Lake Cullen
Environmental Water Management Plan
Final

North Central Catchment Management Authority

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

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EXECUTIVE SUMMARY

This Environmental Water Management Plan investigates and documents existing knowledge about Lake Cullen. Its aim is to assist in the development of environmental watering proposals for the consideration of Environmental Water Holders. It is not a holistic management plan for the site, but is focused on specific environmental water management at Lake Cullen.

The following information is provided in the Plan to facilitate appropriate environmental water management at Lake Cullen into the future.

Lake Cullen is a 629ha intermittent saline wetland located within the Kerang Wetlands Ramsar site, the only natural wetland of this type within the site. The wetland is a wetland of international importance and classified as a Wildlife Reserve managed by Parks Victoria. It is also listed in the Directory of Important Wetlands in Australia and is of particular importance due to its size, habitat and carrying capacity of waterbirds.

Lake Cullen provides habitat for a range of flora and fauna species listed under various international, national and Victorian state legislation. The vegetation communities are considered important due to their vulnerable or endangered status, however more detailed mapping is required to understand the vegetation communities that occur within the bed of Lake Cullen.

The wetland is part of a large lake system which formed near the junction of the Avoca and Loddon rivers, north of the Gredwin Ridge. While there is not widespread surface water interaction between Lake Cullen (Loddon system) and the Avoca Marshes and Lake Bael Bael (Avoca system), there is a high degree of groundwater interaction between the two systems.

Due to the groundwater interactions with neighbouring wetlands, environmental water planning and delivery will need to be adaptive, and informed by climatic and catchment conditions in the region. Specifically, filling Lake Cullen to 73m AHD as proposed below should not be undertaken unless the Avoca Marshes are holding water, or recent flood levels have resulted in the replenishment of the freshwater lens under the Marshes. Both of these cases may prevent the migration of saline groundwater to the Avoca Marshes when Lake Cullen is filled.

Conversely, if the Avoca Marshes receive significant flood water, environmental water and/or other water should be sourced to deliver to Lake Cullen to prevent groundwater migration from the Marshes to Lake Cullen.

Background information and local technical input was used to determine an environmental water management goal and appropriate watering regime for Lake Cullen. These are summarised below:

Lake Cullen environmental water management goal

To provide an appropriate water regime that targets the maintenance of a submerged salt-tolerant aquatic plant assemblage typical of an intermittent saline lake, and ability to support high levels of waterbird use.

Optimal watering regime

Provide two watering events every ten years.

Fill wetland to 73m AHD in spring of year one to provide water to Black Box areas. Ensure inundation period in this region does not exceed two months before allowing water to draw down naturally over the subsequent two seasons (wetland should dry during summer of year three). This will target the growth and recruitment of submerged aquatic and macrophyte species.

Allow wetland to remain completely dry for three seasons (years four to six), then provide water to 72m AHD during spring of year (seven). Provide a top up watering to 72m AHD the following spring (dependent on catchment conditions) to provide opportunities for aquatic plants and macrophyte species, then allow wetland to draw down completely (year nine and ten).

A risk identification process was undertaken to investigate potential risks associated with environmental water delivery and associated site management at Lake Cullen. Detailed risk assessments will be undertaken prior to delivering environmental water to the site in any given season. This will be detailed in the environmental watering proposal for the site.

Knowledge gaps and recommendations are provided which will assist in improving knowledge about environmental water management and ecological outcomes achieved at Lake Cullen. Investment in these recommendations should be considered along with the provision of environmental water to the site.

Community consultation was also undertaken as part of developing this plan. Interviews with community members were focussed on collecting information in relation to the wetland, its values and the environmental watering regime recommendations. The community consultation component of developing the plan was essential in ensuring that the plan is meaningful and robust into the future.

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ACKNOWLEDGEMENTS

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* Mark Tscharke (Parks Victoria)
* Shelley Heron (Kellogg Brown and Root)
* Emer Campbell (North Central CMA)
* Ross Stanton (Goulburn-Murray Water)

In addition, the assistance provided by Lyndall Rowley, Darren White and Phil Slessar (North Central CMA) is greatly appreciated.

North Central CMA acknowledges the cross-collaboration with Goulburn Broken CMA, Mallee CMA and DSE in the development of the Environmental Water Management Plans.

ABBREVIATIONS

BE	Bulk Entitlement
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
CEWH	Commonwealth Environmental Water Holder
CMAs	Catchment Management Authorities
DEPI	Department of Environment and Primary Industries
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
EVC	Ecological Vegetation Class
EWMP	Environmental Water Management Plan
FSL	Full Supply Level
GL	Gigalitre (one billion litres)
G-MW	Goulburn-Murray Water
IWC	Index of Wetland Condition
JAMBA	Japan-Australia Migratory Bird Agreement
MDBA	Murray-Darling Basin Authority (formally Murray-Darling Basin Commission, MDBC)
ML	Megalitre (one million litres)
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RRG	River Red Gum
TLM	The Living Murray Initiative
TSL	Targeted Supply Level
VEWH	Victorian Environmental Water Holder

1. INTRODUCTION

1.1. Background

Environmental water management in Victoria is entering a new phase as ongoing water recovery means significant volumes of water are being returned to the environment. This has provided new opportunities to protect, restore and reinstate high value aquatic ecosystems throughout northern Victoria. The spatial coverage of environmental watering has expanded considerably in recent years and this trend is likely to continue into the future.

Environmental watering in Victoria has historically been supported by management plans that document key information such as the watering requirements for a site, predicted ecological responses and any water delivery arrangements. State and Commonwealth environmental watering programs now have the potential to extend watering beyond those sites that have been traditionally watered in the past. It is important that there is a consistency in planning for environmental watering across both jurisdictions and therefore, new plans are required which will reflect this.

Environmental Watering Management Plans (the Plans) are currently being developed by Victorian Catchment Management Authorities for all current and future environmental watering sites throughout northern Victoria. It is intended that the Plans will provide a tool for consistent, transparent and informed management of environmental water across all sites.

1.2. Purpose

The purpose of the Plans is to investigate and document all existing knowledge about a site to facilitate the development of proposals for environmental watering for consideration by the State and/or Commonwealth Environmental Water Holders.

Critical information provided within the Plan for each site will include:

- management responsibilities
- environmental, social and economic values
- existing water delivery arrangements including recent delivery records and any identified issues
- environmental condition and threats
- environmental objectives
- any potential risks
- recommended water regimes to meet objectives under a range of climatic conditions
- delivery system constraints and any opportunities to improve delivery with infrastructure changes
- identification of any knowledge gaps and recommendations to resolve.

This document is the Environmental Water Management Plan for Lake Cullen in the North Central Catchment Management Authority (North Central CMA) region. The Plan is not a holistic management plan for the site, but rather is focused on specific environmental water management at the site.

1.3. Site location

The North Central CMA region is approximately three million hectares in size, bordered by the Murray River to the north, and the Central Highlands to the south (refer to Figure 1). The region includes the Campaspe, Loddon, Avoca and Avon-Richardson rivers and a number of significant wetland complexes, including Gunbower Forest, Kerang Wetlands, Avoca Marshes and the Boort Wetlands.

Lake Cullen is located in the north-western part of the region, within the Kerang Wetlands Ramsar Site (refer to Figure 2). It was historically associated with the Loddon and Avoca river systems, and would have received floodwaters from these systems during large flood events. Since the development of the Torrumbarry Irrigation System and river regulation, Lake Cullen has become isolated from the floodplain. It receives fresh water through channel deliveries and is a terminal wetland which becomes hyper-saline as water recedes (Macumber 2003).

