecosystem function). Lake Murphy's ecosystem functions that meet the assessment indicators are described in Appendix 6.

## 4.2. Social values

### 4.2.1. Cultural heritage

The Traditional Owners of Lake Murphy include the Wamba Wamba, Barapa Barapa and Wadi Wadi Peoples Native Title Claimants (VC00/5). There are no Registered Aboriginal Parties (RAPs) in the Lake Murphy area.

Lake Murphy is an area of cultural heritage sensitivity (DPCD 2007). A number of cultural sites such as middens, mounds and scatters have been identified at the wetland, particularly on the eastern perimeter. To conserve and protect these values fencing works have been completed at some selected locations. Further information can be obtained from AAV.

### 4.2.2. Recreation

Lake Murphy is used as a place for public recreation in the Kerang area, supporting the following activities:

- Bird watching and nature based activities;
- Hunting (particularly duck hunting);
- Picnicking;
- Walking (Heron & Nieuwland 1989).

## 4.3. Economic values

The economic value of a particular wetland to the regional economy can be difficult to measure. For the purpose of this Plan, a general discussion of the economic benefit of wetlands is provided, based on a paper by 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 (ACF 2010). Direct uses of Lake Murphy include the income generated from recreational pursuits and tourism, while indirect 'uses' include ecosystem services such as groundwater recharge, nutrient treatment and carbon storage (DEWHA 2010).

## 4.4. Conceptualisation of the site

A schematic is provided (Figure 7) to illustrate the various components of the wetland including the west and east depths and the shallower neck. It also illustrates the Black Box/Lignum community and mudflats that are being targeted by the watering regime.

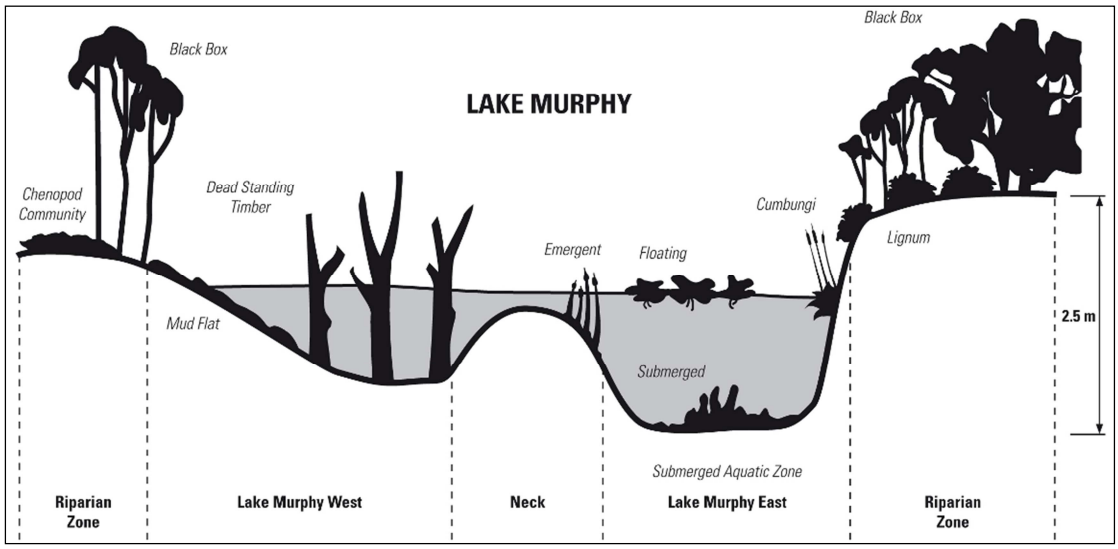



**Figure 7. Schematic of wetland areas to be targeted (not to scale) (North Central CMA 2010)**

## 4.5. Significance

Lake Murphy is an ecologically significant wetland and a contributor to the network of severely depleted temporary freshwater marshes across Victoria. It has high environmental values and provides critical habitat for native flora and fauna – some of which are nationally and internationally recognised e.g. through listings under international agreements. From a State perspective, Lake Murphy supports endangered species and Ecological Vegetation Classes. Lake Murphy is an important cultural heritage site and provides valuable social and recreational opportunities for those in the local area.

Lake Murphy is distinctive for its size as it occupies 172 hectares, which is large in comparison to other wetlands within the North Central CMA region. Only 6% of wetlands within the region are greater than 100 hectares in size (North Central CMA 2005).

# 5. Ecological condition

## 5.1. Context

The hydrological changes described in Section 3.1.2 including land use change and extreme climatic events, coupled with a history of grazing, saline groundwater intrusion and pest plant and animal encroachment has resulted in a decline in the health of Lake Murphy. The following section describes the results of a number of monitoring measures used to describe the current condition of Lake Murphy.

## 5.2. Current condition

*Index of Wetland Condition*

In 2012, a partial Index of Wetland Condition (IWC) assessment was undertaken at Lake Murphy. This occurred at the end of a period of prolonged drought when the wetland was full after flooding during 2010/2011. This assessment only measured the biota sub-index of the IWC. The biota component of the IWC assessment is heavily weighted in the overall score and measures wetland vegetation quality using the variables of critical lifeforms, presence of weeds, evidence of altered processes, vegetation structure and health (DSE 2007).

The overall IWC score (based on the biota sub-index) for Lake Murphy in 2012 provided in Table 14 indicates that the wetland was in poor condition. This score is a reflection of the small area of remaining remnants and relatively high weediness. Altered hydrology has caused degradation of wetland vegetation; in particular ponding of water for extended periods has resulted in the loss of canopy trees and displacement of the original vegetation communities across most of the wetland (Australian Ecosystems 2012).

**Table 14. IWC biota sub-index scores for Lake Murphy**

| EVC/Overall score | Biota sub-index score out of 20 | Condition Category |
|---|---|---|
| **EVC 813** (Majority of Lake Murphy) | 5.65 | Poor |
| **EVC 813** (Small area in the north of Lake Murphy West) | 15.37 | Moderate |
| **EVC 823** (Only found on the western margins of Lake Murphy West) | 10.33 | Poor |
| **Overall score** for Lake Murphy | 5.87 | Poor |

The same assessment was completed again in 2014 (Rakali Ecological Consulting 2014a), and Lake Murphy was scored at 3.94, which is extremely poor condition. This decline in condition between 2012 and 2014 is attributable to the high cover of weeds on the bed of the lake in the northern section, surveyed during a dry phase (2014) compared to when wet (2012).

*Tree Condition*

The condition of 28 live Black Box and 2 River Red Gum trees were assessed in 2012 using the *Protocol for The Living Murray Tree Condition Assessment of River Red Gum and Black Box* (Souter et al. 2010) methodology. A high number of standing dead Black Box and River Red Gum are scattered throughout the wetland, but there is a small a number of live (though stunted) Black Box along elevated ground to the north of Lake Murphy West, and some evidence of River Red Gum regeneration in the same area. Attributes that were assessed include crown extent and density, bark cracking, mistletoe, leaf die-off, new tip growth, epicormic growth and reproduction.

In general, the results of the assessment found the standing trees to be in good health. The crown extent of the sampled trees covered a wide range from between 20 percent to 90 percent. The majority of trees, however, were recorded within the medium to major range for crown density. Over 96 percent of the trees were observed with flowering and fruiting buds/capsules either common or in abundance. Tree attributes that are indicative of poor tree health were largely absent from the trees sampled, showing no leaf die-off; supporting intact bark in most instances, and no mistletoe visible (Australian Ecosystems 2012).

*Changes to native vegetation*

Prior to 2011, an area of Cumbungi and Common Reed was present near the channel outfall that provided important habitat for waterbirds and a viable seedbank for regeneration, filtered water entering the wetland (North Central CMA 2010). The floods scoured much of this vegetation away, leaving very little presence of vascular plants (North Central CMA 2015). However, the recent watering in 2014-15 has seen a small recovery of these species particularly to the north of the wetland. Rushes and sedge species provide valuable habitat for waterbirds, frogs and other water-dependent species, and their growth at Lake Murphy is encouraged. However, it is critical to monitor regularly and maintain the extent of these species to an appropriate level. In a number of other wetlands throughout the Kerang region (i.e. Johnson Swamp, McDonalds Swamp and Hird Swamp), these species have proliferated and formed large, mono-specific patches at the expense of species diversity (Rakali Ecological Consulting 2014b). In some instances, these patches cover more than half the wetland, reducing critical open water habitat.

*Changes to fauna species diversity and composition*

Bird monitoring surveys since 2012 have indicated that Lake Murphy is able to support very high numbers of waterbirds, with 5680 individuals recorded in November 2014 during the recent environmental watering. Even at low water levels, over a thousand waterbirds have been recorded (Dedini 2015).

The scarcity of littoral and riparian vegetation at Lake Murphy has been exacerbated by the large floods of 2011, removing important habitat for waterbirds and other fauna. Furthermore, weed control projects involving the removal of Tamarisk (*Tamarix ramosissima*) have reduced refuge habitat and protection for woodland birds and the more cryptic waterbirds (Waterson, B, 2015 personal communication, [Birdlife Australia] 2 March). Encouragement of emergent native vegetation and lignum aims to restore this habitat type.

*Poor Water Quality*

Poor water quality may reduce habitat available for native aquatic biota, reducing its diversity and abundance. The water quality in Lake Murphy may be impacted by groundwater intrusion increasing the salinity levels in the wetland; runoff containing high nutrient loads or pollutants entering the wetland from surrounding agricultural land; and the introduction of exotic fish such as Carp (*Cyprinus carpio*) via water delivery from the 17/2 channel, causing a rise in turbidity.

*Exotic flora and fauna*

High threat weeds at Lake Murphy include Box Thorn (*Lycium ferocissimum*), Tamarisk (*Tamarix ramosissima)*, Spiny Rush (*Juncus acutus*) and Horehound (*Marrubium vulgare*). The recent flooding of the lake has significantly aided in weed control, as prolonged inundation has killed many Box Thorn, Tamarisk and Spiny Rush plants that fringed the wetland. The current distribution of high threat weeds is shown below. Further control of these species will be necessary to ensure they do not further degrade native vegetation.

During the 2012 vegetation survey, rabbit warrens were observed around Lake Murphy, particularly on the lunette to the east of the wetland (Australian Ecosystems 2012). Rabbits have a severe impact on native vegetation, preventing the successful recruitment of woody species and disturbing the soil through digging (Australian Ecosystems 2012). Foxes have also been detected at the wetland and have the potential to negatively impact on breeding waterbirds and other fauna. Exotic fauna control will be important complementary work at Lake Murphy, to maximise the outcomes of environmental water delivery.

### 5.3. Condition trajectory – do nothing scenario

Lake Murphy has received natural flooding and environmental water in nine of the last 19 years since 1995 (Section 3.4). The water regime in recent years has not met the hydrological requirements of Lake Murphy's ecological values, and the condition of the wetland has deteriorated. It is therefore essential that Lake

Murphy receives environmental water in a way that restores the hydrology of the system and enables the values and services provided by the wetland to be maintained.

Given the partial IWC assessment in 2012 indicated the wetland vegetation was in poor condition, the additional pressure posed by a lack of water (if environmental deliveries are ceased) may cause irreversible damage. For example, there is a risk that the viability of the seedbank within the wetland system may decline over time in response to minimal flooding opportunities. Environmental water is therefore needed to stimulate a wetland vegetation response and enable life history processes to be completed for flora species, which can then support the fauna communities (such as waterbirds) within the wetland.

# 6. Management objectives

## 6.1. Management goal

The environmental water management goal for Lake Murphy over the next five to ten years is outlined below. It has been developed with consideration of the environmental values in Section 4, and is based on information from a range of technical reports, the VWMS, and the North Central Waterway Strategy.

**Lake Murphy long term management goal**

Maintain Lake Murphy as a temporary freshwater marsh able to support a diversity of vegetation communities that provide high quality feeding and breeding habitat for a diversity of waterbirds and frogs.

## 6.2. Ecological objectives

Ecological objectives describe the intended outcomes of environmental water delivery. They contribute towards achieving the long term management goal. The ecological objectives for Lake Murphy are based on the key water-dependent values of the site (in line with the *Victorian Waterway Management Strategy 2013*) that are discussed in Section 4.

Where appropriate, the ecological objectives 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.

Ecological objectives are presented as primary objectives and as secondary objectives. Primary objectives are related to the key values of Lake Murphy and summarise the overall objectives for those values. Secondary objectives either support the primary objectives (e.g. macroinvertebrates are a food source for fish) or are objectives for values for which little baseline information is known (e.g. frogs). If the monitoring budget in future years is restricted it is anticipated that the North Central CMA will prioritise monitoring of primary objectives.

The ecological objectives for Lake Murphy and the justification for each are shown in Table 15.

**Table 15. Ecological objectives and their justifications for Lake Murphy**

| Objective | Justification |
|---|---|
| **1. Primary objectives - species** | |
| 1.1 Rehabilitate feeding opportunities for a diversity of waterbirds | ▪ Provide high quality habitat that supports a high carrying capacity of waterbirds from a range of feeding guilds. Swans and ducks (including Blue-billed Ducks) have previously bred at Lake Murphy.<br>▪ Supports recruitment of waterbirds at a landscape scale.<br>▪ Frequently used by a range of significant species such as Freckled Duck, Brolga, Hardhead and Musk Duck. |
| 1.2 Maintain opportunistic breeding of waterbirds | ▪ Swans and ducks have previously bred at Lake Murphy (see Table 9.<br>▪<br>▪<br>▪ Table 9Supports recruitment of waterbirds at a landscape scale.<br>▪ Providing a diversity of habitats through achieving the secondary objectives below will promote breeding of other opportunistic waterbird species. |
| **2. Secondary objectives – species** | |
| 2.1 Rehabilitate habitat for frog and macroinvertebrate populations | ▪ Lake Murphy supports a number of frog species that will utilise water bodies of short to long duration (<3 to >6 months) watering cycles. Frogs fulfil a role in the food web by providing a food resource for terrestrial and water-dependent birds, reptiles, and mammals. |
| **3. Secondary objectives - habitat** | |
| 3.1 Maintain open water and associated mudflat habitat | ▪ Provides open water foraging habitat for deep-water foragers, dabbling ducks and fish eaters.<br>▪ Provides mudflat foraging habitat for large waders, grazing waterfowl, shoreline foragers and dabbling ducks.<br>▪ Provides habitat for macroinvertebrates and frogs (which provide food resources for waterbirds).<br>▪ Dead standing timber provides roosting habitat for waterbirds |

| Objective | Justification |
|---|---|
| 3.2 Rehabilitate the existing amphibious herb assemblage associated with Brackish Aquatic Herbland, Brackish Lakebed Herbland, Freshwater Lake Aggregate, and Dwarf Floating Aquatic Herbland EVCs. * | ▪ Provides habitat for macroinvertebrates and frogs (which provide food resources for waterbirds).<br>▪ Aquatic herbs (e.g. Red Water-milfoil and Nitella sp.) are a food source for waterbirds.<br>▪ Provides foraging habitat for dabbling ducks, grazing waterfowl and shoreline foragers.<br><br>* The amphibious herb assemblage habitat was not included in the previous Lake Murphy Environmental Watering Plan, but has been added in the EWMP following detection of this habitat zone by ecologists in 2012. |
| 3.3 Maintain emergent vegetation at the outfall and littoral zone | ▪ Cumbungi and Common Reed are present in small patches at Lake Murphy. Whilst these species provide valuable habitat to waterbirds, their extent should be monitored as they can form mono-specific patches at the expense of species diversity.<br>▪ Provides habitat for macroinvertebrates and frogs (food resources for waterbirds).<br>▪ Aquatic macrophytes are a food source for waterbirds.<br>▪ Provides refuge habitat for waterbirds (e.g. protection from predation by foxes).<br>▪ Provides opportunistic breeding habitat (e.g. black swans)<br>▪ Provides a wetland buffer (e.g. slows and filters catchment runoff which reduces erosion and improves runoff water quality)<br>▪ Provides foraging habitat for large waders and shoreline foragers. |
| 3.4 Rehabilitate the Tangled Lignum (*Duma florulenta*) habitat | ▪ Provides habitat for macroinvertebrates (which are food resources for waterbirds).<br>▪ Provides opportunistic breeding habitat.<br>▪ Provides roosting habitat for waterbirds.<br>▪ Provides refuge habitat for waterbirds (e.g. protection from predation by foxes).<br>▪ Provides a wetland buffer (e.g. slows catchment runoff which reduces erosion and protects the Lake edge from wind erosion).<br>▪ Provides foraging habitat for dabbling ducks. The endangered Freckled Duck particularly uses lignum habitat. |
| 3.5 Maintain the existing Black Box (E. largiflorens) overstorey and provide conditions to promote recruitment, where possible. | ▪ Provides habitat for macroinvertebrates (which are food resources for waterbirds).<br>▪ Helps maintain wetland productivity by providing organic inputs to the water column (e.g. carbon and nutrient inputs from leaf litter)<br>▪ Provides nesting material (including hollows) and roosting habitat for waterbirds. |

### 6.3. Lake Murphy Environmental Water Requirements

A series of hydrological requirements based on the ecological objectives detailed in Section 6.2 have been developed for Lake Murphy. To meet the hydrological requirements of the Lake Murphy EWMP, environmental water requirements have been set (Table 16) considering the following factors:

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

The volumes to fill to the target supply level for each objective are calculated from bathymetric data overlaid on the EVC mapping for Lake Murphy. Due to the potential to inundate private property, the FSL for Lake Murphy is set at 78.00m AHD. This elevation sees inundation of the wetland EVCs that are described in the ecological objectives and therefore the volume is the same for each objective. See Appendix 5 for a map of Lake Murphy's contours overlaid on EVC mapping.