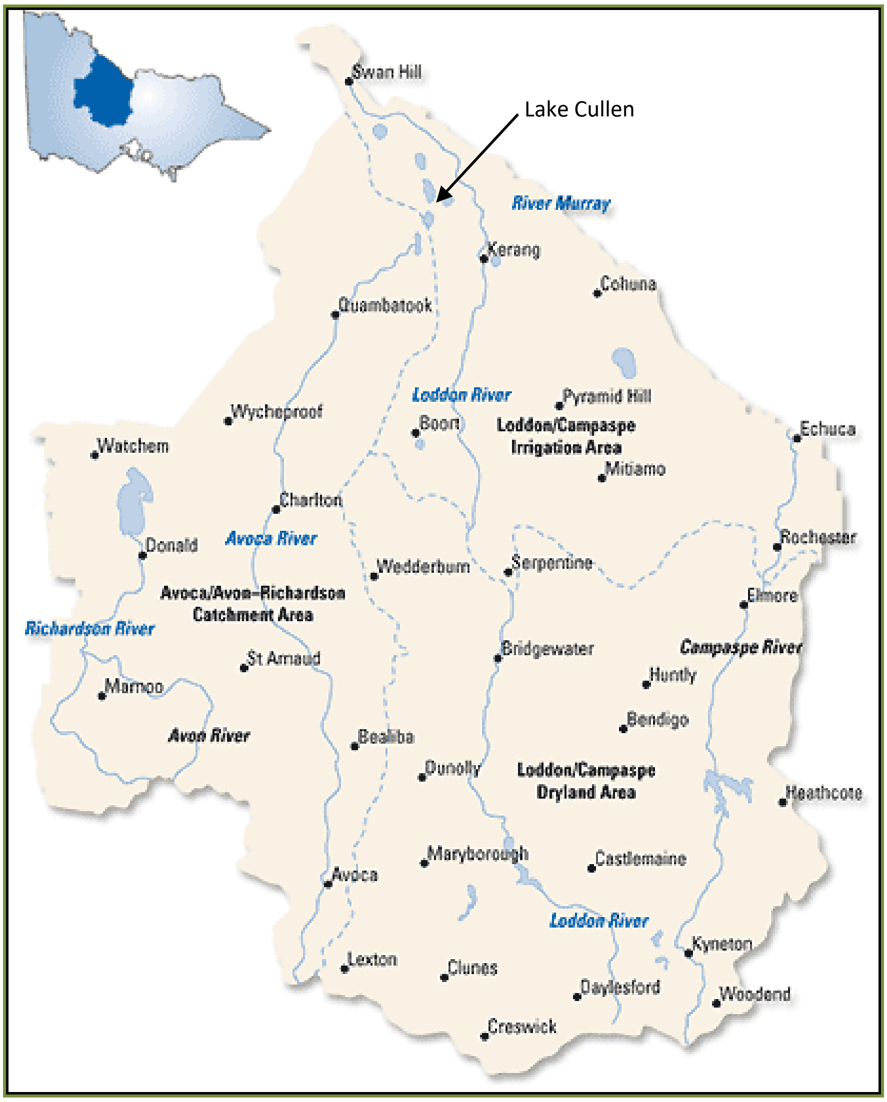


Figure 1. North Central CMA region

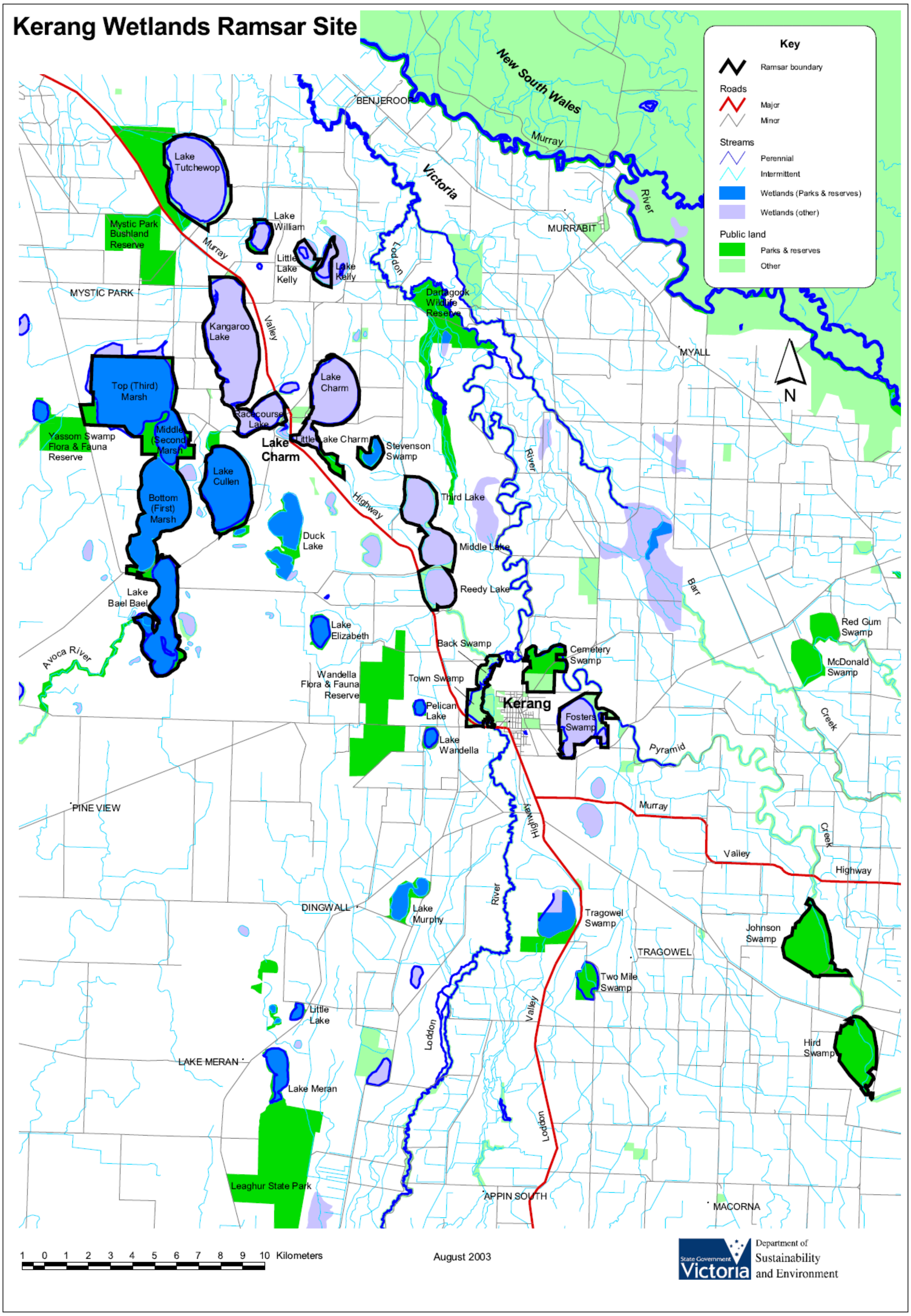


Figure 2. Kerang Wetlands Ramsar Site. Source: DSE 2004

1.4. Consultation

Specific consultation in the development of this plan was undertaken with a local technical group at a workshop held on 16 June 2011. Members represented at this workshop were: Mark Tscharke (Parks Victoria – Land Manager), Ross Stanton (Goulburn-Murray Water), Shelley Heron (KBR), Emer Campbell (North Central CMA), Andrea Joyce, and Bridie Velik-Lord (North Central CMA). Representatives from regional DSE were unable to attend the workshop. Outcomes and key discussion points from the workshop are presented in Appendix 7.

Consultation was also undertaken with adjoining landholders and community members who have had a long association with the wetland and proven interest in maintaining its environmental value. Other stakeholders were directly engaged to provide technical and historic information including G-MW, Field & Game Association, bird observers and field naturalists. A summary of the information sourced from this process is provided in Appendix 9.

1.5. Information sources

Information used in the development of this Plan has been compiled from various sources including scientific reports, management plans, Geographic Information System layers, and stakeholder knowledge. A full list of information sources used can be found in the reference section of this Plan.

1.6. Limitations

The information sources used in the development of this Plan have some limitations. In particular, the management plans and reports relied upon vary in age and therefore the degree to which they reflect the current situation. Every effort has been made to use best available information in the development of this Plan, and it is acknowledged that there is an on-going intention to update the Plan as new information and knowledge become available.

2. SITE OVERVIEW

2.1. Catchment setting

Lake Cullen is located within the Kerang Wetlands Ramsar site, north-west of the Kerang township (refer to Figure 3). The system of wetlands is on the western side of the Riverine Plain and includes approximately 9,419ha of permanent and temporary wetlands, including permanent freshwater lagoons, permanent open freshwater lakes, deep freshwater marshes, saline and hypersaline wetlands (DSE 2004a).

Land use surrounding Lake Cullen is agricultural-based, with the area supporting grazing, irrigated horticulture (e.g. wine grape production), dairying and cropping (see Figure 4) (DSE 2004a). The catchment area of the wetland system is associated with the Avoca, Loddon and Murray River floodplains and historically the wetlands in the area filled via flood flows through these catchments (DSE 2004a). These wide floodplain areas have encouraged the formation of depressional wetlands during, and after flooding (DEWHA 2010). With agricultural and commercial development in this area since European settlement, the nature of flooding including extent and duration through the Kerang Wetland system has been altered significantly (DSE 2004a).

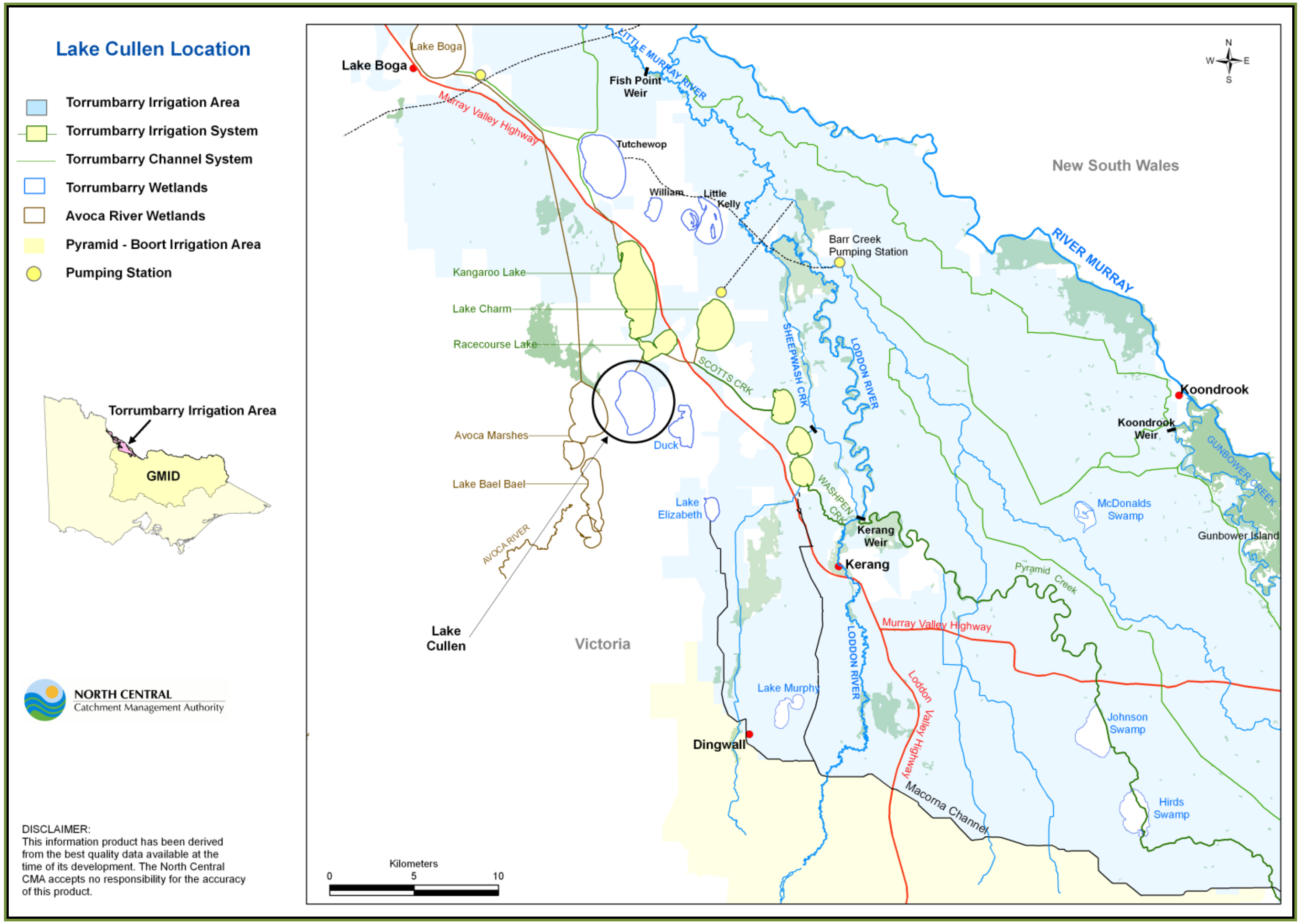


Figure 3. Lake Cullen location.

Figure 4. Lake Cullen and surrounding land (grape vines in the foreground). December 2010.

2.2. Land status and management

Lake Cullen is classified as a Wildlife Reserve and is managed by Parks Victoria (Nolan-ITU, 2000). The Victorian Environment Assessment Council (VEAC) River Red Gum Forests Investigation (VEAC 2008) lists Lake Cullen as a wildlife area within the natural features reserve (Lake Cullen is site G85). The recommendations provided for wildlife areas listed in the River Red Gum Forests Investigation relate to *'...conserving and protecting species, communities or habitats of indigenous animals and plants'* (VEAC 2008 pg. 85), while supporting the site *'...for public recreation (including hunting in season as specified by the land manager) and education, where this does not conflict with the primary objective.'* (VEAC 2008 pg. 85). Further, these sites (including Lake Cullen) should *'...be reserved under the Wildlife Act 1975 as state game reserves for the purpose of hunting.'* (VEAC 2008 pg. 85).

Management of the Torrumbarry irrigation system is undertaken by Goulburn-Murray Water as the local water authority and the regional environmental water manager is North Central CMA. Table 1 describes key stakeholders with possible involvement in Lake Cullen's management.

Table 1. Agencies and stakeholder groups with a responsibility or interest in the environmental water management of Lake Cullen

Agency / Stakeholder Group	Responsibility / Interest
Commonwealth Environmental Water Holder	Management of Commonwealth environmental water entitlements.
Department of Primary Industries	Provision of technical and extension support for the sustainable management of agriculture surrounding Lake Cullen.
Department of Sustainability and Environment	Provision of financial, policy and strategic support for the management of public and private land (including wetlands). Management of hunting licensing on public land. Currently manage environmental water entitlements on behalf of the Minister for Environment. Management of recreational duck hunting on Lake Cullen. Liaison with hunters and community groups.
Gannawarra Shire Council	Local council for area including Lake Cullen. Responsible for regulation of local development through planning schemes and on-ground works.
Goulburn-Murray Water	Rural water corporation responsible for the management of water-related services in the irrigation area of northern Victoria. Resource manager responsible for making seasonal allocations in the region. Operational coordination of water management and delivery in the Torrumbarry Irrigation Region including operation, management and maintenance of infrastructure.
Community	Recreational users of Lake Cullen, including passive recreational pursuits (walking, bird watching), hunting.
Local landholders	Management of private land surrounding Lake Cullen.
Murray-Darling Basin Authority	Responsible for preparing, implementing and enforcing the Murray-Darling Basin Plan. Responsible for planning integrated management of water resources across the Murray-Darling Basin.
North Central CMA	Coordination and monitoring of natural resource management programs in north central Victoria. Local operational management of the Environmental Water Reserve to rivers and wetlands including Lake Cullen.
Parks Victoria	Custodian and land manager of Lake Cullen Wildlife Reserve.
Victorian Environmental Water Holder	Due to be operational from 1 July 2011. Will manage Victorian environmental water entitlements into the future.
Wamba Wamba and Barapa Barapa Traditional Owners	Traditional owner groups of the Kerang Wetlands.

2.3. Wetland characteristics

Wetlands in Victoria are currently classified using a system developed by Corrick and Norman which includes information on water depth, water permanency and salinity (Corrick and Norman 1980 in DSE 2007) (refer to Appendix 1 for further information about the wetland categories). Wetlands through Victoria were mapped and classified between 1975 and 1994 and developed into spatial GIS layers. These layers represent the wetland characteristics at the time of mapping (referred to as Wetlands 1994 layer), as well as a categorisation of the wetland characteristics prior to European settlement (referred to as Wetlands 1788 layers) (DNRE 2000a; DNRE 2000b).

Under the Wetlands 1994 layer, Lake Cullen is classified as a permanent saline wetland with shallow open water. This classification is considered representative of the wetland during the time it was mapped and classified. Lake Cullen was historically used as part of the Torrumbarry irrigation system and maintained with water on a permanent basis through to the 1990s.

In the Wetlands 1788 layer, Lake Cullen is also classified as a permanent saline wetland. This may be representative of the size of the wetland, and the fact that when the wetland fills, it is unlikely that the water would drawdown to empty within a 12-month period. Natural floods through the system would have also been more frequent prior to river regulation which may have resulted in more frequent flooding events.

The Ramsar Convention provides a classification system for wetland types (The Ramsar Convention on Wetlands 1996). Within this system, Lake Cullen is classified as a seasonal/intermittent, saline/brackish/alkaline lake (DSE 2004; DSE 2010; DEWHA 2010). The main difference in these two classifications for Lake Cullen relates to its water permanency characteristics. The intermittent nature of the wetland is considered more representative of how the wetland has been managed over the past two decades than the Corrick classification (Appendix 5 details recent watering history for Lake Cullen). The Ramsar classification is also considered representative of proposed future management of the site, as its productivity for waterbird use can, in part, be attributed to the provision of wetting and drying cycles (DEWHA 2010).

Table 2 describes the wetland characteristics of Lake Cullen.

Table 2. Summary of Lake Cullen characteristics

Characteristics	Description
Name	Lake Cullen
Mapping ID	7626 510523
Area	629.23 ha
Bioregion	Victorian Riverina
Conservation status	Ramsar listed wetland; listed on the Register of National Estate; wetland listed in the Directory of Important Wetlands in Australia
Land status	State Wildlife Reserve
Land manager	Parks Victoria
Surrounding land use	Grazing, cropping, irrigated agriculture, irrigated horticulture
Water supply	Regulated flow from irrigation channel linking Racecourse and Kangaroo Lakes (Torrumbarry 1/3/7 Channel). Maximum outfall rate to the wetland is 300ML/day
1788 wetland category	Permanent saline wetland
1994 wetland category and sub-category	Permanent saline wetland with shallow open water (<5m)
Ramsar category[1]	Seasonal/intermittent, saline/brackish/alkaline lake and flats (R)
Wetland capacity	13,440ML at full supply level of 73m AHD (Nolan-ITU, 2000)
Wetland depth at capacity	Average 2m, maximum 2.6m deep at 73m AHD (DEWHA 2010)

2.4. Environmental water

Due to the changes in management of Lake Cullen over recent decades (from maintaining it on a permanent basis with water, to no longer requiring it as part of the irrigation system), the only water that the wetland receives is from managed deliveries. Even in the record flooding during 2010 and 2011, Lake Cullen remained isolated in the floodplain.