## Table 16. Hydrological requirements for ecological values at Lake Murphy

| Ecological Objectives | Water management area | Hydrological Requirements | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Recommended number of events in 10 years | | | Tolerable interval between events once wetland is dry (months) | | | Duration of ponding (months) | | | Preferred timing of inflows |
| | | Min | Opt | Max | Min | Opt | Max | Min | Opt | Max | |
| *1. Primary objectives* | | | | | | | | | | | |
| 1.1 Rehabilitate feeding opportunities for waterbirds | Bed/riparian | 2 | 3 | - | 4 | 6-18 | - | 4 | 6-8 | 12 | Autumn to spring |
| 1.2 Maintain opportunistic breeding of waterbirds | Bed/riparian | 3 | 4-5 | 10 | - | <24* | - | 4 | 9 | 12 | Winter/ Spring/ early summer, top up water if needed |
| *2. Secondary objectives – species* | | | | | | | | | | | |
| 2.1 Rehabilitate frog and macro/micro invertebrate habitat | Bed/riparian | Prefer ephemeral or semi-permanent water bodies but will retreat to permanent water bodies in drought conditions | | | | | | 3 | 3-6 | 12 | Winter to summer |
| *3. Secondary objectives – habitat* | | | | | | | | | | | |
| 3.1 Maintain open water and associated mudflat habitat | Bed | 2 | 4 | 5 | 5 | 5 | 5 | 9 | 18 | 24 | Late winter/spring |
| 3.2 Rehabilitate the existing aquatic herb assemblage | Bed | 5 | 6-8 | 8 | <12 | 12 | 24 | 4 | 5 | 6 | Early spring/ late summer |
| 3.3 Maintain emergent vegetation at the outfall and littoral zone | Bed | 4 | 6-8 | 8 | <12 | 6-12 | 24 | 4-6 | 5-9 | 6-12 | Winter to summer |
| 3.4 Rehabilitate the Tangled Lignum (Muehlenbeckia florulenta) habitat | Bed/riparian | 1 | 2 | 3 | 1 | 3 | 24-36 | Up to 7 | Up to 7 | 7 | Autumn/winter (not critical) |
| 3.5 Maintain the existing black box (E. largiflorens) overstorey and provide conditions to promote recruitment, where possible. | Riparian | 1 | 2 | 3 | 12 | 60 | 7 years | 2 | 6 | 12 | Late winter/ early spring |

Sources: Butcher et al. 2015; Northern Land Solutions 2014; Roberts & Marston 2011; Sainty & Jacobs 1981

* Waterbird life expectancy ranges from three to four years for ducks and up to eight years for larger birds such as ibis and egrets (North Central CMA 2009).

### 6.4. Watering regime

The wetland watering regime for Lake Murphy has been derived from the ecological and hydrological objectives detailed in Section 6.3. To allow for adaptive and integrated management, the watering regime is framed using the seasonally adaptive approach. This means that a watering regime is identified for optimal conditions, as well as the maximum and minimum tolerable watering scenarios. The minimum watering regime is likely to be provided in drought or dry years, the optimum watering regime in average conditions and the maximum watering regime in wet or flood years. Due to the inter-annual variability of these estimates (particularly the climatic conditions), determination of the volume needed for any given year will need to be undertaken by the environmental water manager when watering is planned.

**Please note:** Environmental water management of Lake Murphy should be considered complementary to natural flooding from the Loddon River, rainfall events and channel leakage. Maintaining natural longitudinal connectivity is considered a key environmental objective in the Basin-wide Environmental Watering Strategy (MDBA, 2014) and will assist with supporting biological processes cued by flood stimulation (i.e. waterbird breeding). Therefore if natural flooding occurs, environmental water may be required to maintain depth and flood duration. Under this scenario, the wetland should be allowed to recede naturally and remain dry for a minimum of twelve months before a managed watering event is implemented.

**Minimum watering regime**

**Fringe and wetland target years (2 events in 10 years)**: Fill wetland to 78.0m AHD late winter/early spring (variable timing recommended) to inundate Black Box Woodland and Tanged Lignum fringe. Provide top-ups if required to maintain depth to support waterbird breeding. Allow wetland to recede in late summer or autumn.

**Dry Years (8 in 10 years):** allow wetland to remain dry for up to two years at a time between fill events.

**Optimum watering regime**

**Fringe and wetland target years (2 events in 10 years)**: Fill wetland to 78.0m AHD late winter/early spring (variable timing recommended) to inundate Black Box Woodland and Tanged Lignum fringe. Provide top-ups if required to maintain depth to support waterbird breeding.

**Wetland only target years (an additional 2 in 10 years**): Fill wetland up to 77.7m AHD (up to 1m depth) between autumn and spring (variable timing recommended) to inundate wetland bed (i.e. wetland EVCs - Brackish Lakebed Herbland/Intermittent Swampy Woodland).

Allow wetland to recede in late summer or autumn.

**Dry Years (6 in 10 years):** allow wetland to remain dry for up to eighteen months between fill events.

**Maximum watering regime**

**Fringe and wetland target years (2 events in 10 years)**: Fill wetland to 78.0m AHD late winter/early spring (variable timing recommended) to inundate Black Box Woodland and Tanged Lignum fringe. Provide top-ups if required to maintain depth to support waterbird breeding.

**Wetland only target years (an additional 3 events in 10 years**): Fill wetland up to (up to 1m depth) depth between autumn and spring (variable timing recommended) to inundate wetland bed (i.e. wetland EVCs - Brackish Lakebed Herbland/Intermittent Swampy Woodland).

Allow wetland to recede in late summer or autumn.

**Dry Years (5 in 10 years):** allow wetland to remain dry for up to twelve months between fill events.

*Volumes*

A surface water balance model (SWET) with associated calculations to define the hydrological characteristics of Lake Murphy was developed through the EWP (North Central CMA 2010). Results are presented in Appendix 3.

## 7. 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 17).

**Table 17. Risk Matrix**

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

The results from the Lake Murphy EWMP risk assessment are presented in Table 18. 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 (e.g. environmental releases causes flooding of private land) are assessed as part of the development of the *Central Murray Wetlands Seasonal Watering Proposal* which includes Lake Murphy.

**Table 18. Possible risks and mitigation measures associated with environmental water delivery to Lake Murphy**

| Risk No | Threat | Outcome | Relevant Objective | Likelihood | Severity | Risk Rating | Management measure | Residual risk |
|---|---|---|---|---|---|---|---|---|
| **1** | **Threats from environmental water** | | | | | | | |
| | Groundwater intrusion due to elevated groundwater levels | Poor vegetation health<br>Limited regeneration and dominance of salt tolerant species<br>Unsuitable habitat for waterbirds and food sources | All | Possible | Moderate | Moderate | • Monitoring of groundwater levels and salinity within wetland.<br>• Adaptive management of watering regime | Moderate |
| | Changes to wetland vegetation structure (loss or over-abundance), particularly Cumbungi | Cumbungi is a key habitat feature of Lake Murphy. Reduced or increased wetting could facilitate conditions that impact on the dominance of this species. | 3.3 | Possible | Moderate | Moderate | • The recommended water regime has been developed to support the health of the Cumbungi habitat. However regular monitoring of vegetation health and condition will be undertaken to inform adaptive management of the wetland. | Moderate |
| | Poor water quality (i.e. high salinity, turbidity and nutrient levels) | Reduced primary production (turbid water), limiting food resources for aquatic invertebrates and waterbirds.<br>Encroachment of nutrient tolerant vegetation Cumbungi and Common Reed.<br>Excessive algal growth<br>Potential fish kills | 1.1,1.2<br>2.1<br>3.2, 3.3 | Possible | Moderate | Moderate | • Monitoring of groundwater levels, salinity and nutrient inputs in conjunction with a regular water quality monitoring program.<br>• Adaptively manage water regime and delivery. Environmental water could be used to provide 'freshening' flows.<br>• Fencing and revegetation<br>• Residual risk altered to reflect water regime as a management tool. | Moderate |
| **2** | **Threats to ecological values** | | | | | | | |
| | Introduced species- foxes and rabbits | Lack of recruitment of woody species due to grazing pressure from high numbers of rabbits. | 1.1, 1.2, 2.1 | Possible | Moderate to Major | Moderate to High | • Continued rabbit control program required<br>• Erect rabbit proof fencing around the perimeter of the wetland<br>• Active revegetation (including use of plant guards) | Moderate |

| Risk No | Threat | Outcome | Relevant Objective | Likelihood | Severity | Risk Rating | Management measure | Residual risk |
|---|---|---|---|---|---|---|---|---|
| | | Foxes predate on native species | | | | | may be required in heavily impacted areas<br>• Fox control program<br>• Residual risk reduced to reflect active management | |
| | Introduced species – fish | European Carp and Gambusia are possibly present in Lake Murphy during inundation events, as they are present in the irrigation system. A high abundance of these species may limit the establishment of aquatic plants, predate on frogs (food sources for waterbirds) and reduce water quality. However they may also provide a source of food for piscivorous waterbirds. | 2.1, 3.1, 2.2 | Possible | Moderate | Moderate | • Periodic drying (as per recommended regime) will manage population<br>• investigate options to prevent Carp access to wetland during fill events (carp screen)<br>• A broad scale method for carp control is identified as a knowledge gap across the entire Murray-Darling Basin | Low |
| | High threat perennial weeds such as Spiny Rush and Tamarisk | Establishment of native species limited by dominance of exotic species such as Tamarisk and Spiny Rush. These are common weeds in the area and as such, can potentially infest Lake Murphy. | 1.1, 1.2<br>3.4, 3.5 | Possible | Moderate | Moderate | • Removal of weeds identified in mapping<br>• Residual risk reduced to reflect active management | Low |
| | Chytridiomycosis (amphibian chytrid fungus disease) | Chytridiomycosis is an infectious disease of amphibians, caused by the chytrid fungus (*Batrachochytrium dendrobatidis*) that impairs osmoregulation. Although there has been no testing for the disease at Lake Murphy, it is considered widespread in Victoria. Mortality rates of up to 100% are common, with adults more vulnerable than tadpoles. | 2.1 | Possible | Moderate | Moderate | • Undertake zoospore counts to identify presence of disease- N.B. the disease is not as prevalent in semi-arid regions (vivacity linked to wet and cold conditions)<br>• No change to residual risk due to limited control measures available. | Moderate |

Key for likelihood & consequence ratings: Very Low, Low, Medium, High, Very High. Key for risk ratings – Low, Med (Medium), High, Ext (Extreme)

# 8. Environmental water delivery infrastructure

## 8.1. Infrastructure and operational constraints

Environmental water can be delivered to Lake Murphy along the 17/2 irrigation channel (capacity of 180 ML/day) through the drop-bar outfall structure (capacity 70 ML/day) (Figure 8). Environmental water delivery needs to be managed around irrigation demand on the system (spare channel capacity). The irrigation off-season (no irrigation demand) occurs from 15 May to 15 August each year and this could provide an opportunity to deliver environmental water up to the maximum volumes currently enabled by the infrastructure (70 ML/day), but off-season deliveries would need to be negotiated with GMW. During the irrigation season, water deliveries become constrained by irrigation demand. The Victorian Minister for Water is currently determining the cost arrangements around environmental water delivery.

In 2014 the willows in and around the supply channel to Lake Murphy were mechanically removed (refer to photo insert in Figure 8). This has significantly enhanced the efficiency and effectiveness of water delivery to Lake Murphy.

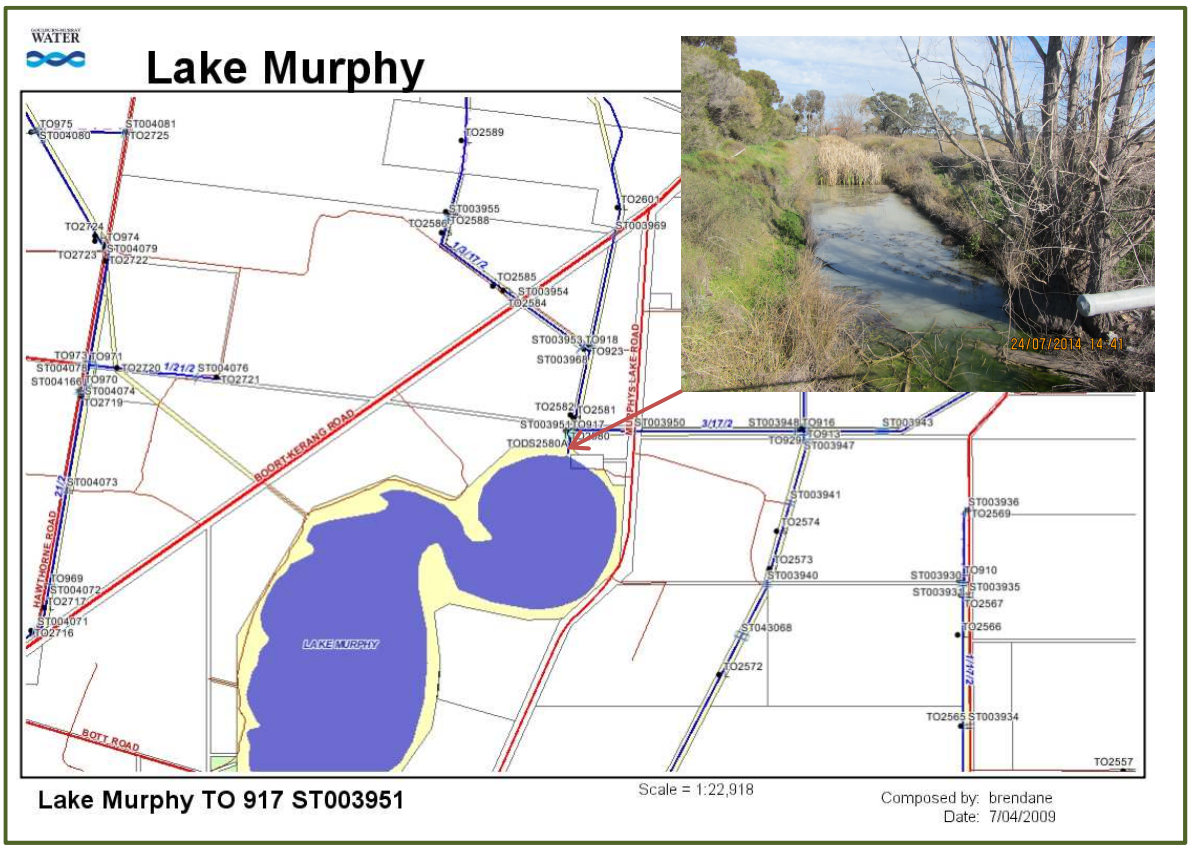



**Figure 8. Lake Murphy GMW infrastructure**

## 8.2. Irrigation modernisation

As part of the GMW Strategic Connections Project, the Torrumbarry 17/2 channel is planned to be automated as far as the 3/17/2 channel offtake, approximately 1.4 km upstream of the Lake Murphy outfall structure (North Central CMA 2010). The 3/17/2 channel may also become a backbone extension to at least the west side of the Boort-Kerang Road and the offtake that services Lake Murphy may be upgraded (Appleby B, 2014, personal communication, [GMW], April).

The Environmental Watering Plan for Lake Murphy recommended the outfall structure to the wetland not be upgraded so that the leakage from the 3/17/2 channel continues to support the existing wetland values in the absence of more natural inflows (North Central CMA 2010). Therefore, depending on the extent of

upgrades undertaken through the Connections Project, mitigation water may need to be identified for Lake Murphy.

### 8.3. Infrastructure recommendations

Additional works to improve the operational management of delivering environmental water to Lake Murphy are outlined below.

*Replacement of existing drop-bar outfall structure*

The operational management of environmental water to Lake Murphy could be improved through replacement and upgrade to the existing outfall structure to a fully automated structure, by minimising losses (bar leakage) and enhancing safety and useability. It is estimated that upgrading this structure would cost approximately $40,000 (Lacy P, NVIRP & Chant R, 2009, personal communication [GMW]). However, if an upgrade is planned, quantification of the leakage should occur to ensure upgrading the structure does not result in any negative impacts on the wetland (North Central CMA 2010).

## 9. Complementary actions

Table 19 documents the recommended actions that should be adopted to complement the delivery of environmental water to Lake Murphy.

**Table 19. Complementary actions to enhance the outcomes of environmental water**

| Activity | Rationale | Recommendation | Priority |
|---|---|---|---|
| Willow control | In 2014, a willow blockage at the outfall channel was removed. Follow up works may be required to remove any willow regrowth. | Monitor willow regeneration and undertake works as required. | High |
| Carp screen | Carp are abundant within the channel system and there is currently no carp screen between the channel system and Lake Murphy. There is potential benefit from installing a carp screen to prevent larger fish entering the wetland, especially when filling from empty following a dry period (O'Brien R, 2010, personal communication, [DPI] 30 March). | A screen with a spacing size of 50 mm would minimise debris blockage (a common downside of carp screens) while restricting the passage of large breeding sized carp (SKM 2005). Although it would not totally exclude the passage of carp it will significantly reduce the population size, facilitating regeneration of wetland vegetation (North Central CMA 2010). | High |
| Fox control | Foxes have also been detected at the wetland and have the potential to negatively impact on breeding waterbirds and other fauna. | Undertake fox control measures such as baiting, fox drives and education activities to encourage compliance by surrounding landholders. Particularly important during periods when waterbirds are breeding. | High |
| Rabbit Control | During the 2012 vegetation survey, rabbit warrens were observed around Lake Murphy, particularly on the lunette to the east of the wetland (Australian Ecosystems 2012). Rabbits have a severe impact on native vegetation, preventing the successful recruitment of woody species and disturbing the soil through digging (Australian Ecosystems 2012). | Undertake rabbit control measures such as warren fumigation, baiting and education activities to encourage compliance by surrounding landholders. Consider rabbit proof fences to exclude from reserve area. | High |
| Exotic flora control | Thirty nine exotic flora species were recorded at Lake Murphy. These plant species that have the potential to disturb the function of native vegetation through displacement and competition. Exotic plants also impact on primary production within a system, which in turn feeds into all other food web interactions that take place within a system. | Undertake weed control such as manual removal and chemical application. | Moderate |
| Revegetation works | There are opportunities to improve the habitat quality at Lake Murphy through active revegetation. Revegetation works would assist with stabilising soils, reducing evaporation (i.e. shading water), increase organic matter and filtering catchment runoff. | Small-scale introduction of aquatic and semi-aquatic species.<br>Consider a long-term approach to vegetation management on the surrounding terrestrial public land to protect and extend areas of high-quality ground flora and re-introduce woody species. | Moderate |

# 10. Demonstrating outcomes

Monitoring is required to enable the North Central CMA and VEWH to justify the application of environmental water by demonstrating that watering is achieving environmental outcomes. Monitoring is undertaken to assist with determining the success of the hydrological outcome, in consideration of other limiting factors that may inhibit full realisation.

Two types of monitoring are recommended to assess the effectiveness of the proposed water regime on 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 effect of environmental water on Victorian wetlands. This program is currently in its early stages of development. Currently only internal monitoring is undertaken by North Central CMA staff in Lake Murphy. The monitoring program described in the Lake Murphy EWMP should be revised once the statewide monitoring program has been established.

## 10.1. Long-term monitoring

Long term condition monitoring is required to evaluate any changes to the wetland values over time. It should be noted that condition monitoring is recommended to be conducted in conjunction with intervention monitoring to comprehensively evaluate any changes to Lake Murphy.

**Table 20. Required long-term condition monitoring for Lake Murphy**

| Ecological Objective | Objective No.[1] | Method | When |
|---|---|---|---|
| Rehabilitate a diversity of feeding opportunities for waterbirds | 1.1 | Comprehensive waterbird monitoring including abundance, diversity and breeding. | Ideally each year that water is present in the wetland. |
| Maintain opportunistic breeding of waterbirds | 1.2 | | |
| Maintain open water and associated mudflat habitat | 3.1 | Comprehensive vegetation condition surveys including tree health, Index of Wetland Condition, EVC condition, species presence and abundance and weediness | Ideally each year that water is present in the wetland. |
| Rehabilitate the existing amphibious herb assemblage* | 3.2 | | |
| Maintain emergent vegetation at the outfall and littoral zone | 3.3 | | |
| Rehabilitate the Tangled Lignum (*Duma florulenta*) habitat | 3.4 | | |
| Maintain the existing Black Box (E. largiflorens) overstory and provide conditions to promote recruitment, where possible. | 3.5 | | |
| Note[1]: As per those identified in Table 15 (ecological objectives) | | | |

## 10.2. Intervention monitoring

An ongoing monitoring program to inform environmental water delivery and resource planning for Lake Murphy will be conducted by the North Central CMA. This is undertaken as part of the implementation of the Seasonal Watering Proposal and includes photopoint monitoring as well as rapid condition assessments. Each year, environmental water is delivered based on an assessment of the previous year's monitoring data, climatic conditions and water availability. However, due to the lack of resourcing, this is relatively limited and does not adequately cover the full suite of ecological objectives and their response to environmental water delivery.

Monitoring in response to key environmental values to the provision of environmental water is imperative in informing adaptive management of the recommended water regime. Monitoring will also assess the success of implementation and the achievement of ecological objectives outlined in this EWMP with results used to reassess and amend the recommended flow regime as required.

The following recommendations have been made for variables to be monitored in order to assess the response to the provision of environmental water and to inform adaptive management for Lake Murphy. It should be noted that these components are presented as recommendations only and the degree to which they are undertaken will be dictated by year to year funding circumstances.

Event-based monitoring will be required at Lake Murphy to determine:

- whether the hydrological objectives were achieved for each watering event i.e. if the intended water regime was delivered;
- whether the ecological objectives and outcomes were achieved for each watering event;
- what risks eventuated for each watering event and the effectiveness of mitigation measures; and
- whether the overall condition of Lake Murphy is improving over time.

The monitoring activities assist in making informed management decisions, as well as demonstrating ecological outcomes. The monitoring generated will assist in the development of future seasonal watering proposals.

Table 21 shows the ideal monitoring activities to be undertaken at Lake Murphy (all subject to funding availability). All monitoring results will be provided to the VEWH for use in reporting activities.

**Table 21. Required intervention monitoring activities for Lake Murphy**

| Ecological objective | | Monitoring question | When | Method |
|---|---|---|---|---|
| 1.1 | Rehabilitate a diversity of feeding opportunities for waterbirds | Does Lake Murphy provide resources for waterbirds and are breeding events occurring? | Event based surveys during spring and summer | Visual monitoring as well as the use of monitoring cameras in key areas of the wetland (i.e. in trees over water).<br>Monitor water levels to ensure appropriate levels are maintained if bird breeding occurs. |
| 1.2 | Maintain opportunistic breeding of waterbirds | | | |
| 2.1 | Rehabilitate habitat for frog and macroinvertebrate populations | Are frog populations increasing? | Event based surveys during spring and summer. | Call-back and visual surveys |
| | | Are populations of macro invertebrates increasing? | Event based surveys | Establish monitoring sites across the wetland to capture information about abundance and diversity of micro/macro invertebrates. |

| Ecological objective | | Monitoring question | When | Method |
|---|---|---|---|---|
| 3.1 | Maintain open water and associated mudflat habitat | Are environmental water deliveries to Lake Murphy promoting a positive response in the various vegetation communities including the amphibious herbs, emergent vegetation, Tangled Lignum and Black Box? | Event based surveys in spring and summer. | Establish monitoring sites that represent the diversity of wetland and terrestrial communities within and surrounding the Lake.<br>Photopoint and rapid condition assessment monitoring |
| 3.2 | Rehabilitate the existing amphibious herb assemblage* | | | |
| 3.3 | Maintain emergent vegetation at the outfall and littoral zone | | | |
| 3.4 | Rehabilitate the Tangled Lignum (Duma florulenta) habitat | | | |
| 3.5 | Maintain the existing Black Box (E. largiflorens) overstory and provide conditions to promote recruitment, where possible. | | | |
| **Risks** | | **Monitoring question** | **When** | **Method** |
| | Monitor water quality to ensure any issues are observed in a timely manner, and can be managed appropriately. This includes salinity issues with adjacent land that may arise with fluctuating groundwater levels. | Have there been any water quality issues such as blackwater and salinity? | Continuous | Water quality loggers to monitor parameters such as dissolved oxygen and salinity.<br>Groundwater monitoring |
| | Monitor fish including exotic species (particularly carp) to determine the necessity for a carp screen. | Is the carp population increasing? | Annual surveys post water delivery | Where possible, fish surveys should be conducted in spring or summer following watering events – this will help capture the carp breeding response to the watering. |
| | Undertake vegetation monitoring for undesirable encroachment of native flora species. | Are any flora species encroaching into zones at the expense of other native flora species? | Annual surveys post watering delivery. This could be included in the above recommended monitoring activities for vegetation communities. | Photopoint monitoring<br>Comparison of 2014 mapping to aerial imagery |
| | Erosion monitoring at outfall. | Is erosion occurring at the outfall point? | Key high flow periods | Erosion inspections<br>Monitor erosion at location of outfall if filling during dry conditions or during high inflows, where there may be a higher risk of erosion. |

| Ecological objective | Monitoring question | When | Method |
|---|---|---|---|
| Note[1]: As per those identified in Table 15 (Ecological objectives) and Table 18 (Risks).<br>Note[2]: To be established during first watering event | | | |

## 11. Consultation

Consultation undertaken to inform this EWMP included a combination of that undertaken in 2009 to develop the *Lake Murphy Environmental Watering Plan 2010* (North Central CMA 2010) as well as additional targeted consultation to identify any new information.

Community and stakeholder consultation for the Lake Murphy EWMP has been undertaken via telephone interviews during the week of the 28 April 2014. To finalise the EWMP local and technical input and knowledge was required, particular pertaining to changes that have occurred post 2010-11 flooding. The interviews were focused on collecting information relating to the value, threats, condition and water management goal and regime.

Discussions with eight individuals have occurred in 2014 to confirm the current values and threats at Lake Murphy and help inform the goals and objectives within this Plan. This has included Gannawarra Shire, landholders, Indigenous representatives and local community members (e.g. recreational users of the wetland).

Key messages received included (further information is available in Appendix 1):

- The general consensus from the community is that the condition of Lake Murphy is good and has remained fairly consistent through time.
- There is however a need to undertake revegetation (particularly in shallow water zone and littoral area as there is a lack of shelter for birds) and pest plant and animal works.
- Thinning of Black Box trees on the island was also recommended as was the addition of timber to the littoral zone to habitat diversity.
- Cumbungi should be managed to ensure that it does not encroach on the open water zone in the future.
- The regeneration of trees through the bed of the wetland would also promote habitat diversity.

## 12. Knowledge gaps and recommendations

The Lake Murphy 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 22.

**Table 22. Knowledge gaps and recommendations**

| Knowledge Gap | Objective/ Risk | Recommendation | Who | Priority |
|---|---|---|---|---|
| **Objectives** | | | | |
| There is a risk of inundating private land to the south of Lake Murphy (under Bott Road) if the capacity of the wetland is exceeded (78.0m AHD). | All | Identify whether there is a need for a flood easement on the private land to the south of Lake Murphy, to remove the risk of future litigation. | North Central CMA | Medium |
| Infrastructure upgrade implemented through GMW Connection Project | 3.3 | Quantification of the leakage should occur to ensure upgrading the structure does not result in any negative impacts on the wetland (mitigation water may be required)<br>Review of environmental watering regime to maintain emergent zone | North Central CMA | High if upgrade occurs |
| Groundwater response to environmental watering | All | Review bore hydrographs for the 2014/15 environmental water event | North Central CMA | High |
| Ecological response from watering | All | Undertake monitoring (Section 10.2) to identify whether the expected objectives eventuate and whether the identified risks impact on the achievement of these objectives | North Central CMA | High |
| Presence of pest fish | All | Visual assessments of biomass in the drying phase will identify fish presence/absence. | North Central CMA | Medium |
| Erosion at outfall. | 3.1, 3.2, 3.3 | Area around channel outfall to be monitored for possible erosion impacts during delivery. | North Central CMA | High |

## 13. References


Australian Conservation Foundation (ACF) 2010, *Wetlands: Underpinning a Robust Rural Economy, A briefing paper on the economic benefits of Australian wetlands: Hattah Lakes case study*, Australian Conservation Foundation, Melbourne.

Australian Ecosystems 2012, *Wetland and Terrestrial Vegetation Condition Monitoring: Kerang Wetlands, Richardson's Lagoon and Leaghur State Park*, report prepared for North Central CMA, Huntly.

Australian and New Zealand Environment Conservation Council (ANZECC) 2000, National Water Quality Management Strategy Paper No. 4: Australian and New Zealand Guidelines for Fresh and Marine Water Quality Vol. 1- The Guidelines, Australian and New Zealand Environment Conservation Council, Artarmon, New South Wales.

Brooks S, Cottingham P, Butcher R & Hale J 2013, *Murray-Darling Basin aquatic ecosystem classification: Stage 2 report*, report prepared for the Commonwealth Environmental Water Office and Murray-Darling Basin Authority by Peter Cottingham & Associates.