Environmental water available for use at Lake Cullen can come from a number of sources, as detailed in Table 3 and expanded in Appendix 2.

[1] The Ramsar category (seasonal/intermittent, saline/brackish/alkaline lake and flats) is considered to be the most appropriate classification of Lake Cullen for the purpose of this document (DSE 2004; DSE 2010; DEWHA 2010).

Table 3. Environmental water that may be used at Lake Cullen

Water entitlement	Environmental water management agency
Bulk Entitlement (River Murray – Flora and Fauna) Conversion Order 1999 (incl. Amendments Orders and Notices 2005, 2006, 2007 and 2009)	Environment Minister / Victorian Environmental Water Holder
Environmental Entitlement (River Murray Environmental Water Reserve) 2010	Environment Minister / Victorian Environmental Water Holder
River Murray Unregulated Flows	Department of Sustainability and Environment / Victorian Environmental Water Holder
Surplus / flood mitigation flows	Goulburn-Murray Water
Commonwealth Environmental Water Holdings	Commonwealth Environmental Water Holder

Water availability from all these water sources will vary from season to season, according to climatic conditions, volumes held in storage, carryover entitlements and seasonal priorities for watering.

2.5. Legislative and policy framework

There are a range of international treaties, conventions and initiatives, as well as National and State Acts, policies and strategies that direct management of wetlands within Northern Victoria. Those which may have particular relevance to Lake Cullen and the management of its environmental and cultural values are listed below. For the functions and major elements of each refer to Appendix 3.

International treaties, conventions and initiatives:

- Convention on Wetlands (Ramsar) 1971
- China Australia Migratory Birds Agreement (CAMBA) 1986
- Republic of Korea Australia Migratory Birds Agreement (ROKAMBA) 2002
- Japan Australia Migratory Birds Agreement (JAMBA) 1974
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) 1979

Commonwealth legislation and policy:

- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Part IIA)
- *Australian Heritage Commission Act 1975 (Register of the National* Estate)
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- *Native Title Act 1993*
- *Water Act 2007*
- Wetlands Policy of the Commonwealth Government of Australia 1997
- A Framework for Determining Commonwealth Environmental Watering Actions 2009
- A Directory of Important Wetlands in Australia 1993 (first edition), 1996 (second edition) and 2001 (third edition)

Victorian legislation:

- *Aboriginal Heritage Act 2006*
- *Catchment and Land Protection Act 1994*
- *Water Act 1989*
- *Flora and Fauna Guarantee Act 1988* (FFG Act)
- *Wildlife Act 1975*

- State Environment Protection Policy (Waters of Victoria) 2003

Victorian policy, codes of practice, charters and strategies:

- North Central Regional Catchment Strategy (North Central CMA 2003)
- Northern Region Sustainable Water Strategy (DSE 2009b)
- Our Water Our Future (DSE 2004b)
- Victorian threatened flora and fauna species (advisory list).

2.6. Related plans and activities

As Lake Cullen forms part of the Kerang Wetlands Ramsar Site, a key document related to its management is the *Kerang Wetlands Ramsar Site Strategic Management Plan* (DSE 2004a).

A project is currently underway which will detail the baseline conditions of the Kerang Wetlands Ramsar Site, as required for all nominated Ramsar Sites and referred to as Ecological Character Descriptions (ECD). A first iteration of this process was undertaken by DSE in 2010 (DSE 2010). The framework for ECD development was modified after this document was completed, and a new ECD is being currently being finalised according to the new framework. This is referred to as the *Draft Kerang Wetlands Ramsar Site Ecological Character Description* (DEWHA 2010).

In addition to these general site plans, the *Lake Cullen Feasibility Study and Operational Guidelines* (Nolan-ITU 2000) provides detailed information about the wetland while *A Review of Lake Cullen Salinity and the Cullen Feasibility Study* (Macumber 2003) provides reviews of the environmental water management cycle from 2001 to 2003 and the groundwater assumptions developed in Nolan-ITU (2000).

In addition, a draft management plan was completed for Lake Cullen in 1999 (Kelly 1999).

A range of on-ground works have been undertaken at Lake Cullen, including revegetation, invasive plant and animal control, fencing and the construction of duck nesting boxes (Heron Environmental Consulting 2006; Nolan-ITU 2000). The wetland is currently being monitored for water quality, water bird activity and vegetation responses to the 2010-11 watering event (a combination of environmental water and flood flows was provided to Lake Cullen during 2010-11 – refer to Appendix 5).

There are a number of other complementary management actions that could be undertaken to benefit the site, and increase the ecological outcome of environmental water management. Some of these actions are outlined below:

- invasive terrestrial animal management (particularly relating to rabbits and foxes)
- carp management[2]
- revegetation
- vehicle exclusion from wetland bed when dry.

[2] While the intermittent nature of Lake Cullen means that carp will die when the lake dries, there may be impacts on the wetland form and function caused by large carp entering the wetland during the filling phase. This was observed in the 2010-11 filling event when the channel from Racecourse Lake was opened and large-bodied carp were seen entering Lake Cullen with the water. Effective management strategies for carp can include carp cages or screens (DSE 2004), and regular drying of wetlands.

3. WATER DEPENDENT VALUES

3.1. Environmental

3.1.1. Listings and significance

Lake Cullen is considered a wetland of international importance due to its inclusion in the Kerang Wetlands Ramsar Site and listing under the Ramsar Convention (the Kerang Wetlands were listed on 15 December 1982 [Ramsar Secretariat, 2010]). It is also listed in the Directory of Important Wetlands (DIW) (Environment Australia 2001) within the Riverina Bioregion (1 of 30 sites). Under the DIW, Lake Cullen is considered a seasonal/intermittent saline lake (B8), and has been listed for the following reasons (Environment Australia 2001):

- it is a good example of a wetland type occurring within a biogeographic region in Australia
- it is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex
- it is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail
- the wetland supports 1% or more of the national populations of any native plant or animal taxa
- the wetland is of outstanding historical or cultural significance.

Lake Cullen is the only naturally saline wetland of intermittent nature in the Kerang Wetlands Ramsar site, making its role within this system very valuable (DEWHA 2010). Due to the saline conditions of the wetland, particularly as water begins to recede, vegetation growth is limited to submerged, salt adapted species such as *Ruppia* spp. (DEWHA 2010). Due to the lack of suitable vegetation communities for nesting, Lake Cullen does not support large waterbird breeding events. Despite a lack of large breeding events, Lake Cullen did support small breeding events during 1987, 1988 and 1998 including Red-capped Plover (*Charadrius ruficapillus*), Australian Shelduck (*Tadorna tadornoides*), Black Swan (*Cygnus atratus*) and Whiskered Tern (*Chlidonias hybridus*) (DSE 2004). These species breed amongst aquatic vegetation, in the water and/or on ground (DSE 2004) which is typical of the ecosystem provided by Lake Cullen.

While not heavily utilised for breeding events, Lake Cullen is highly valued for its large size and unique environment which is utilised extensively for waterbird foraging (DEWHA 2010). Lake Cullen has also been classified as excellent in relation to its non-breeding waterbird use (Corrick and Cowling 1975 and Lugg 1989 in DSE 2004).

DSE (2010) analysed waterbird records from the Atlas of Victorian Wildlife between 1980 and 2003 and found that Lake Cullen supported the greatest number of species of all the wetlands within the Kerang Wetlands Ramsar Site (56 species in total). Some of the highest abundances of waterbirds within the Ramsar Site have also been recorded at Lake Cullen, including the following (DSE 2010):

- Grey Teal (*Anas gracilis*) - 85,000 recorded in 1987; 27,600 in February and March 1992; 9,000 in 2002
- Eurasian Coot (*Fulica atra*)– 35,000 in October 1987
- Whiskered Tern - 6,000 in 1987
- Sharp-tailed Sandpiper (*Calidris acuminate*) – 8,000 in 1987
- Pink-eared Duck (*Malacorhynchus membranaceus*) – 5,000 in 1987 and 1992

In total, 413,468 waterbirds were recorded at Lake Cullen between 1980 and 2003 (DSE 2004). This is the highest number of waterbird records for any of the wetlands within the Kerang Wetlands Ramsar Site (DSE 2004).

Figure 5. Lake Cullen before (top), and during (bottom) environmental watering event in 2010.

Figure 6. Lake Cullen before (top), and during (bottom) environmental watering event in 2010-2011.

Table 4 details the legislation, agreements, conventions and listings that are relevant to Lake Cullen.

Key fauna recorded at Lake Cullen is protected by international, national and Victorian state legislation.