Boulton, A., and Brock, M., (1999). *Australian Freshwater Ecology: Processes and Management*, Gleneagles Publishing, Adelaide.

Bureau of Meteorology (BOM) 2014, *Climate Statistics for* Kerang, viewed April 2014, <http://www.bom.gov.au/climate/averages/tables/cw_080023.shtml>.

Butcher, R, Cottingham, P, Frood, D, Hocking, M & Vietz, G, 2015, *Scientific Review of ecological objectives and environmental watering requirements for Lake Wandella, Tang Tang Swamp and Wirra-Lo Wetland Complex*, report prepared for the North Central Catchment Management Authority by Water's Edge Consulting.

Commonwealth Environmental Water Holder (CEWH) 2015, *Environmental water holdings*, viewed 24 February 2015, <http://www.environment.gov.au/water/cewo/about/water-holdings>.

Davies, R, Davies, D, & Downs, H 2005, *Wetland Vegetation Monitoring, Annual Report: Kerang – Swan Hill Salinity Management Plan Area*, Department of Primary Industries, Kerang.

Dedini, M 2015, *Wetland waterbird monitoring in the Kerang region,* unpublished raw data collected for North Central Catchment Management Authority, Huntly, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2015, Biodiversity Interactive Mapper, viewed January – March 2015, <http://mapshare2.dse.vic.gov.au/MapShare2EXT/imf.jsp?site=bim>.

DELWP 2015b, 'WETLAND_PRE_EUROPEAN', viewed March 2015, <http://www.data.vic.gov.au/raw_data/wetlands-extent-for-victoria-prior-to-european-settlement-deduced/5179>.

DELWP 20115c, 'WETLAND_CURRENT', viewed March 2015, <http://www.data.vic.gov.au/raw_data/victorian-wetland-environments-and-extent-up-to-2013/5208>.

Department of Environment and Primary Industries (DEPI) 2014a, *Guidelines: Wetland Environmental Water Management Plans*, Department of Environment and Primary Industries, Melbourne, Victoria.

DEPI 2014b, *The Victorian wetland classification framework 2014,* Department of Environment and Primary Industries, East Melbourne, Victoria.

DEPI 2014c, *Water Dictionary*, viewed 31 October 2014, <http://waterregister.vic.gov.au/water-dictionary>.

DEPI 2014d *Water Monitoring Data*, viewed 8 April 2014, <http://data.water.vic.gov.au/monitoring.htm>.

DEPI 2014e, *EVC Benchmarks – Murray Fans Bioregion*, viewed 25 March 2015 <http://www.depi.vic.gov.au/environment-and-wildlife/biodiversity/evc-benchmarks>.

DEPI 2013, *Victorian Waterway Management Strategy*, Department of Environment and Primary Industries, Melbourne, Victoria.

Department of Environment Water Heritage and the Arts (DEWHA) 2010, *DRAFT Kerang Wetlands Ramsar Site: Ecological Character Description*, report prepared by Kellogg Brown and Root for the Department of Environment, Water, Heritage and the Arts, Canberra.

Department of Natural Resources and Environment (DNRE) 1997, *Victoria's Biodiversity Directions in Management,* Department of Natural Resources and Environment, Melbourne.

Department of Planning and Community Development (DPCD) 2007, *General Practice Note The Aboriginal Heritage Act 2006 and the Planning Permit Process July 2007* (Revised October 2007), the Department of Planning and Community Development, Melbourne.

Department of Primary Industries (DPI) & HydroEnvironmental 2007, *Irrigation Drainage Memorandum of Understanding Decision Support System: Assumptions for Management Actions – North Central Catchment*, report prepared by Brian Holmes, Department of Primary Industries, Kerang.

Department of Sustainability and Environment (DSE) 2009, Northern Region: Sustainable Water Strategy, Department of Sustainability and Environment, Melbourne.

DSE 2007, *Index of Wetland Condition: Review of Wetland Assessment Methods*, Department of Sustainability and Environment, Melbourne.

DSE 2005, *Index of Wetland Condition: Conceptual framework and selection of measures*, Victorian Government, Melbourne.

DSE 2004, *Kerang Wetlands Ramsar Site Strategic Management Plan*, Department of Sustainability and Environment, Melbourne.

Environment Protection Authority (EPA) 2010, Environmental Quality Guidelines for Victorian Lakes, EPA Publication 1302, Environment Protection Authority, Melbourne, Victoria.

GHD 2011

Gippel, CG 2010, *Comments on Application of SWET Water Balance Model to Terminal Wetlands_V1,* report prepared by Dr. Chris Gippel, Fluvial Systems Pty Ltd, Stockton, NSW.

Gippel, CJ 2005a, *Operational procedure to calculate water recovery from wetlands and lakes at the source (individual wetlands,* report prepared for The Living Murray, Murray-Darling Basin Commission by Fluvial Systems Pty Ltd, Stockton, NSW.

Gippel, CJ 2005b, *Model to calculate water recovery from wetlands and lakes at the source (individual wetlands) – Example application to Euston Lakes and Edward Gulpa wetlands*, report prepared for The Living Murray, Murray-Darling Basin Commission by Fluvial Systems Pty Ltd, Stockton, NSW..

Gippel, CJ 2005c, *SWET (Savings at Wetlands from Evapotranspiration daily Time-Series). A model to calculate water recovery from wetlands and lakes at the source (individual wetlands). Model Manual,* report prepared for The Living Murray, Murray-Darling Basin Commission by Fluvial Systems Pty Ltd, Stockton, NSW.

Goulburn Murray Water (GMW) 2008a, *GMW Murray Strategic Monitoring Project*, Goulburn-Murray Water, Shepparton.

GMW 2008b, *Environmental Water Allocations - Calculations for the SIRTEC*, Agenda Paper Compiled by Sam Green and Mary Shi, Tatura.

Heron, S & Nieuwland, C 1989, *Recreation on Public Land in the Kerang Lakes Area,* Department of Conservation, Forests and Lands, November, Kerang.

Lugg, A, Heron, S, Fleming, G & O'Donnell, T 1989, *Conservation Value of the Wetlands in the Kerang Lakes Area,* report to Kerang Lakes Area Working Group, Department of Conservation Forests & Lands, Bendigo.

Macumber, PG 2002, *A review of the hydrology of Lake Elizabeth and Lake-Groundwater interactions*, report prepared for DNRE Kerang.

Mitch, W & Gosselink, J 2000, *Wetlands,* John Wiley and Sons, New York.

North Central CMA 2015, *Lake Murphy: Aquatic vegetation investigation*, North Central Catchment Management Authority, Huntly.

North Central CMA 2014a, *North Central Regional Waterway Strategy* 2014-2022*,* North Central Catchment Management Authority, Huntly.

North Central CMA 2014b, *2014-15 Seasonal Watering Proposal – Central Murray Wetland Complex,* North Central Catchment Management Authority, Huntly.

North Central CMA 2012, *North Central CMA Regional Catchment Strategy 2014-22*, North Central Catchment Management Authority, Huntly.

North Central CMA 2010, *Lake Murphy Environmental Watering Plan*, North Central Catchment Management Authority, Huntly.

North Central CMA 2005, *Wetlands Background Paper,* North Central Catchment Management Authority, Huntly.

Northern Land Solutions 2014, *Investigation of Bathymetry Survey – Lake Murphy*, prepared for North Central Catchment Management Authority, Huntly.

O'Brien, R 2009, *History of Lake Murphy*, with contributions from George Ross (dec.), John Murphy, Alan Marshal, Barry Baulch & Chris Coleborn, report prepared for North Central Catchment Management Authority, Huntly.

Rakali Ecological Consulting 2014a, *Kerang Ramsar and other significant wetlands monitoring project 2014*, report prepared for North Central Catchment Management Authority by Rakali Ecological Consulting.

Rakali Ecological Consulting 2014b, *Mapping of Typha and Phragmites australis in 3 Central Murray wetlands*, report prepared for North Central Catchment Management Authority by Rakali Ecological Consulting.

Reid, M & O'Brien, R 2009, *Technical comments on current hydrogeological status and environmental risk of Lake Murphy Swamp in reference to future water management*, Future Farming Systems Research Group, Department of Primary Industries, Epsom.

RMCG 2012, *Environmental Works and Measures Feasibility Program,* report prepared for the North Central CMA, Bendigo.

Roberts, J & Marston, F 2000, *Water Regime of Wetland & Floodplain Plants in the Murray-Darling Basin – A Source Book of Ecological Knowledge, Technical Report 30/00*, CSIRO Land and Water, Canberra.

Sainty & Jacobs 1981, *Water plants of New South Wales.* New South Wales Water Resources Commission, Sydney, New South Wales.

SKM 2008, *Food Bowl Modernisation Project – Environmental Referrals*, report prepared for the Department of Sustainability and Environment, Melbourne.

SKM 2005, *Gunbower Forest Flooding Enhancement,* report prepared for the North Central Catchment Management Authority, Huntly.

SKM 1997, *Development of Flushing Outfall Options for Lake Murphy*, report prepared for the Department of Natural Resources and Environment, Melbourne.

Souter, N, Cunningham, S, Little, S, Wallace, T, McCarthy, B, Henderson, M, & Bennetts, K 2010, *Protocol for The Living Murray Tree Condition Assessments of River Red Gum and Black Box Version 12*, prepared for Murray Darling Basin Authority.

Victorian Environmental Assessment Council (VEAC) 2008, *River Red Gum Forests Investigation,* Victorian Environmental Assessment Council, Melbourne.

Victorian Environmental Water Holder (VEWH) 2012, *Water Holdings*, viewed 24 February 2015, <http://www.vewh.vic.gov.au/managing-the-water-holdings>.

## 14. Abbreviations and acronyms

| | |
|---|---|
| AVIRA | Aquatic Value Identification and Risk Assessment |
| 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 |
| Central Murray EWAG | Central Murray 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: DELWP Victoria and DELWP Victoria in 2015) |
| DPI | Department of Primary Industries (Now Department of Economic Development, Jobs, Transport and Resources) |
| 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 |
| 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 |
| LTCE | Long Term Cap Equivalent |
| MDBA | Murray-Darling Basin Authority (formerly Murray-Darling Basin Commission, MDBC) |
| ML | Megalitre (one million litres) |
| ML/d | Megalitres per day |
| North Central RWS | North Central Regional Waterway Strategy |
| ROKAMBA | Republic of Korea-Australia Migratory Bird Agreement |
| RWS | Regional Waterway Strategy |
| SWP | Seasonal Watering Proposal |
| TLM | The Living Murray Initiative |
| VEWH | Victorian Environmental Water Holder |
| VWMS | Victorian Waterway Management Strategy |
| VWQN | Victorian Water Quality Network |

## Appendix 1: Community Consultation

**Method**

Community and stakeholder consultation for the Lake Murphy EWMP has been undertaken via telephone interviews during the week of the 28 April 2014. To finalise the EWMP local and technical input and knowledge was required, particular pertaining to changes that have occurred post 2010-11 flooding. The interviews were focused on collecting information relating to the value, threats, condition and water management goal and regime.

The information collected has been summarised below and has been used to update, revise and complete the plan. The community and stakeholder consultation component of developing the plan is essential in ensuring that the plan is meaningful and robust into the future.

Community and stakeholder representatives interviewed:

John Murphy, Allan Marshall, Russell Bott, Mark Daley (Field and Game Australia), Leeza Wishart (Parks Victoria), Simon Starr (BirdLife Australia), Betty Waterson (BirdLife Australia) and Andrea Keleher (DEPI).

1. Wetland information (general)
    - The trees in the bed of the wetland have been dead for a long time (historical records indicate a large flood in 1916 but may have been dead before this)- one community member said that his father use to remove timber around the 1920s.
    - The wetland can receive drainage from a number of sources including a community drain at the southern end which receives drainage water from properties below Appin Hill (about 6-8 km on south end)
    - Cumbungi was an issue most notably in the 1970s when it was extremely dense and impenetrable, particularly in the eastern section which is fresher.
    - When prolific, the cumbungi supported waterbird such as water hens and ibis however it also provided harbour for foxes and rabbits.
    - During this time, the wetland would have had a lower water holding capacity and effectively been shallower, due to the Cumbungi forming dense mats.
    - When irrigation water was removed from Lake Murphy the wetland dried. This saw the die back of cumbungi with the extent significantly reduced by the late 1980s.
    - Although reduced, Cumbungi was present in the eastern section near the outlet and within the 28/2 channel up until the 2010-11 floods.
    - The community agree that the condition of the wetland has improved since the implementation of a dry watering regime and the subsequent loss of cumbungi.
    - The wetland experience salinity issues in the west section when landholders were draining at the south end and freshwater was entering at the north end via the 28/2 channel. However most of the community believe that this issue have been improved since the 2010-11 floods.
    - The wetland does not hold water for a long time due to its depth and the high evaporation rates experienced in the region. The western section (larger end) dries first as the eastern side is deeper.
2. Recent history (post flooding in 2010-11)
    - During the floods water was entering the swamp from all directions including the south side of Macorna main, from Bott Road, via a number of small surrounding drains and from the outfall at the north. The wetland was rising at a rate over a foot per day.

- An emergency bank was constructed on the frontage to prevent water from entering a number of properties surrounding Lake Murphy. This was undertaken using earth moving equipment and was not approved by the land authority at the time.
- As levels continued to rise, flood waters were also redirected back through the channel system towards Reedy Lake. This elevated some of the risk to surrounding properties.
- Flood water knocked over most of the dead standing trees within the bed of the wetland.
- The floods also drowned a lot of the young Black Box saplings. However a lot of regeneration has occurred post flooding, particularly on the north and northwest sides of the wetland. The health of these trees appears to be better now than before the floods.
- Rabbits were forced on to surrounding farmland during and immediately after the floods. Rabbits returned to the wetland as the water level receded and fresh vegetation was exposed.
- Flooding inundated a small ephemeral area to the north west of the island located in the top of the western section of the wetland. This supported a health community of rushes and sedges which had regenerated after the floods.
- Flooding also drowned much of the remaining Tamarisk, Box Thorn, Spiny Rush and Cumbungi (noted be floating on top of the water after the floods). Some of these species have regenerated post flooding.
- During and immediately after the floods waterbirds were not observed on the wetland. Instead they were utilising surrounding farmland for feeding. Waterbirds began utilising the wetland as it began to drawdown with species such as ducks, swan, coots and brolgas observed in extremely high numbers. Black Swans were observed making nests out of the dead cumbungi particularly on the north western side and a high number of cygnets were observed.
- The water in the wetland was initially very black. This may have resulted in the initial death of many of the aquatic plants however species such as Milfoils and Nitella spp. began to appear as the wetland receded.

3. Wetland values
    - The wetland is noted to support a diversity of waterbirds with waders, divers, predatory and shoreline foragers common. The trees surrounding the wetland are also utilised by woodland birds.
    - The types of birds utilising Lake Murphy often occur in cycles and seemed to be dependent on the condition of other wetlands in the region.
    - Common waterbirds observed include dotterels, ducks and swans. Community members remember plague proportions of wood ducks and black swans utilising the wetland during past inundation periods.
    - The east and west side provide different functions for some waterbirds i.e. western side used for foraging whilst eastern side provides shelter (particularly in the past when cumbungi was present).
    - On occasion, species such as Glossy Ibis and Whistling Tree Duck are observed in mobs during spring. A pair of brolgas has also been observed utilising the site during wet periods (including post flooding). Sea eagles have also frequently used the Black Box trees to the western side of the wetland.
    - When inundated the wetland attracts a high number of Freckled Duck during summer and subsequently has been closed in the past for duck hunting.
    - The wetland provides feeding opportunities for migratory shoreline birds including Sharp-tailed Sandpipers and Red-necked during the summer drawdown phase. Most of these species leave by March-April.