Table 4. Legislation, agreements, convention and listings relevant to the site, or species recorded at the Lake Cullen.

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	✓
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	✓
Directory of Important Wetlands in Australia	National	✓
Flora and Fauna Guarantee Act 1988 (FFG Act)	State	✓
DSE advisory lists	State	✓

3.1.2. Fauna

Lake Cullen provides habitat for a range of fauna species and communities. A number of these species are considered threatened under various legislation. In particular, the wetland is known to support large number of waterbirds. The benefit of the open water habitat Lake Cullen provides is observed through this high utilisation by waterbirds.

Figure 7. Cormorants at Lake Cullen. May 2011 .

There are also some migratory species which utilise Lake Cullen, and their habitat requires protection under international migratory agreements. Table 5 shows listed fauna species recorded at Lake Cullen.

Table 5. Significant fauna species recorded at the site. Source: DSE 2011a.

Common name	Scientific name	Type	International agreements	EPBC status	FFG status	DSE status
Sanderling	*Calidris alba*	B	J, C, R, B	NL	NL	NT
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	B	C	NL	L	V
Freckled Duck	*Stictonetta naevosa*	B	NL	NL	L	EN
Australasian Shoveler	*Anas rhynchotis*	B	NL	NL	NL	V
Royal Spoonbill	*Platalea regia*	B	NL	NL	NL	V
Brolga	*Grus rubicund*	B	NL	NL	L	V
Musk Duck	*Biziura lobata*	B	NL	NL	NL	V
Flathead Galaxias	*Galaxias rostratus*	F	NL	NL	I	V
Eastern Great Egret	*Ardea modesta*	B	B	NL	NL	V
Hardhead	*Aythya australis*	B	NL	NL	NL	V
Blue-billed Duck	*Oxyura australis*	B	NL	NL	L	EN
Pied Cormorant	*Phalacrocorax varius*	B	NL	NL	NL	NT
Glossy Ibis	*Plegadis falcinellus*	B	C, B	NL	NL	NT
Black-tailed Godwit	*Limosa limosa*	B	J, C, R, B	NL	NL	V
Caspian Tern	*Hydroprogne caspia*	B	C, B	NL	L	NT
Regent Parrot	*Polytelis anthopeplus monarchoides*	B	NL	NL	L	V

Legend

Type: Invertebrate, Fish, Amphibian, Reptile, Bird, Mammal
International: Camba, Jamba, Rokamba, Bonn, Not Listed
EPBC status: EXtinct, CRitically endangered, ENdangered, VUlnerable, Conservation Dependent, Not Listed
EPBC presence: Known to occur, Likely to occur, May occur, Not Listed
FFG status: Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing
DSE status: presumed EXtinct, Regionally Extinct, Extinct in the Wild, CRitically endangered, ENdangered, Vulnerable, Rare, Near Threatened, Data Deficient, Poorly Known, Not Listed

3.1.3. Flora

Vegetation communities

Lake Cullen is located in the Victorian Riverina Bioregion, which occurs in northern Victoria between the highlands of the north-east, and the Mallee country in the west. The bioregion is bordered by the Goldfields, Central Victorian Uplands, Murray Mallee, Murray Fans and Northern Inland Slopes bioregions. It is an ancient riverine floodplain characterised mainly by river alluvium (DPI 2009). The fertile soils make the area suitable for irrigated agriculture with over 94% of the bioregion privately owned and used for agricultural production (DPI 2009).

The three dominant Ecological Vegetation Classes (EVCs) of Lake Cullen were sampled in the 2012 vegetation assessment (Australian Ecosystems, 2012). .When inundated the dominant EVC in the central section of this wetland is Saline Aquatic Meadow (EVC 842). As water levels recede and the lake floor is exposed another EVC colonises the drying substrate known as Brackish Lake Bed Herbland (EVC 539). On the northern shoreline of the lake just above the level of the normal high water mark there is a small remnant of Intermittent Swampy Woodland (EVC 813). The terrestrial EVC occurring around the lake is Riverine Chenopod Woodland (EVC 103). Table 6 shows the list of EVCs recorded at Lake Cullen, along with their bioregional conservation status.

Table 6. Ecological vegetation classes recorded at the site. Source: Australian Ecosystems, 2012.

EVC no.	EVC name	Bioregional Conservation Status
		Victorian Riverina Bioregion
842	Saline Aquatic Meadow	Endangered
539	Brackish Lakebed Herbland	Endangered
813	Intermittent Swampy Woodland	Depleted
821	Tall Marsh	Depleted
103	Riverine Chenopod Woodland	Vulnerable

In 2000, a field survey was completed at Lake Cullen with the aim of mapping plant communities and topographic features (Nolan-ITU 2001). Findings suggest that the shallow bowl shape of the wetland provides a relatively simple delineation of plant communities through the majority of the wetland (site 1), and that there is another area of the wetland which is influenced by leakage from the delivery channel (site 2) (Nolan-ITU 2001).

The field survey was completed when Lake Cullen was dry in 2001. This field survey did not map EVCs within the wetland, but focused on flora species within vegetation zones identified from an aerial photograph. Despite being dry, it was suggested that three aquatic plant species were known to occur up to about 100,000 EC and likely to occur at Lake Cullen. These species are Ruppia spp. Potamogeton spp. and Lepilaena spp.

The first site investigated by Nolan-ITU (2001) was the area fringing the salt encrusted wetland bed. This consisted of a Samphire/Chenopod community and considered salt-tolerant. Further up the wetland margin consisted of Black Box trees and the upper zone consisted mainly of grasses and exotic pasture (Nolan-ITU 2001).

Site two of the wetland (the area influenced by the leaking channel structure) showed similarities with the rest of the wetland, however an area of freshwater marsh had developed and was supported by this water. The area included Ludwigia spp., Ranunculus spp., Azolla spp., Typha spp., Cotula spp. and an unidentified grass (Nolan-ITU 2001). The influence that the leaking channel has on this part of the wetland is significant as it contributes to the maintenance of a specific ecological component of the wetland of approximately 20ha in size.

Into the future if there is any direction to modify the channel structure due to irrigation modernisation, an assessment should be completed to investigate the environmental values its current operation has been supporting.

Through the bed of the wetland itself, mats of dried Ruppia spp. were observed (Nolan-ITU 2001), highlighting the dominance of this aquatic macrophyte species when Lake Cullen holds water.

Flora species

A total of 118 species of vascular plants were recorded at Lake Cullen during the 2012 vegetation survey, 80 of which were indigenous. Seven rare or threatened plant species have been recorded at this site, however two of these were planted as part of revegetation works. These included the rare Spiny Lignum (*Muehlenbeckia horrida subsp. Horrida*); the vulnerable Spear-fruit Copperburr (*Sclerolaena patenticuspis*) and Cane Grass (*Eragrostis australasica*) and the poorly known Dark Roly-poly (*Sclerolaena muricata var. semiglabray*). The endangered Hoary Scurf-pea (*Cullen* *cinereum)* was also recorded at Lake Cullen in 1983 when the lake bed was dry (refer to Table 7).

Table 7. Significant flora species and ecological communities recorded at the site (DSE 2011a)

Common name	Scientific name	EPBC status	FFG status	DSE status
Cane Grass	*Eragrostis australasica*	NL	NL	V
Dark Roly-poly	*Sclerolaena muricata var. semiglabray*	NL	NL	PK
Pearl Bluebush	*Maireana sedifolia*	NL	NL	R
Salt Paperbark	*Melaleuca halmaturorum subsp. halmaturorum*	NL	L	V
Spiny Lignum	*Muehlenbeckia horrida* subsp. *horrida*	NL	NL	R
Spear-fruit Copperburr	*Sclerolaena patenticuspis*	NL	NL	V
Hoary Scurf-pea	*Cullen cinereum*	NL	L	EN
EPBC status: EXtinct, CRitically endangered, ENdangered, VUlnerable, Conservation Dependent, Not Listed **FFG status:** Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing **DSE status:** presumed EXtinct, ENdangered, Vulnerable, Rare, Poorly Known, Not Listed				

While the flora species listed in Table 7 are valuable due to their rarity and significance on a Victorian statewide basis, macrophytes in Lake Cullen are important to consider for their ability to provide the food base for macroinvertebrates and waterbirds (DEWHA 2010). An important macrophyte which is known to occur at Lake Cullen is Large-fruit Tassel (*Ruppia megacarpa*) and this should be considered an important species to target management due to the structure and habitat it provides for fauna species (including fish, macroinvertebrates and waterbirds). The Directory of Important Wetlands in Australia describes *Ruppia* spp. as a critical plant at Lake Cullen (Environment Australia 2001).