- Nesting opportunities for waterbirds are considered sparse due to the lack of lignum, island habitat and trees within the wetland. Some ducks are noted to have nested in the Nitre Bush surrounding the wetland whilst others have utilised the channels and paddocks surrounding the swamp.
- The most common species observed breeding at Lake Murphy is the Black Swan. A prolific breeding event occurring in 2004.
- At a landscape scale the wetland is noted to be located within the flight path of birds moving between the Boort and Kerang wetlands.
- After the 2010-11 floods, a high abundance of water hens were utilising the wetland. Water hens had not been observed in such high numbers in the past.
- Spiny Lignum, which is typically located on elevated areas around the wetland (particularly along the eastern edge of the east section), has been noted to flourish during periods when the wetland is full.
- Frogs are often heard in the wetland during inundated periods. It was also noted that frogs are often observed on the roads alongside the wetland in high numbers following rainfall.
- The wetland is not considered a popular recreational spot, with only duck hunters and bird watchers utilising it. A few tables and chairs were constructed in the past but they are currently inaccessible due to overgrown grass areas.

4. Wetland threats
    - Rabbits are particularly prevalent at the junction of the east and west sections where there are also a number of large rabbit warrens.
    - Nitre Bush is considered a management issue at Lake Murphy as it provides harbour for rabbits and foxes. In the past landholders had sprayed areas on the reserve to assist with management of rabbits on their properties.
    - Tamarisk was prevalent at Lake Murphy, particularly around the eastern section prior to works undertaken in mid 2000s to remove it. The community supported the removal works but believe that revegetation of other species should have also occurred to ensure that sufficient habitat for fauna was maintained at Lake Murphy. The surrounding vegetation is now considered bare.
    - Prior to the floods Spiny Rush was encroaching the north end of the western side (from the eastern section)
5. Environmental watering goal and regime
    - The community supported the proposed water management goal and believe that the wetlands primary function is waterbird feeding with some opportunistic breeding.
    - Most of the community supported the proposed watering regime and believe that the wetland has improved since it was implemented.
    - However evidence of dead Black Box trees in the bed of the wetland may indicate a drier regime historically. The current regime is more likely to encourage recruitment of River Red Gums as opposed to Black Box.
    - It was suggested that a one in five years optimum regime may be more appropriate as it aligns better with the historical condition of the wetland.
    - It was also suggested that filling should occur earlier in the season (i.e. August not October) to ensure conditions are appropriate for waterbird breeding. However most of the community noted that there has not been a lot of breeding at the wetland in the past and that water management should focus on promoting feeding conditions.

- Some of the community believed that watering at Lake Murphy should occur over a broader time frame (i.e. longer than prescribed 6 months) to ensure that the wetland remains inundate through summer, with drawdown occurring in late autumn.
- It was suggested that the wetland should not be filled when others are dry in the landscape. This is aimed at elevating the pressure on waterbird populations during duck hunting season
- Monitoring should be undertaken to ensure that open water habitat is maintained- if extent is lost some migratory shorebirds will no longer utilise wetland (favour wetlands with sparse vegetation)

6. Recommendations and long term vision
    - The general consensus from the community is that the condition of Lake Murphy is good and has remained fairly consistent through time.
    - There is however a need to undertake revegetation (particularly in shallow water zone and littoral area as there is a lack of shelter for birds) and pest plant and animal works.
    - Thinning of Black Box trees on the island was also recommended as was the addition of timber to the littoral zone to habitat diversity.
    - Cumbungi should be managed to ensure that it does not encroach on the open water zone in the future.
    - The regeneration of trees through the bed of the wetland would also promote habitat diversity.
7. Other comments
    - Mixed support for willow removal in the 28/2 channel. Some believe money would be better spent undertaking PPA works and revegetation.
    - Some of the community believe that the wetland losses water to the groundwater system (some anecdotal accounts of recharge occurring in dams when the wetland is full)
    - A noticeable volume of water was entering the wetland during May 2012 from the southern drain (may have been un-used irrigation water at the end of the season)
    - Wetlands should be managed a through flow systems to ensure that they filter water and exchange nutrients. Water should not be left just to evaporate.

## Central Murray EWAG membership

| Name | Representation |
|---|---|
| Amy Russell | North Central CMA |
| Andrea Keleher | DELWP |
| Andy Huxham | CEWH |
| Ben Hall | Community member |
| Betty Waterson | Community member |
| Bruce McBeath | Community member |
| Charlie Gillingham | NRMC Rep |
| Chloe Wiesenfeld | VEWH |
| Dianne Bowles | Board Rep |
| Emer Campbell | North Central CMA |
| Erin Ashcroft | VEWH |
| Geoff Rollinson | Gannawarra Shire Council |
| Harry Pugh | Community member |
| Heidi Kleinert | North Central CMA |
| Helen Tresize | Community member |
| John Foster | CEWH |
| Keith Stockwell | Birdlife Australia |
| Kerry Webber | CEWH |
| Leeza Wishart | Parks Victoria |
| Mark Daley | Field and Game Australia |
| Mick Dedini | DEPI |
| Morgana Russell | Acting as Swan Hill RCC |
| Murray Thorson | Parks Victoria |
| Simon Star | Birdlife Australia |
| Stan Archard | Community member |
| Ted Gretgrix | NRMC Rep |
| Tori Perin | VEWH |
| Tuesday Browell | Community member |

## Appendix 2: Species List

### Table 2.1 Fauna species recorded within 2 km of Lake Murphy

| Common Name | *Scientific Name* | Last Record | Source |
|---|---|---|---|
| *Amphibians* | | | |
| Common Froglet | *Crinia signifera* | 2012 | Australian Ecosystems 2012 |
| Plains Froglet | *Crinia parinsignifera* | 1995 | DELWP 2015 |
| Spotted Marsh Frog | *Limnodynastes tasmaniensis* | 1995 | DELWP 2015 |
| *Water-dependent birds* | | | |
| Australasian Darter | *Anhinga novaehollandiae* | 2015 | Dedini 2015 |
| Australasian Grebe | *Tachybaptus novaehollandiae* | 2015 | Dedini 2015 |
| **Australasian Shoveler** | ***Anas rhynchotis*** | **2015** | **Dedini 2015** |
| Australian Pelican | *Pelecanus conspicillatus* | 2015 | Dedini 2015 |
| Australian Shelduck | *Tadorna tadornoides* | 2015 | Dedini 2015 |
| Australian Spotted Crake | *Porzana fluminea* | 2006 | DELWP 2015 |
| Australian White Ibis | *Threskiornis molucca* | 2015 | Dedini 2015 |
| Australian Wood Duck | *Chenonetta jubata* | 2015 | Dedini 2015 |
| Banded Stilt | *Cladorhynchus leucocephalus* | 1991 | DELWP 2015 |
| **Bar-tailed Godwit** | ***Limosa lapponica*** | **1989** | **DELWP 2015** |
| Black Swan | *Cygnus atratus* | 2015 | Dedini 2015 |
| Black-fronted Dotteral | *Elseyornis melanops* | 2013 | Dedini 2015 |
| **Black-tailed Godwit** | ***Limosa limosa*** | **2006** | **DELWP 2015** |
| Black-tailed Native-hen | *Tribonyx ventralis* | 2015 | Dedini 2015 |
| Black-winged Stilt | *Himantopus himantopus* | 2015 | Dedini 2015 |
| **Blue billed duck** | ***Oxyura australis*** | **2015** | **Dedini 2015** |
| ***Brolga*** | ***Grus rubicunda*** | **2012** | **Dedini 2015** |
| **Caspian Tern** | ***Hydroprogne caspia*** | **2006** | **DELWP 2015** |
| Chestnut Teal | *Anas castanea* | 2015 | Dedini 2015 |
| Clamorous Reed Warbler | *Acrocephalus stentoreus* | 2006 | DELWP 2015 |
| **Common Greenshank** | ***Tringa nebularia*** | **2006** | **DELWP 2015** |
| **Curlew Sandpiper** | ***Calidris ferruginea*** | **2005** | **DELWP 2015** |
| **Double-banded Plover** | ***Charadrius bicinctus*** | **2006** | **DELWP 2015** |
| Dusky Moorhen | *Gallinula tenebrosa* | 2006 | DELWP 2015 |
| **Eastern Great Egret** | ***Ardea modesta*** | **2015** | **Dedini 2015** |
| Eurasian Coot | *Fulica atra* | 2015 | Dedini 2015 |
| **Freckled Duck** | ***Stictonetta naevosa*** | **2015** | **Dedini 2015** |
| **Glossy Ibis** | ***Plegadis falcinellus*** | **2014** | **Dedini 2015** |
| Great Cormorant | *Phalacrocorax carbo* | 2015 | Dedini 2015 |
| Great Crested Grebe | *Podiceps cristatus* | 2005 | DELWP 2015 |
| Grey Teal | *Anas gracilis* | 2015 | Dedini 2015 |
| ***Hardhead*** | ***Aythya australis*** | **2015** | **Dedini 2015** |
| Hoary-Headed Grebe | *Poliocephalus poliocephalus* | 2015 | Dedini 2015 |
| **Intermediate Egret** | ***Ardea intermedia*** | **2012** | **Dedini 2015** |
| Little Black Cormorant | *Phalacrocorax sulcirostris* | 2015 | Dedini 2015 |
| **Little Egret** | ***Egretta garzetta nigripes*** | **1994** | **DELWP 2015** |
| Little Pied Cormorant | *Microcarbo melanoleucos* | 2015 | Dedini 2015 |
| **Little Stint** | ***Calidris minuta*** | **2006** | **DELWP 2015** |
| **Long-toed Stint** | ***Calidris subminuta*** | **2006** | **DELWP 2015** |
| **Marsh Sandpiper** | ***Tringa stagnatilis*** | **2006** | **DELWP 2015** |

| Common Name | *Scientific Name* | Last Record | Source |
|---|---|---|---|
| Masked Lapwing | *Vanellus miles* | 2015 | Dedini 2015 |
| *Musk Duck* | ***Biziura lobata*** | **2015** | **Dedini 2015** |
| Pacific Black Duck | *Anas superciliosa* | 2015 | Dedini 2015 |
| **Pectoral Sandpiper** | ***Calidris melanotos*** | **2006** | **DELWP 2015** |
| **Pied Cormorant** | ***Phalacrocorax varius*** | **2015** | **Dedini 2015** |
| **Pink-eared duck** | *Malacorhynchus membranaceus* | 2015 | Dedini 2015 |
| Purple Swamphen | *Porphyrio porphyrio* | 2015 | Dedini 2015 |
| Red-kneed Dotteral | *Erythrogonys cinctus* | 2013 | Dedini 2015 |
| Red-necked Avocet | *Recurvirostra novaehollandiae* | 2015 | Dedini 2015 |
| **Red-necked Stint** | ***Calidris ruficollis*** | **2006** | **DELWP 2015** |
| ***Royal Spoonbill*** | ***Platalea regia*** | **2015** | **Dedini 2015** |
| **Ruff** | ***Philomachus pugnax*** | **2006** | **DELWP 2015** |
| ***Sharp tailed sandpiper*** | ***Calidris acuminata*** | **2014** | **Dedini 2015** |
| Silver Gull | *Chroicocephalus novaehollandiae* | 2015 | Dedini 2015 |
| Spotless Crake | *Porzana tabuensis* | 2006 | DELWP 2015 |
| Straw-necked Ibis | *Threskiornis spinicollis* | 2015 | Dedini 2015 |
| ***Whiskered Tern*** | ***Chlidonias hybridus*** | **2014** | **Dedini 2015** |
| **White-bellied Sea-Eagle** | ***Haliaeetus leucogaster*** | **2015** | **Dedini 2015** |
| White-faced Heron | *Egretta novaehollandiae* | 2015 | Dedini 2015 |
| White-necked Heron | *Ardea pacifica* | 2014 | Dedini 2015 |
| **Wood Sandpiper** | ***Tringa glareola*** | **2006** | **DELWP 2015** |
| **Yellow-billed Spoonbill** | *Platalea flavipes* | 2015 | Dedini 2015 |
| ***Terrestrial birds*** | | | |
| Black Kite | *Milvus migrans* | 2006 | DELWP 2015 |
| Swamp Harrier | *Circus approximans* | 2006 | DELWP 2015 |
| Australian Magpie | *Cracticus tibicen* | 2012 | Australian Ecosystems 2012 |
| Australian Raven | *Corvus coronoides* | 2006 | DELWP 2015 |
| **Black Falcon** | ***Falco niger*** | **2012** | **Australian Ecosystems 2012** |
| Black-shouldered Kite | *Elanus axillaris* | 2014 | Dedini 2015 |
| Black-faced Cuckoo-Shrike | *Coracina novaehollandiae* | 2012 | Australian Ecosystems 2012 |
| Bluebonnet | *Northiella haematogaster* | 2012 | Australian Ecosystems 2012 |
| Brown Falcon | *Falco berigora* | 2012 | Australian Ecosystems 2012 |
| Brown Goshawk | *Accipiter fasciatus* | 2014 | Dedini 2015 |
| Brown Quail | *Cotunix yspilophora* | 2012 | Australian Ecosystems 2012 |
| Common Myna | *Sturnus tristis* | 2012 | Australian Ecosystems 2012 |
| Common Starling | *Sturnus vulgaris* | 2012 | Australian Ecosystems 2012 |
| Crested Pigeon | *Ocyphaps lophotes* | 2012 | Australian Ecosystems 2012 |
| Dusky Woodswallow | *Artamus cyanopterus* | 2006 | DELWP 2015 |
| Eastern Rosella | *Platycerus eximius* | 2012 | Australian Ecosystems 2012 |
| Flame Robin | *Petroica phoenicea* | 2006 | DELWP 2015 |
| Galah | *Eolophus roseicapillus* | 2012 | Australian Ecosystems 2012 |
| Grey Shrike-thrush | *Colluricincla harmonica* | 2012 | Australian Ecosystems 2012 |
| House Sparrow | *Passer domesticus* | 2012 | Australian Ecosystems 2012 |
| Laughing Kookaburra | *Dacelo novaeguineae* | 2012 | Australian Ecosystems 2012 |
| Little Grassbird | *Megalurus gramineus* | 2006 | DELWP 2015 |
| Little Raven | *Corvus mellori* | 2012 | Australian Ecosystems 2012 |
| Magpie-lark | *Grallina cyanoleuca* | 2012 | Australian Ecosystems 2012 |
| Marsh Harrier | *Falco cenchroides* | 2015 | Dedini 2015 |
| Noisy Miner | *Manorina melanocephala* | 2012 | Australian Ecosystems 2012 |
| Peregrin Falcon | *Falco peregrinus* | 2014 | Dedini 2015 |

| Common Name | *Scientific Name* | Last Record | Source |
|---|---|---|---|
| Pied Butcherbird | *Cracticus nigrogularis* | 2012 | Australian Ecosystems 2012 |
| Red Wattlebird | *Anthochaera carunculata* | 2012 | Australian Ecosystems 2012 |
| Red-rumped Parrot | *Psephotus haemotonotus* | 2012 | Australian Ecosystems 2012 |
| Restless Flycatcher | *Myiagra inquieta* | 2012 | Australian Ecosystems 2012 |
| Singing Honeyeater | *Lichenostomus virescens* | 2006 | DELWP 2015 |
| Striated Pardalote | *Pardalotus striatus* | 2006 | DELWP 2015 |
| Superb Fairy-wren | *Malurus cyaneus* | 2012 | Australian Ecosystems 2012 |
| Tree Martin | *Petrochelidon nigricans* | 2012 | Australian Ecosystems 2012 |
| Welcome Swallow | *Hirundo neoxena* | 2012 | Australian Ecosystems 2012 |
| Whistling kite | *Haliastur sphenurus* | 2014 | Dedini 2015 |
| White-browed Woodswallow | *Artamus superciliosus* | 2006 | DELWP 2015 |
| White-fronted Chat | *Epthianura albrifrons* | 2012 | Australian Ecosystems 2012 |
| White-plumed Honeyeater | *Lichenostomus penicillatus* | 2012 | Australian Ecosystems 2012 |
| White-winged Fairy-wren | *Malurus leucopterus* | 2012 | Australian Ecosystems 2012 |
| Willie Wagtail | *Rhipidura leucophrys* | 2012 | Australian Ecosystems 2012 |
| Yellow-rumped Thornbill | *Acanthiza chrysorrhoa* | 2012 | Australian Ecosystems 2012 |
| Zebra Finch | *Taeniopygia guttata* | 2006 | DELWP 2015 |
| *Introduced species* | | | |
| Cattle (feral) | *Bos taurus* | 1995 | DELWP 2015 |
| Carp | *Cyprinus carpio* | 1981 | DELWP 2015 |
| European Rabbit | *Oryctolagus cuniculus* | 2012 | Australian Ecosystems 2012 |
| Redfin | *Perca fluviatilis* | 1981 | DELWP 2015 |
| Red Fox | *Vulpes vulpes* | 2012 | Australian Ecosystems 2012 |
| Tench | *fam. Cyprinidae gen. Tinca* | 1981 | DELWP 2015 |