Within temporary (including intermittent) saline wetlands, Boulton and Brock (1999) state that vegetation communities are generally characterised by a small number of species which dominate the environment. Within the terrestrial-aquatic zones of the wetland there will be salt marsh species, and within the aquatic zone it is likely that *Ruppia* spp. and *Lepilaena* spp. will dominate. This aligns with findings from Nolan-ITU (2001) which discuss the likelihood of these species being present at Lake Cullen, along with *Potamogeton* spp. All these species are considered important in the maintenance of waterbird habitat. Sainty and Jacobs (1981) note that the fruits of *Potamogeton* spp. are readily eaten by waterfowl, and that *Lepilaena* spp. is eaten by waterbirds, particularly swans.

There may also be charophyte alga such as *Lamprothamnium papulosum* which is known to occur with *Ruppia* spp. and *Lepilaena* spp. in saline environments. These species are adapted to the temporary nature of the wetland environments they are found in, and cope with the fluctuations of salinity and drying through a variety of physiological, morphological and life-cycle adaptations (Boulton and Brock 1999).

Lugg *et al*. (1989) describe Lake Cullen as an wetland supporting abundant aquatic plant growth with the main aquatic plant being *Ruppia* spp. (possibly three different species) which can stand salinities of at least up to 80,000EC. However, its vigour and abundance appears to decline as salinity approaches this level. During March 1989, *Potamogeton pectinatus* was recorded at the wetland when the salinity was approximately 8,000EC (Lugg *et al*. 1989). It is likely that this species will be present in the early stages of the wetland holding water, but will die out and be replaced with *Ruppia* spp. as salinities increase. The progression of species should be viewed as an important component of the wetland transition over a watering event, in response to changes in salinity levels.

3.1.4. Wetland depletion and rarity

Victoria's wetlands are currently mapped and are contained within a state wetland database, using an accepted statewide wetland classification system, developed by Andrew Corrick from the Arthur Rylah Institute (ARI). Mapping was undertaken from 1981 using 1:25,000 colour aerial photographs, along with field checking. This database is commonly known as the 1994 wetland layer (DNRE 2000b) and contains the following information (refer to Appendix 1):

- categories (primary) based on water regime
- subcategories based on dominant vegetation.

At the same time, an attempt was made to categorise and map wetland areas occupied prior to European settlement. This was largely interpretive work and uses only the primary category, based on water regime, referred to as the 1788 wetland layer (DNRE 2000a).

It has been possible to determine the depletion of wetland types across the state using the primary category only, based on a comparison of wetland extent between the 1788 and 1994 wetland layers.

Comparison between the wetland layers has demonstrated the impact of European settlement and development on Victorian wetlands. This has been severe, with approximately one-third of the state's wetlands being lost since European settlement; many of those remaining are threatened by continuing degradation from salinity, drainage and agricultural practices (ANCA 1996). Across the state, the greatest losses of original wetland area have been in the freshwater meadow (43 per cent), shallow freshwater marsh (60 per cent) and deep freshwater marsh (70 per cent) categories (DNRE 1997).

Lake Cullen is classified as a permanent saline wetland within the Wetlands 1994 layer (DNRE 2000b). However, a revised classification in the Kerang Wetlands Ramsar site documents Lake Cullen as a seasonal/intermittent, saline/brackish/alkaline lake (DSE 2004; DSE 2010; DEWHA 2010). To assist in understanding the significance of Lake Cullen in a landscape context, analyses have been undertaken focusing on the comparative areas of semi-permanent saline wetlands within the North Central CMA region; Goulburn-Murray Irrigation District; Victorian Riverina bioregion; the Ramsar Wetland Site; and Victoria as a whole (Table 8).

Within the Victorian Riverina bioregion, the wetland area that Lake Cullen contributes to the total area of semi-permanent saline wetlands is significant (34%). Further, within the Ramsar Wetland Site, Lake Cullen is considered the only seasonal/intermittent, saline/brackish/alkaline lake or flat (Table 8) (DSE 2004; DSE 2010; DEWHA 2010). Owing to this uniqueness within the landscape and its large size, it is a high priority for its values to be supported with environmental water.

Table 8. Current area of the site's classification in the region

Classification	Region				
	North Central CMA Region	Goulburn-Murray Irrigation District	Victorian Riverina bioregion	Ramsar Wetlands Site	Victoria
Semi-permanent saline wetland (ha)	3,611	3,243	1,843	-	70,947
Seasonal/intermittent, saline/brackish/alkaline lakes and flats (ha)	-	-	-	629	-
Lake Cullen (ha)	629	629	629	629	629
Lake Cullen as a proportion of the region (%)	17%	19%	34%	100%	0.9%

3.1.5. Ecosystem functions

Wetlands are considered ecologically important due to their role in maintaining biological diversity, promoting biochemical transformation and storage and decomposition of organic materials (DSE 2007). They also provide crucial habitats for flora, invertebrates, fish, birds, reptiles, amphibians and mammals, improve water quality through filtration, control floods, regulate carbon levels and provide significant cultural and recreational values (DSE 2007).

Despite being disconnected from the floodplain, Lake Cullen is known to provide all the ecosystem functions outlined above. In addition, DEWHA (2010) describes supporting services provided by the Kerang Wetlands as:

- biodiversity – high diversity of waterbird species
- critical habitat – drought refuge and breeding habitat for waterbirds (although Lake Cullen is not known for its breeding habitat)
- threatened species and communities – habitat for threatened species
- priority wetland species and ecosystems.

3.2. Social

3.2.1. Cultural heritage

The traditional owner groups of the Kerang Wetlands area are the Wamba Wamba and Barapa Barapa (DSE 2004a). The area is considered one of the most archaeologically important areas of Victoria with numerous middens, mounds, artefacts, scar trees and surface scatters documented with the Ramsar site (DEWHA 2010).

Lake Cullen is in an area of cultural heritage sensitivity, with artifact scatters recorded to the north of the wetland, and mounds recorded to the west (DPI, 2011).

3.2.2. Recreation

As Lake Cullen is a State Wildlife Reserve, certain waterfowl species can be hunted during the open season (March – June) (DSE 2005). In addition to hunting, other recreational pursuits can be undertaken at Lake Cullen including bird watching, bushwalking, and non-motorised water sports. When dry, Lake Cullen has been used for motorised and non-motorised recreational pursuits.

3.3. Economic

The economic value of a particular wetland to the regional economy can be quite difficult to measure. There are direct and indirect uses of wetlands which generate economic benefit on a local scale, regional and wider scale (ACF 2010). Direct uses of Lake Cullen include the income generated from recreational pursuits and tourism, while indirect uses include benefits such as groundwater recharge, nutrient treatment and carbon storage (DEWHA 2010).

Lake Cullen can be used by Goulburn-Murray Water during flood events as a flood storage site. During the 2010-11 floods in the region, flood waters were diverted to Lake Cullen to assist in taking the peak off the event.

4. HYDROLOGY AND SYSTEM OPERATIONS

The hydrology of a wetland will affect the chemical and physical aspects of that wetland (North Central CMA 2009). The chemical and physical aspects will in turn influence the flora and fauna communities that the wetland supports (DSE 2005). A wetland's hydrology is determined by surface and groundwater inflows and outflows in addition to precipitation and evapotranspiration (Mitsch and Gosselink, 2000 in DSE 2005). Duration, frequency and seasonality (timing) are the main components of the hydrological regime for wetlands and rivers.

4.1. Water management and delivery

4.1.1. Pre-regulation

Lake Cullen is part of a large lake system which formed near the junction of the Avoca and Loddon rivers, north of the Gredwin Ridge (Macumber 2003). While First Marsh and Lake Bael Bael on the Avoca floodplain system are located less than 1km to the west of Lake Cullen (Figure 8), a large sand lunette isolates the two wetlands and defines the surface floodplain boundary.

There is also a distinctive lunette clay dune on the eastern side of Lake Cullen. This lunette was originally blown out of the wetland during past periods when water tables were seasonally lower than they are currently. During this time it is likely that the wetland floor would have been saline which permitted the formation of sand-sized clay pellets which were capable of being deflated (Mcumber 2003).

Lake Cullen is part of the Kerang Wetlands complex, and would have naturally received water from Kangaroo Lake and Racecourse Lake during flood events. As Lake Cullen is not a throughflow wetland from a surface water perspective, water would have ponded at the site, increasing in salinity as the surface water was lost to evaporation and seepage (Macumber 2003).

Despite the lack of interaction between Lake Bael Bael and Lake Cullen from a surface water perspective, the two wetlands have a high degree of interaction through groundwater. The aquifer below this part of the wetland system occurs at a relatively shallow depth, and is formed by the saline marine Parilla Sands (Macumber 2003). Furthermore, Macumber (2003) suggests that *'[a] freshwater lens initially present in a number of bores between Lake Cullen and First Marsh probably has its origin in groundwater flow from the Avoca Marshes when hydraulic gradients were eastwards towards Lake Cullen.'* (Macumber 2003 pg. 17). Additionally, it is likely that under some conditions, groundwater flow will be in one direction (i.e. from the Marshes to Lake Cullen), and with different conditions this flow will be reversed (Macumber 2003).