**Table 2.2 Flora species recorded within 2km of Lake Murphy**

| Common Name | *Scientific Name* | Last Record | Source |
|---|---|---|---|
| *Water-dependent flora* | | | |
| Annual Cudweed | *Euchiton sphaericus* | 2012 | Australian Ecosystems 2012 |
| Austral Mudwort | *Limosella australis* | 2012 | Australian Ecosystems 2012 |
| Austral Water-mat | *Lepilaena australis* | 1997 | DELWP 2015 |
| Australian Hollyhock | *Malva preissiana s.l.* | 2012 | Australian Ecosystems 2012 |
| Australian Saltmarsh Grass | *Puccinellia stricta var. stricta* | 2012 | Australian Ecosystems 2012 |
| Blackseed Glasswort | *Tecticornia pergranulata subsp. pergranulata* | 2012 | Australian Ecosystems 2012 |
| Bonefruit | *Osteocarpum salsuginosum* | 1986 | DELWP 2015 |
| Broad-leaf Cumbungi | *Typha orientalis* | 2012 | Australian Ecosystems 2012 |
| **Chariot Wheels** | ***Maireana cheelii*** | **1986** | **DELWP 2015** |
| Clammy Goosefoot | *Chenopodium pumilio* | 2012 | Australian Ecosystems 2012 |
| Clove-strip | *Ludwigia peploides subsp. montevidensis* | 2012 | Australian Ecosystems 2012 |
| Common Blown-grass | *Lachnagrostis filiformis s.s.* | 2012 | Australian Ecosystems 2012 |
| Common Nardoo | *Marsilea drummondii* | 2012 | Australian Ecosystems 2012 |
| Common Spike-sedge | *Eleocharis acuta* | 2012 | Australian Ecosystems 2012 |
| Couch | *Cynodon dactylon* | 1986 | DELWP 2015 |
| Creeping Monkey-flower | *Mimulus repens* | 2012 | Australian Ecosystems 2012 |
| Cumbungi | *Typha sp.* | 2012 | Australian Ecosystems 2012 |
| Eumong | *Acacia stenophylla* | 2012 | Australian Ecosystems 2012 |
| Finger Rush | *Juncus subsecundus* | 2012 | Australian Ecosystems 2012 |
| Flat Spurge | *Chamaesyce drummondii* | 2012 | Australian Ecosystems 2012 |
| Glaucous Goosefoot | *Chenopodium glaucum* | 2012 | Australian Ecosystems 2012 |
| **Goat Head** | ***Malacocera tricornis*** | **2012** | **Australian Ecosystems 2012** |
| Gold Rush | *Juncus flavidus* | 1977 | DELWP 2015 |
| Hairy Carpet-weed | *Glinus lotioides* | 2012 | Australian Ecosystems 2012 |
| Lesser Joyweed | *Alternanthera denticulata s.l.* | 2012 | Australian Ecosystems 2012 |
| Lesser Sea-spurrey | *Spergularia marina s.s.* | 2012 | Australian Ecosystems 2012 |
| Mallee Love-grass | *Eragrostis dielsii* | 2012 | Australian Ecosystems 2012 |
| Narrow-leaf Dock | *Rumex tenax* | 2012 | Australian Ecosystems 2012 |
| Nitella | *Nitella sp.* | 2012 | Australian Ecosystems 2012 |
| Pacific Azolla | *Azolla filiculoides* | 2012 | Australian Ecosystems 2012 |
| Pale Knotweed | *Persicaria lapathifolia* | 2012 | Australian Ecosystems 2012 |
| Poison Pratia | *Lobelia concolor* | 2012 | Australian Ecosystems 2012 |
| Rat-tail Couch | *Sporobolus mitchellii* | 2012 | Australian Ecosystems 2012 |
| Red Water-milfoil | *Myriophyllum verrucosum* | 2012 | Australian Ecosystems 2012 |
| Rigid Panic | *Walwhalleya proluta* | 2012 | Australian Ecosystems 2012 |
| River Club-sedge | *Schoenoplectus tabernaemontani* | 1997 | DELWP 2015 |
| River Oak | *Casuarina cunninghamiana subsp. cunninghamiana* | 2012 | Australian Ecosystems 2012 |
| River Red-gum | *Eucalyptus camaldulensis* | 2012 | Australian Ecosystems 2012 |
| Rosinweed | *Cressa australis* | 2012 | Australian Ecosystems 2012 |
| Short-wing Saltbush | *Sclerochlamys brachyptera* | 2012 | Australian Ecosystems 2012 |
| Slender Groundsel | *Senecio glossanthus s.s.* | 2012 | Australian Ecosystems 2012 |
| Slender Knotweed | *Persicaria decipiens* | 2012 | Australian Ecosystems 2012 |
| Small Loosestrife | *Lythrum hyssopifolia* | 2012 | Australian Ecosystems 2012 |
| Small-fruit Water-mat | *Lepilaena bilocularis* | 2012 | Australian Ecosystems 2012 |
| Smooth Heliotrope | *Heliotropium curassavicum* | 2012 | Australian Ecosystems 2012 |
| Southern Cane-grass | *Eragrostis infecunda* | 2012 | Australian Ecosystems 2012 |

| | | | |
|---|---|---|---|
| Southern Liquorice | *Glycyrrhiza acanthocarpa* | 2012 | Australian Ecosystems 2012 |
| Spiny Flat-sedge | *Cyperus gymnocaulos* | 2012 | Australian Ecosystems 2012 |
| **Spiny Lignum** | ***Duma horrida subsp. horrida*** | **2012** | **Australian Ecosystems 2012** |
| Star Bluebush | *Stelligera endecaspinis* | 2012 | Australian Ecosystems 2012 |
| Starry Goosefoot | *Scleroblitum atriplicinum* | 2012 | Australian Ecosystems 2012 |
| **Swamp Cane Grass** | ***Eragrostis australasica*** | **2012** | **Australian Ecosystems 2012** |
| Tall Fireweed | *Senecio runcinifolius* | 2012 | Australian Ecosystems 2012 |
| Tangled Lignum | *Duma florulenta* | 2012 | Australian Ecosystems 2012 |
| Thin Duckweed | *Landoltia punctata* | 1986 | DELWP 2015 |
| Toad Rush | *Juncus bufonius* | 2012 | Australian Ecosystems 2012 |
| *Terrestrial species* | | | |
| Babbagia | *Osteocarpum acropterum var. deminutum* | 2012 | Australian Ecosystems 2012 |
| Berry Saltbush | *Atriplex semibaccata* | 2012 | Australian Ecosystems 2012 |
| Black Box | *Eucalyptus largiflorens* | 2012 | Australian Ecosystems 2012 |
| Black Cotton-bush | *Maireana decalvans* | 2012 | Australian Ecosystems 2012 |
| **Black Roly-poly** | ***Sclerolaena muricata var. muricata*** | **2012** | **Australian Ecosystems 2012** |
| Blue Rod | *Stemodia florulenta* | 2012 | Australian Ecosystems 2012 |
| Bristly Wallaby-grass | *Rytidosperma setaceum var. setaceum* | 2012 | Australian Ecosystems 2012 |
| Coast Sand-spurrey | *Spergularia media s.l.* | 1997 | DELWP 2015 |
| Common Purslane | *Portulaca oleracea* | 2012 | Australian Ecosystems 2012 |
| Common Wallaby-grass | *Rytidosperma caespitosum* | 2012 | Australian Ecosystems 2012 |
| Corky Saltbush | *Atriplex lindleyi subsp. inflata* | 2012 | Australian Ecosystems 2012 |
| Cotton Fireweed | *Senecio quadridentatus* | 2012 | Australian Ecosystems 2012 |
| Cottony Saltbush | *Chenopodium curvispicatum* | 2012 | Australian Ecosystems 2012 |
| Fuzzy New Holland Daisy | *Vittadinia cuneata* | 2012 | Australian Ecosystems 2012 |
| Grey Roly-poly | *Sclerolaena muricata var. villosa* | 2012 | Australian Ecosystems 2012 |
| Hairy Bluebush | *Maireana pentagona* | 2012 | Australian Ecosystems 2012 |
| Jersey Cudweed | *Pseudognaphalium luteoalbum* | 2012 | Australian Ecosystems 2012 |
| Kneed Spear-grass | *Austrostipa bigeniculata* | 2012 | Australian Ecosystems 2012 |
| **Mealy Saltbush** | ***Atriplex pseudocampanulata*** | **2012** | **Australian Ecosystems 2012** |
| Moonah | *Melaleuca lanceolata subsp. lanceolata* | 2012 | Australian Ecosystems 2012 |
| Native Picris | *Picris angustifolia* | 1986 | DELWP 2015 |
| Native Sow-thistle | *Sonchus hydrophilus* | 2012 | Australian Ecosystems 2012 |
| Nitre-bush | *Nitraria billardierei* | 2012 | Australian Ecosystems 2012 |
| Nodding Saltbush | *Einadia nutans subsp. nutans* | 2012 | Australian Ecosystems 2012 |
| Old-man Saltbush | *Atriplex nummularia* | 2012 | Australian Ecosystems 2012 |
| Pale Goodenia | *Goodenia glauca* | 1986 | DELWP 2015 |
| Pale Twin-leaf | *Zygophyllum glaucum* | 2012 | Australian Ecosystems 2012 |
| Pink Bindweed | *Convolvulus erubescens spp. agg.* | 2012 | Australian Ecosystems 2012 |
| Plump Spear-grass | *Austrostipa aristiglumis* | 2012 | Australian Ecosystems 2012 |
| Prickly Saltwort | *Salsola tragus subsp. tragus* | 2012 | Australian Ecosystems 2012 |
| Quena | *Solanum esuriale* | 2012 | Australian Ecosystems 2012 |
| Rough Spear-grass | *Austrostipa scabra subsp. falcata* | 2012 | Australian Ecosystems 2012 |
| Ruby Salt-bush | *Enchylaena tomentosa var. tomentosa* | 2012 | Australian Ecosystems 2012 |
| Short-leaf Bluebush | *Maireana brevifolia* | 2012 | Australian Ecosystems 2012 |
| Slender-fruit Saltbush | *Atriplex leptocarpa* | 2012 | Australian Ecosystems 2012 |
| Small Saltbush | *Atriplex eardleyae* | 1986 | DELWP 2015 |
| Spear Grass | *Austrostipa spp.* | 2012 | Australian Ecosystems 2012 |
| Spider-grass | *Enteropogon acicularis* | 2012 | Australian Ecosystems 2012 |

| | | | |
|---|---|---|---|
| Sprawling Saltbush | *Atriplex suberecta* | 2012 | Australian Ecosystems 2012 |
| Variable Sida | *Sida corrugata* | 2012 | Australian Ecosystems 2012 |
| Windmill Grass | *Chloris truncata* | 1986 | DELWP 2015 |
| Wingless Bluebush | *Maireana enchylaenoides* | 2012 | Australian Ecosystems 2012 |
| Woolly Buttons | *Leiocarpa panaetioides* | 2012 | Australian Ecosystems 2012 |
| Woolly New Holland Daisy | *Vittadinia gracilis* | 2012 | Australian Ecosystems 2012 |
| **Yakka Grass** | ***Sporobolus caroli*** | **2012** | **Australian Ecosystems 2012** |
| *Introduced water-dependent species* | | | |
| Aster-weed | *Aster subulatus* | 2012 | Australian Ecosystems 2012 |
| Bathurst Burr | *Xanthium spinosum* | 2012 | Australian Ecosystems 2012 |
| Berry Seablite | *Suaeda baccifera* | 2012 | Australian Ecosystems 2012 |
| Celery Buttercup | *Ranunculus sceleratus subsp. sceleratus* | 2012 | Australian Ecosystems 2012 |
| Clustered Dock | *Rumex conglomeratus* | 2012 | Australian Ecosystems 2012 |
| Common Heliotrope | *Heliotropium europaeum* | 2012 | Australian Ecosystems 2012 |
| Curled Dock | *Rumex crispus* | 2012 | Australian Ecosystems 2012 |
| Drain Flat-sedge | *Cyperus eragrostis* | 2012 | Australian Ecosystems 2012 |
| Ferny Cotula | *Cotula bipinnata* | 2012 | Australian Ecosystems 2012 |
| Hairy Hawkbit | *Leontodon taraxacoides subsp. taraxacoides* | 1986 | DELWP 2015 |
| Hastate Orache | *Atriplex prostrata* | 2012 | Australian Ecosystems 2012 |
| Jointed Rush | *Juncus articulatus subsp. articulatus* | 1997 | DELWP 2015 |
| Marsh Bitter-cress | *Rorippa palustris* | 2012 | Australian Ecosystems 2012 |
| Noogoora Burr | *Xanthium strumarium spp. agg.* | 2012 | Australian Ecosystems 2012 |
| Paradoxical Canary-grass | *Phalaris paradoxa* | 1986 | DELWP 2015 |
| Speedwell | *Veronica spp. (naturalised)* | 1997 | DELWP 2015 |
| Spiny Rush | *Juncus acutus subsp. acutus* | 2012 | Australian Ecosystems 2012 |
| Water Buttons | *Cotula coronopifolia* | 1997 | DELWP 2015 |
| Water Couch | *Paspalum distichum* | 1997 | DELWP 2015 |
| *Introduced terrestrial species* | | | |
| African Box-thorn | *Lycium ferocissimum* | 2012 | Australian Ecosystems 2012 |
| Annual Beard-grass | *Polypogon monspeliensis* | 2012 | Australian Ecosystems 2012 |
| Barb Grass | *Parapholis spp.* | 1997 | DELWP 2015 |
| Barley-grass | *Hordeum leporinum* | 2012 | Australian Ecosystems 2012 |
| Bearded Oat | *Avena barbata* | 2012 | Australian Ecosystems 2012 |
| Black Nightshade | *Solanum nigrum s.l.* | 2012 | Australian Ecosystems 2012 |
| Burr Medic | *Medicago polymorpha* | 2012 | Australian Ecosystems 2012 |
| Cape weed | *Arctotheca calendula* | 1986 | DELWP 2015 |
| Common Peppercress | *Lepidium africanum* | 2012 | Australian Ecosystems 2012 |
| Common Sow-thistle | *Sonchus oleraceus* | 2012 | Australian Ecosystems 2012 |
| Flaxleaf Fleabane | *Conyza bonariensis* | 2012 | Australian Ecosystems 2012 |
| Horehound | *Marrubium vulgare* | 2012 | Australian Ecosystems 2012 |
| Italian Rye-grass | *Lolium multiflorum* | 1997 | DELWP 2015 |
| Little Medic | *Medicago minima* | 2012 | Australian Ecosystems 2012 |
| Musky Heron's-bill | *Erodium moschatum* | 2012 | Australian Ecosystems 2012 |
| Notch-leaf Sea-lavender | *Limonium sinuatum* | 2012 | Australian Ecosystems 2012 |
| Ox-tongue | *Helminthotheca echioides* | 2012 | Australian Ecosystems 2012 |
| Paddy Melon | *Cucumis myriocarpus subsp. leptodermis* | 2012 | Australian Ecosystems 2012 |
| Peppercorn | *Schinus molle* | 2012 | Australian Ecosystems 2012 |
| Prickly Lettuce | *Lactuca serriola* | 2012 | Australian Ecosystems 2012 |
| Prostrate Knotweed | *Polygonum aviculare s.l.* | 2012 | Australian Ecosystems 2012 |
| Red Sand-spurrey | *Spergularia rubra s.s.* | 2012 | Australian Ecosystems 2012 |