Macumber (2003) discusses the salinity-groundwater interactions of Lake Cullen in detail, and describes two major salt sources in the wetland. The first of these relates to re-dissolved salts being flushed into the underlying groundwater when Lake Cullen holds water. The second process involves saline groundwater emerging at the wetland bed as freshwater begins entering the wetland. Once filled, the pressure exerted by the wetland increases and the freshwater displaces the saline water away from the wetland bed. Macumber (2003) also found that Lake Cullen is likely to be self-regulating in relation to salinity build-up.

Figure 8. Lake Cullen, Lake Bael Bael and The Marshes, Racecourse Lake and Kangaroo Lake. December 2010

4.1.2. Post-regulation

Between the 1920s and 1970s, Lake Cullen was used as a storage lake associated with the irrigation system and maintained with fresh water (Macumber 2003). After this time the wetland was removed from the Torrumbarry irrigation distribution system and has only received minimal flooding from nearby channel outfalls, or environmental water. Appendix 5 provides more information about water management at Lake Cullen over the past two decades.

The delivery mechanism to Lake Cullen is via the Torrumbarry Irrigation Channel 1/3/7. This channel links Lake Cullen with Racecourse Lake, which in turn is linked to Kangaroo Lake. Therefore, water delivery to Lake Cullen is managed through Kangaroo Lake operations. The outfall mechanism to Lake Cullen is through a structure comprising a middle manual gate, and two drop-board structures on either side (Figure 9). Goulburn-Murray Water operates the structure. The maximum delivery capacity available using all three bays is 300ML/day, with the operation of only the middle gate allowing about 100ML/day to enter the wetland.

Figure 9. Delivery channel at Lake Cullen.

5. CONDITION AND THREATS

5.1. Current condition

A comprehensive vegetation survey at Lake Cullen was conducted in 2002 when the wetland was dry. Almost half the flora species recorded were introduced. Species included Sea Barley Grass (*Cristension marinum*), Rye Grass (*Lolium* spp.) and African Boxthorn (*Lycium ferocissimum*) (DPI 2010c in DEWHA 2010). The presence of these introduced flora species is considered to have an impact on the site as they compete with the native species, reducing the prevalence of native salt-tolerant species and affect the wetland's diversity of habitat (DPI 2010c in DEWHA 2010). Native tree health was considered to be declining based on the general appearance of the trees indicating water-stress (DPI 2010c in DEWHA 2010). Nolan-ITU (2001) note that Lake Cullen is essentially a shallow bowl, resulting in a relatively simple delineation of plant communities during the dry phase of the wetland cycle.

In May 2012 additional information regarding the current condition of Lake Cullen was collected by Australian Ecosystems. A total of 118 species of vascular plants were recorded at Lake Cullen during this study, 80 (68%) of which were indigenous. The overall IWC biota score for this wetland was assessed as 17, indicating it was in good condition (Australian Ecosystems, 2012).

5.2. Water dependent threats

General threats to the wetlands analysed through the Plan process have been informed by the Aquatic Value Identification and Risk Assessment (AVIRA) process developed by DSE (DSE 2009a). The general threat categories are outlined below and these have been used to identify specific threats and their likelihood of impacting Lake Cullen (Table 9).

Altered water regime (specifically relating to a changed water regime):

The hydrology of a wetland is an important component to consider for the overall ecological functioning of a site. Hydrology drives the development of wetland soils and the biotic communities (DSE 2009a).

Activities with the potential to cause a change in water regime are those that (AVIRA):

- change the flow regime of the water source of the wetland
- interfere with the natural connectivity of flow to and from the wetland
- involve disposal of water into the wetland or extraction of water from the wetland
- change wetland depth and, therefore, alter the duration of inundation by changing the rate of evaporation (DSE 2005c in DSE 2009a).

Altered physical form (specifically relating to reduced wetland area and altered wetland form):

Physical form of a wetland is related to the wetland area and wetland bathymetry (DSE 2005c). AVIRA notes the key threats to physical form as being (DSE 2009a):

- reduction in wetland area (through drainage or infilling)
- alteration in wetland form – depth, shape, bathymetry (through excavation, landforming or sedimentation).

AVIRA also notes that the realisation of the threats listed above can modify the availability of wetland for biota through changes in water depth and its resultant impact on duration and inundation area (DSE 2005c, DSE 2006b in DSE 2009a).

Poor water quality (specifically relating to degraded water quality):

Degrading water quality in this instance is particularly focused on landuse activities which impact the water in, or entering the wetland. Within the wetland itself, examples of landuse activities which can degrade the water quality include livestock grazing, feral animals and aquaculture (DSE 2009a). Catchment land practices with potential to degrade wetalnd water quality include clearing of vegetation, land uses such as agriculture or urbanisation, fire, poor irrigation practices and point source discharges (DSE 2009a). Both these aspects may be manifested by changes in several physical and chemical water properties (e.g. nutrient enrichment, salinisation and turbidity) (DSE 2005c in DSE 2009a).

Degraded habitats (soil disturbance in particular):

The soils of wetland habitats are vital component for the wetland to function as a whole. It provides the physical substrate which aquatic vegetation requires to establish, and provides habitat for benthic invertebrates and microorganisms (DSE 2009a). The threatening processes which can impact wetland soils include pugging by livestock and feral animals, human trampling, driving of vehicles in the wetland and carp disturbance (DSE 2009a), resulting in soil disturbance which can reduce water storage capacity of soil, can have negative impacts on some invertebrates and increase turbidity during wetland filling events (DSE 2008e in DSE 2009a).

Exotic flora and fauna (including terrestrial and aquatic species):

The presence of exotic flora (i.e. species introduced from outside Australia) in the terrestrial and aquatic zones of wetlands causes harm when the extent of the exotic species replaces the native EVC components. When this occurs, there can be a threat to biodiversity and primary production of the wetland, increasing the land and water degradation and impacting the native flora and fauna species of the site (DSE 2009a).

Exotic fauna species can also pose a threat to the biodiversity of wetlands, along with its primary production potential (DSE 2009a). This occurs when the exotic specie disturb the functioning of the native vegetation and/or displace native fauna species.

Reduced connectivity (reduced wetland connectivity)

Wetland connectivity is most likely to occur where there are a series of habitat areas arranged in close proximity through the landscape, for example the Kerang wetland complex and the Boort wetland complex (DSE 2009). DEWHA and DAFF (2008) in DSE (2009a) define connectivity as 'the location and spatial distribution of natural areas in the landscape to provide species and populations with access to resources (food, breeding sites and shelter), increase habitat availability and facilitate population processes (dispersal, migration, expansion and contraction) and enable ecological processes (evolution, water, fire and nutrients)'.

When connectivity is reduced through a landscape, there is less opportunity for population to move from one spot to another in the search for food, habitat and population processes.

Table 9. Possible threats and likelihood of detrimental impacts occurring at Lake Cullen (as compared to pre-regulation condition)

Threat	Likelihood of detrimental impact on Lake Cullen	Comment
Altered water regime	High	Due to the regulation of the system, opportunities for floodwaters to link the wetland complex is minimal
Altered physical form	Medium	The bed of the wetland has changed from sand to clay, and has a higher level of silt than historically (Environment Australia 2001)
Poor water quality	Low	Only water source is from irrigation and therefore considered relatively good quality
Degraded habitats	Medium	Particularly relating to impacts of feral animals (rabbits and carp) on soil disturbance
Exotic flora and fauna	Medium	Particularly relating to predation by exotic fauna on native species recruitment (e.g. fox predation on birds)
Reduced connectivity	Medium	Connectivity has reduced as compared to natural conditions, however there are still opportunities for fauna species in particular to move through the landscape

5.3. Condition trajectory

Lake Cullen is cut off from the floodplain system and has been reliant on receiving water from the regulated irrigation system. Since being removed from the irrigation system in the 1970s, Lake Cullen has received water from managed outfall and/or environmental water deliveries.

In recent years the wetland has remained predominantly dry, with the site containing a high proportion of weed species (DPI 2010c in DEWHA 2010). The condition of the wetland during the last decade is considered to have been relatively stable. The recent filling event (2010-11) has shown encouraging ecological outcomes and the wetland is considered to be improving in condition, particularly in relation to aquatic vegetation recruitment. For example, *Ruppia* spp. has been observed regenerating through the wetland. Vegetation surveys will be undertaken during spring 2011 to provide information about specific species present. While waterbird use has not been particularly high this season (total of 433 waterbirds were recorded during a survey undertaken by DSE in June 2011), it is expected that this will increase in spring and summer 2011-12 due to the increasing productivity of aquatic vegetation.

Without management intervention through the provision of environmental water according to the recommended water regime into the future, the wetland is likely to lose its ability to function as a naturally saline wetland. This will be observed through the deterioration of vegetation species typical of semi-saline wetland, such as Large-fruit Tassel (*Ruppia megacarpa)*. Instead of water-tolerant species, there will be an increase in dominance of terrestrial species across the bed of the wetland, which will not respond to a flooding event as well as if the aquatic seedbank had been maintained. In addition, the provision of water to this wetland is a critical component of maintaining its ecological character, as is required for a Ramsar listed wetland.