| | | | |
|---|---|---|---|
| Rough Sow-thistle | *Sonchus asper s.s.* | 2012 | Australian Ecosystems 2012 |
| Saffron Thistle | *Carthamus lanatus* | 1986 | DELWP 2015 |
| Scorzonera | *Scorzonera laciniata* | 2012 | Australian Ecosystems 2012 |
| Sea Barley-grass | *Hordeum marinum* | 2012 | Australian Ecosystems 2012 |
| Shepherd's Purse | *Capsella bursa-pastoris* | 2012 | Australian Ecosystems 2012 |
| Small Ice-plant | *Mesembryanthemum nodiflorum* | 2012 | Australian Ecosystems 2012 |
| Small-flower Mallow | *Malva parviflora* | 2012 | Australian Ecosystems 2012 |
| Smooth Mustard | *Sisymbrium erysimoides* | 2012 | Australian Ecosystems 2012 |
| Soursob | *Oxalis pes-caprae* | 2012 | Australian Ecosystems 2012 |
| Sowbane | *Chenopodium murale* | 2012 | Australian Ecosystems 2012 |
| Spear Thistle | *Cirsium vulgare* | 2012 | Australian Ecosystems 2012 |
| Stemless Thistle | *Onopordum acaulon* | 2012 | Australian Ecosystems 2012 |
| Stink Grass | *Eragrostis cilianensis* | 2012 | Australian Ecosystems 2012 |
| Stinkwort | *Dittrichia graveolens* | 1986 | DELWP 2015 |
| Strawberry Clover | *Trifolium fragiferum var. fragiferum* | 1986 | DELWP 2015 |
| Sweet Melilot | *Melilotus indicus* | 2012 | Australian Ecosystems 2012 |
| Tall Fleabane | *Conyza sumatrensis var. sumatrensis* | 2012 | Australian Ecosystems 2012 |
| Tamarisk | *Tamarix ramosissima* | 2012 | Australian Ecosystems 2012 |
| Toowoomba Canary-grass | *Phalaris aquatica* | 2012 | Australian Ecosystems 2012 |
| Variegated Thistle | *Silybum marianum* | 2012 | Australian Ecosystems 2012 |
| Weeping Willow | *Salix ?sepulcralis* | 2012 | Australian Ecosystems 2012 |
| White Poplar | *Populus alba* | 2012 | Australian Ecosystems 2012 |
| Willow-leaf Lettuce | *Lactuca saligna* | 2012 | Australian Ecosystems 2012 |
| Wimmera Rye-grass | *Lolium rigidum* | 2012 | Australian Ecosystems 2012 |

## Appendix 3: SWET model output

**About the model**

The model used is a simplified version of the Savings at Wetlands from Evapotranspiration daily Time-Series (SWET) (Gippel 2005a, Gippel 2005b, Gippel 2005c). This model has been approved by the Murray Darling Basin Authority for estimating the wetland surface water balance. Modelling the daily water balance enables managers to quantify the volumes required in providing the optimal water regime. It also allows for consideration of variability in climatic conditions and wetland phase.

The main components of the model are outlined below:

- Time Series: the daily time step is set up to run from May 1891 to end of June 2009.
- Wetland capacity: volume required to fill the wetland to the targeted supply level, i.e. FSL (78.0 m AHD).
- Infiltration: volume required to fill the underlying soil profile. Calculation of this volume has been adapted from measurements undertaken by GMW (GMW 2008a). The following assumptions were included in the application of the SWET model for Lake Murphy (Gippel 2005a, Gippel 2005b, Gippel 2005c):
- Infiltration (ML) = Soil cracking (%) x area of wetland (ha) x depth (mm))/100 o Soil cracking – 25% of surface area
- Average depth of 300mm
- Ongoing losses via infiltration are considered negligible due to the low permeability of the underlying soil (GMW 2008b)
- Rainfall/runoff: this includes rainfall directly falling onto the wetland and surface runoff. Surface water inflows/runoff: an average volumetric figure of 0.2 ML/ha/year for the Kerang area (DPI & HydroEnvironmental 2007).
- Climate data: SILO DataDrill including wind data (Bureau of Meteorology 2014).
- Evaporation data: a modelled approach (combination of the Penman-Monteith method with a deBruin adjustment; recommended by the CSIRO) to assessing evaporation at the wetland has been incorporated into the water balance (McJannet et al.2009).

Please note:

- Groundwater is not included in the model (Gippel 2010). While groundwater may contribute in some circumstances it is not readily quantifiable or not easily factored into the model.
- The modelling does not consider water diversion/extraction from Lake Murphy as part of the overall surface water balance.
- The model has been set up so as to manage water levels at a single target level (78.0 m AHD). Therefore, it is not possible to model fluctuating water levels (different target levels) overtime in order to test various management scenarios.

**Model outputs**

See below.

**Table 3.1. SWET output for Lake Murphy**

Insert values in orange cells, or blue cells if necessary. Do not insert values or change any other cells in this sheet. Go to the right of this sheet for results tables. Cut values and paste outside of this sheet is OK.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | set | Wetland Name | Lake Murphy | | | | | | | | |
| 3 | | | Degrees | Degrees | Minutes | | | | | | |
| 4 | set | Latitude | -35.80681 | -35.00 | 48.4083 | | | | | | |
| 5 | set | Longitude | 143.86437 | 143.00 | 51.8623 | | | | | | |
| 6 | | | Metres (AHD) | | | | | | | | |
| 7 | | Altitude | 79.1 | | | | | | | | |
| 8 | | | ha | m^2 | ML/ha/yr | ML/yr | Rainfall n | Total (M | Mean | Max. | Runoff coefficient |
| 9 | set | Local contributing catchment area | 1600 | 1.6E+07 | 0.2 | 320 | 348 | 5560 | 0.058 | 0.2 | |
| 10 | | | %area | Depth | | | | | | | |
| 11 | set | Initial loss to wetland bed parameters | 0.25 | | | | | | | | |
| 12 | | | | | | | | | | | |
| 13 | | | | | | | | | | | |
| 14 | set | Assumed average wetland bed runoff c | 0.150 | 0.46 | | | | | | | |
| 15 | | | ML/d | | | | | | | | |
| 16 | adjust | Notional artificial wetland filling inflow | 70 | | | | | | | | |
| 17 | | | mm/day | | | | | | | | |
| 18 | adjust | Maximum artificial filling rate | 20 | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | | | | | | | |
| 22 | | | | | | | | | | | |
| 23 | | | | | | | | | | | |
| 24 | | | | | | | | | | | |
| 25 | | | | | | | | | | | |
| 26 | | | | | | | | | | | |
| 27 | | | | | | | | | | | |
| 28 | | | | | | | | | | | |
| 29 | | | | | | | | | | | |
| 30 | | | | | | | | | | | |
| 31 | | | | | | | | | | | |
| 32 | | | Day | Month | | | | | | | |
| 33 | adjust | Irrigation year start | 1 | 8 | | | | | | | |
| 34 | | | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | | | | | | | | | | | |
| 37 | | | Elevation | Volume | Area | | | | | | |
| 38 | set | Wetland spill level | 78 | 2000000 | 2E+06 | | | | | | |
| 39 | | | Elevation | Tolerance for drying (m | | | | | | | |
| 40 | adjust | Lowest wetland level | 76.6 | 0.1 | | | | | | | |
| 41 | | | | 1 = Pan; 2 = Modelled | | | | | | | |
| 42 | choose | Factored Pan evaporation or modelled ET method | | 2 | | | | | | | |
| 43 | | | | | | | | | | | |
| 44 | | RESULT | | | | | | | | | |
| 45 | | Calculated for irrigation year | Mean (ML/yr | P95 (ML/yr | ears with no inflo | | | | | | |
| 46 | | Mean long-term annual artificial water | 1,157 | 3,245 | 71 in 118 years | | | | | | |
| 47 | | | ML | No. Period | ecord length (yea | | | | | | |
| 48 | | Average artificial water inflows for filli | 2,905 | 47 | 118 | | | | | | |
| 49 | | Drawdowns over record (number of) | 47 | | | | | | | | |
| 50 | | Drawdowns not fully dried out (number | 15 | | | | | | | | |
| 51 | | Drawdowns not fully dried out (percent | 32% | | | | | | | | |
| 52 | | 95th percentile duration of full period | 4.4 | | | | | | | | |
| 53 | | 50th percentile duration of full period | 3.9 | | | | | | | | |
| 54 | | | | | | | | | | | |
| 55 | | | | | | | | | | | |

| Full cycle length | No. cycles |
|---|---|
| 1 | |
| 2 | 24 |
| 3 | 23 |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |

generally leave as default value

default value

default value

default value

default

This is limited by the capacity of the inflow pipe or channel, water availability, or ecological reasons

This would be specified for ecological reasons. If no limit, set to

nominal start date to tally annual water use

Wetland can be lowest bed level - this value to be regarded as effectively 'Dry'

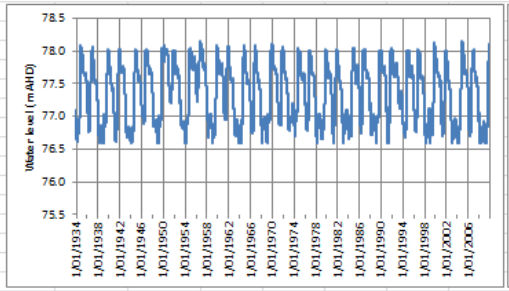
The modelled approach is the

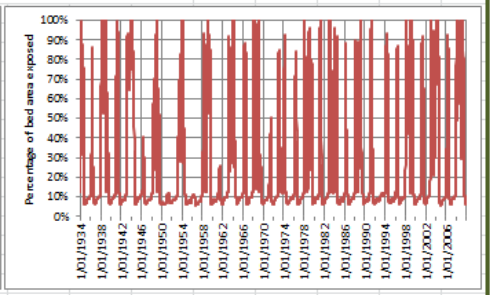
P95 is 95th percentile (high end)

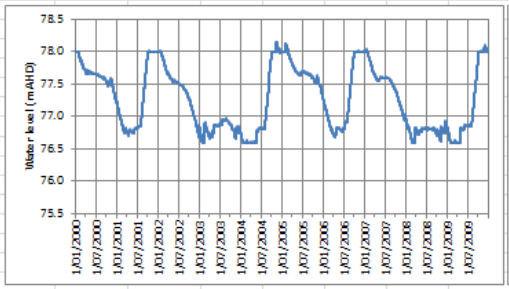
**To operate the model**

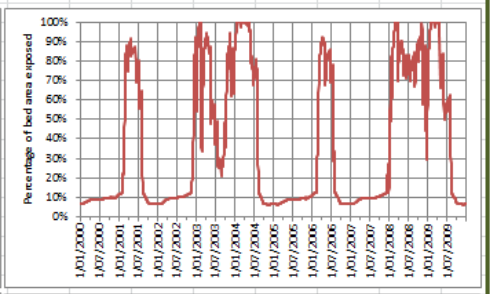
*First fill in the required input data cells. Calculation is set to Manual, so when ready press Function9 (F9) key*

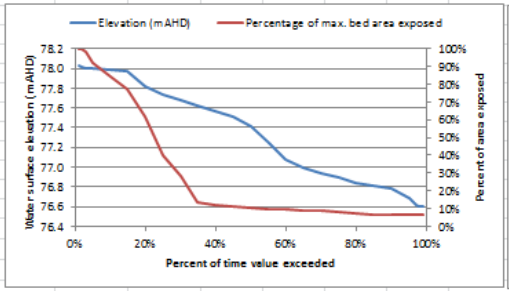
It takes 20 seconds to re-calculate and plot

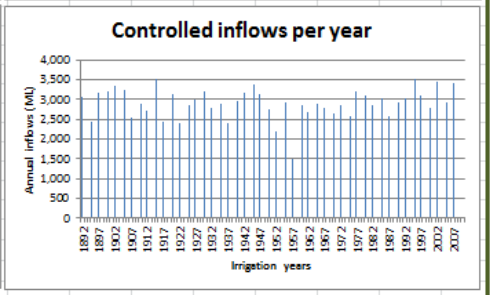


## Appendix 4: Ecological Vegetation Class Mapping

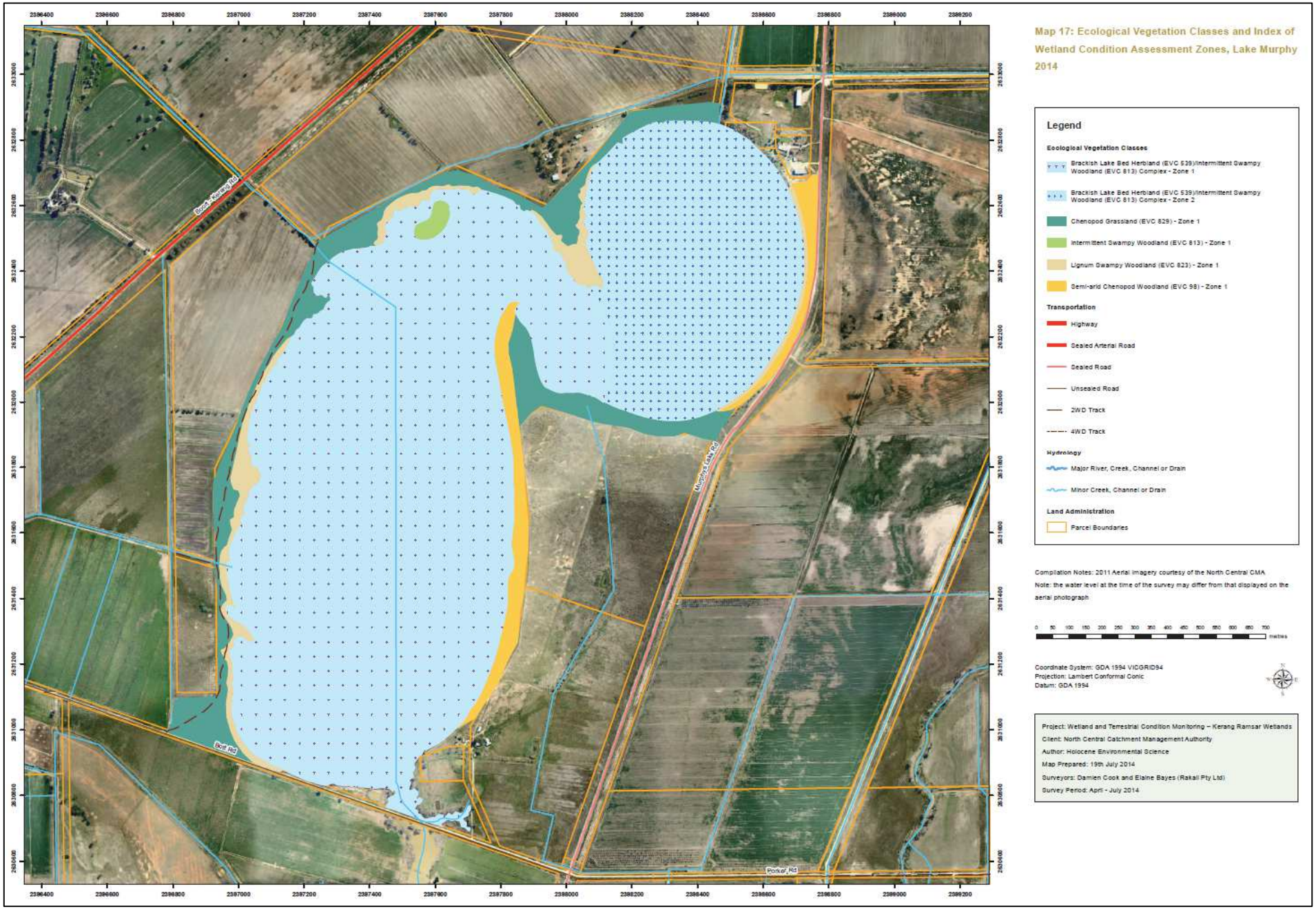



**Figure 4.1. Ecological Vegetation Classes mapped during dry phase (Rakali Ecological Consulting 2014a)**

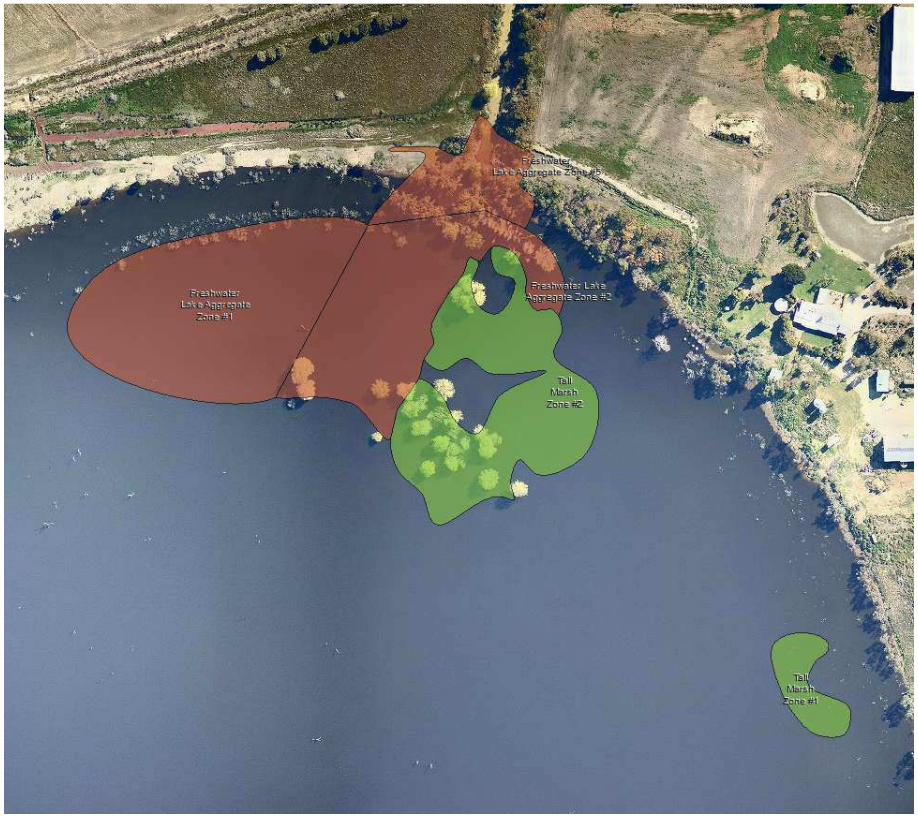



**Figure 4.2. Location of aquatic vegetation at the northern part of Lake Murphy**


**Figure 4.3. Location of aquatic vegetation at the southern part of Lake Murphy**

Source: North Central CMA 2015

**Legend**

Freshwater Lake Aggregate

Tall Marsh

## Appendix 5: Lake Murphy contours and capacity table

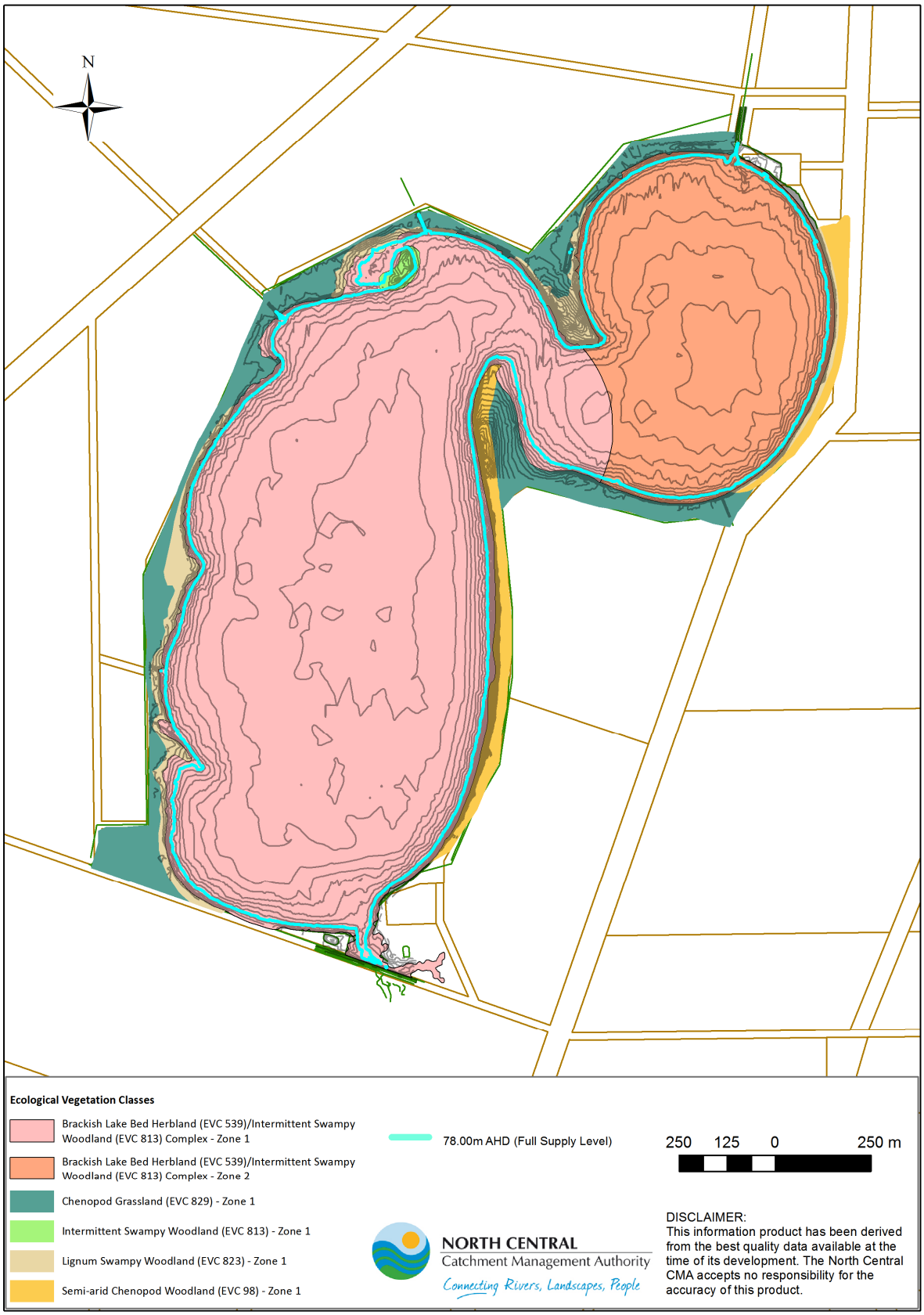



**Figure 5.1. Lake Murphy contours overlaid on wetland EVC mapping**

**Table 23. Lake Murphy holding capacity table**

| Water Level (WL) Range | | Capacity | Accumulative | Surface Area |
|---|---|---|---|---|
| AHD WL from: | AHD WL to: | ML | Capacity (ML) | Ha |
| 76.70 | 76.75 | 0.41 | 0.41 | 3.46 |
| 76.75 | 76.80 | 5.36 | 5.77 | 19.63 |
| 76.80 | 76.85 | 15.08 | 20.84 | 42.89 |
| 76.85 | 76.90 | 27.29 | 48.13 | 65.85 |
| 76.90 | 76.95 | 37.98 | 86.12 | 84.82 |
| 76.95 | 77.00 | 46.57 | 132.68 | 101.58 |
| 77.00 | 77.05 | 54.55 | 187.23 | 115.65 |
| 77.05 | 77.10 | 60.33 | 247.56 | 125.28 |
| 77.10 | 77.15 | 64.64 | 312.20 | 133.08 |
| 77.15 | 77.20 | 68.24 | 380.44 | 139.57 |
| 77.20 | 77.25 | 71.04 | 451.48 | 144.40 |
| 77.25 | 77.30 | 73.16 | 524.64 | 148.00 |
| 77.30 | 77.35 | 74.74 | 599.38 | 150.90 |
| 77.35 | 77.40 | 76.08 | 675.46 | 153.35 |
| 77.40 | 77.45 | 77.21 | 752.68 | 155.47 |
| 77.45 | 77.50 | 78.22 | 830.90 | 157.40 |
| 77.50 | 77.55 | 79.16 | 910.07 | 159.25 |
| 77.55 | 77.60 | 80.08 | 990.14 | 161.04 |
| 77.60 | 77.65 | 80.94 | 1071.09 | 162.72 |
| 77.65 | 77.70 | 81.76 | 1152.85 | 164.28 |
| 77.70 | 77.75 | 82.50 | 1235.34 | 165.68 |
| 77.75 | 77.80 | 83.19 | 1318.53 | 167.08 |
| 77.80 | 77.85 | 83.90 | 1402.43 | 168.53 |
| 77.85 | 77.90 | 84.61 | 1487.04 | 169.89 |
| 77.90 | 77.95 | 85.26 | 1572.30 | 171.16 |
| 77.95 | 78.00 | 85.89 | 1658.19 | 172.40 |
| 78.00 | 78.05 | 86.50 | 1744.69 | 173.59 |
| 78.05 | 78.10 | 87.09 | 1831.78 | 174.74 |
| 78.10 | 78.15 | 87.64 | 1919.41 | 175.79 |
| 78.15 | 78.20 | 88.14 | 2007.55 | 176.76 |
| 78.20 | 78.25 | 88.61 | 2096.17 | 177.70 |
| 78.25 | 78.30 | 89.08 | 2185.25 | 178.62 |
| 78.30 | 78.35 | 89.52 | 2274.78 | 179.47 |
| 78.35 | 78.40 | 89.94 | 2364.72 | 180.29 |
| 78.40 | 78.45 | 90.35 | 2455.07 | 181.09 |
| 78.45 | 78.50 | 90.74 | 2545.81 | 181.87 |
| 78.50 | 78.55 | 91.13 | 2636.94 | 182.64 |
| 78.55 | 78.60 | 91.50 | 2728.44 | 183.38 |
| 78.60 | 78.65 | 91.87 | 2820.31 | 184.10 |
| 78.65 | 78.70 | 92.23 | 2912.54 | 184.83 |
| 78.70 | 78.75 | 92.60 | 3005.15 | 185.58 |
| 78.75 | 78.80 | 92.98 | 3098.13 | 186.36 |
| 78.80 | 78.85 | 93.40 | 3191.53 | 187.25 |
| 78.85 | 78.90 | 93.86 | 3285.39 | 188.23 |
| 78.90 | 78.95 | 94.40 | 3379.79 | 189.37 |

**Notes**

All Heights are referenced to the Australian Height Datum (AHD)

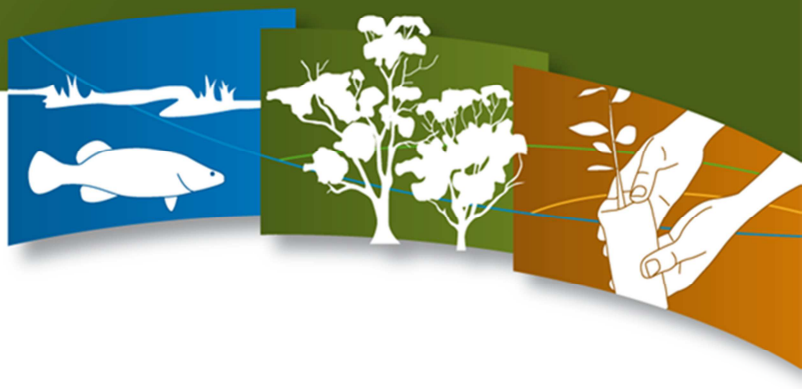
Full Supply Level for Lake Murphy has been nominated at 78.00m AHD

# Appendix 6: Criteria and assessment indicators for Lake Murphy's ecosystem function

### Table 6.1. Lake Murphy assessed against the Murray Darling Basin Plan criteria for identifying an environmental asset

| 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 | X | |
| | (b) with environmental watering, capable of supporting a species listed in or under the JAMBA, CAMBA, ROKAMBA or the Bonn Convention. | ✓ | Lake Murphy has supported species listed under all of the international agreements – JAMBA, CAMBA, ROKAMBA or the Bonn Convention |
| *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 | X | |
| | (b) represents the only example of a particular type of water-dependent ecosystem in the Murray-Darling Basin; or | X | |
| | (c) represents a rare example of a particular type of water-dependent ecosystem in the Murray-Darling Basin. | X | |
| *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:<br>(i) a refuge for native water-dependent biota during dry spells and drought; or | ✓ | Lake Murphy provides a valuable drought refuge function when conditions are dry and has supported a range of waterbird species during previous environmental water delivery events. |
| | (ii) pathways for the dispersal, migration and movements of native water-dependent biota; or | X | |
| | (iii) important feeding, breeding and nursery sites for native water-dependent biota; or | ✓ | Lake Murphy provides extensive mudflat habitat that is not offered by the more permanent lakes within the Kerang region, this habitat is critical for migratory waders |
| | (b) is essential for maintaining, and preventing declines of, native water-dependent biota. | ✓ | Lake Murphy provides important habitat for water dependent fauna in the area, particularly waterbirds |
| *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: | | |

| Item | Criteria | Meets criteria | Justification |
|---|---|---|---|
| | (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) | ✓ | Lake Murphy supports one EPBC-listed flora species and four listed migratory bird species. |
| | (b) supports water-dependent ecosystems treated as threatened or endangered (however described) under State or Territory law; or | ✓ | Lake Murphy supports two endangered, two vulnerable and two depleted EVCs within the Murray Fans Bioregion. |
| | (c) supports one or more native water-dependent species treated as threatened or endangered (however described) under State or Territory law. | ✓ | Lake Murphy supports 27 state listed fauna species. |
| *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 | ✓ | Lake Murphy provides wetland habitat for a substantial number of waterbirds. |
| | (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. | X | |



NORTH CENTRAL
Catchment Management Authority
*Connecting Rivers, Landscapes, People*

*Connecting Rivers, Landscapes, People*

www.nccma.vic.gov.au