6. MANAGEMENT OBJECTIVES

6.1. Management goal

The environmental water management goal for Lake Cullen has been based on information produced in Nolan-ITU (2001), local recommendations for the site (as refined in the regional technical workshop), and has also been informed by other management goals of naturally saline wetlands in the region such as Lake Elizabeth (North Central CMA 2009). Workshop notes from this meeting are provided in Appendix 7.

Lake Cullen environmental water management goal

To provide an appropriate water regime that targets the maintenance of a submerged salt-tolerant aquatic plant assemblage typical of an intermittent saline lake, and ability to support high levels of waterbird use.

6.2. Ecological and hydrological objectives

6.2.1. Ecological objectives

Ecological objectives represent the desired ecological outcomes of the site. In line with the draft policy Victorian Strategy for Healthy Rivers, Estuaries and Wetlands (VSHREW), the ecological objectives are based on the key values of the site (informed by Campbell *et al*. 2005). The ecological objectives are expressed as the target condition or functionality for each key value. The ecological objectives involve establishing one of the following trajectories of each key value, which is related to the present condition or functionality of the value (informed by Marquis-Kyle and Walker 1994; Campbell *et al*. 2005).

Protect – retain the biodiversity and/or the ecosystems at the existing stages of succession.

Improve – improve the condition of existing ecosystems by either returning an area of land to an approximation of the natural condition or to a known state.

Maintain – maintain the biodiversity and/or ecosystems while allowing natural processes of regeneration, disturbance and succession to occur.

Reinstate – reintroduce natural values that can no longer be found in an area.

Reduce - reduce the abundance and cover of undesirable exotic species that impact upon native values.

The ecological objectives developed for Lake Cullen are based on the values that the wetland provides, particularly in relation to its uniqueness in the landscape, and its ability to support a large number and diversity of waterbirds. These ecological objectives for the site are described in Table 10 and have been reviewed by the regional technical workshop participants.

Table 10. Ecological objectives for the site

Ecological objective	Justification (value based)
Maintain submerged aquatic species typical of a saline wetland (e.g. *Ruppia* spp., *Lepilaena* spp. and *Potamogeton* spp.).	Provision of habitat and food source for waterbird species, particularly ducks and waders. Provision of habitat for macroinvertebrates.
Maintain Black box communities surrounding the wetland and promote regeneration of species typical of Black Box communities[3].	Improve the health of the Black Box dominated community typical of a riverine chenopod woodland EVC to provide roosting areas for waterbird species, and habitat areas for a range of terrestrial species.

6.2.2. Hydrological objectives

Hydrological objectives describe the components of the water regime required to achieve the ecological objectives at this site. The hydrological objectives are derived from an understanding of the local hydrology, using a 'landscape logic' for the site (**Error! Reference source not found.** and Figure 10). The landscape logic identifies the relationship between vegetation communities, ecological objectives, position in the landscape and hydrological objectives (i.e. flow requirements).

The hydrological objective defined for Lake Cullen has been based on Nolan-ITU (2000) and local knowledge about the site.

The provision of water to Lake Cullen is recommended on an average of twice every ten years. One cycle of environmental water delivery should target a level of 73m AHD in order to inundate Black Box communities surrounding the edge of the wetland, and recede from this zone over the subsequent one to two months. Once the water has receded from the Black Box zone, water will likely remain at the site for 18 months to two years which will allow submerged aquatic species to germinate, grow and re-seed prior to the wetland drying. In addition, a natural draw-down will expose a large variety of habitats which will result in different vegetation communities establishing over a temporal and spatial scale. This will ensure the diversity of the wetland is maintained through the current watering event, and into the next event through the provision of an established seed bank (Nolan-ITU 2001).

For example, *Ruppia* spp., *Potamogeton* spp. and *Lepilaena* spp. are known to occur in salinities up to about 10,000 EC, however only *Ruppia* spp. is known to occur when salinities are greater than 100,000 EC (Nolan-ITU 2001). It is anticipated that as the wetland goes through its wetting and drying cycle, and progress from fresh to brackish to hypersaline, that these species will also cycle in prevalence.

In addition to the floristic diversity promoted through changes in salinity levels, there will also be a diversity of fauna species which will exist at different salinity levels. When the salinity levels are low, it is expected that macroinvertebrates such as beetles, bugs, mayflies and zooplankton will be prevalent (Nolan-ITU 2001). As salinity rises, the salt lake snail *Coxiella* and Amphipods will likely exist in high numbers (Nolan-ITU 2001).

Overall, it is expected that the highest diversity of flora and fauna will occur with salinities under approximately 10,000 EC (Nolan-ITU 2001). Moderate biodiversity is likely to occur at levels of 10,000 EC to 60,000 EC and a hypersaline community expected above this level (Brock 1984, Williams 1985 in Nolan-ITU 2001). The hypersaline environment will likely have low flora species diversity, but high productivity for waterbird use in particular (Nolan-ITU 2001). Therefore, salinity levels in Lake Cullen should be allowed range from below 10,000 EC to 120,000 EC in accordance with its natural drawdown regime in order to maximise ecological outcomes associated with environmental water management (Nolan-ITU 2001).

[3] Nolan-ITU (2001) recommend increasing the recruitment of Black Box trees between the existing level (~75m AHD) toward the edge of the wetland. Rogers and Ralph (2011) note that maintenance of Black Box condition does not require inundation of trees, however recruitment of new tress does. Therefore, inundation through the wetland should target at least 73m AHD in order to manage this ecological objective.

Macumber (2003) found that salinity levels mostly remain below about 31,000 EC when wetland levels are about 71.5m AHD (i.e. at least one metre of water held in the wetland). Once water levels fall below 71.5m AHD, there is an observed rise in salinity levels, with the highest levels of salinity being reached during the very last stages of wetland drying.

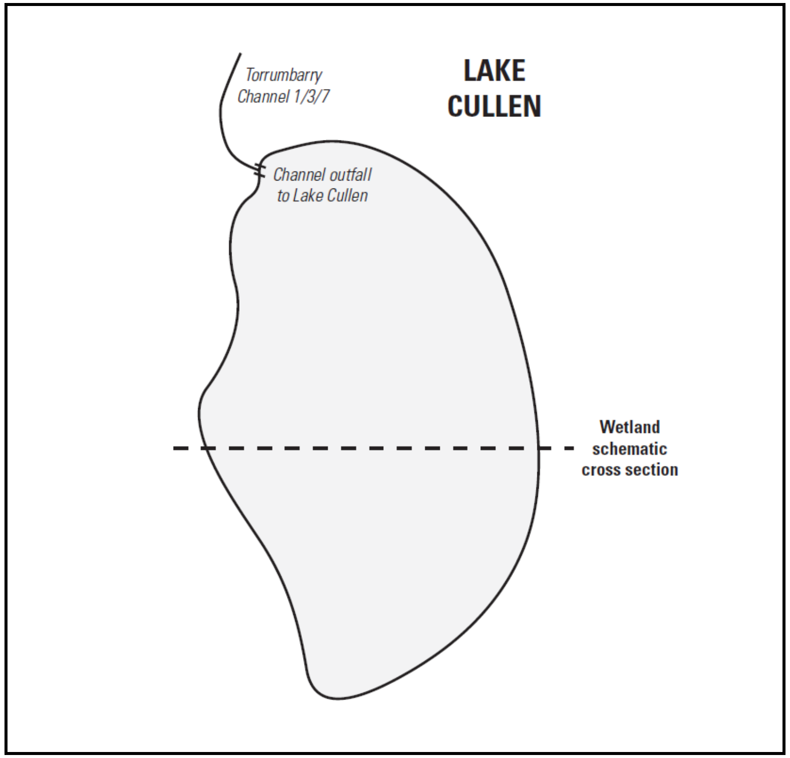
Salinity, however is an important ecological component of Lake Cullen, that requires consideration in association with watering events. Nolan-ITU (2001) note that the cycle of salinity in the surface water of Lake Cullen is a fundamental feature contributing to the biodiversity of the wetland, allowing the life-cycle of a range of species which have different salt tolerances to thrive.

The second cycle of environmental water delivery in a ten-year period should target a height not exceeding 72m AHD so as not to re-wet the Black Box community too frequently. As per the previous cycle, water will likely remain for the subsequent 18 months to two years to promote growth of submerged aquatic vegetation species.

In between these two cycles, the bed of Lake Cullen should be allowed to dry completely and remain completely dry for between one and three seasons prior to refilling.

Wherever possible, this managed hydrological regime should be aligned with local climatic conditions (i.e. the site should be watered when rainfall is occurring through the region).

The groundwater interaction between Lake Cullen and the Avoca Wetlands (Lake Bael Bael and The Marshes) needs to be monitored, particularly when one system is holding water and the other is not. Macumber (2003) found that plumes of groundwater outflow from Lake Cullen were observed in bores toward The Marshes during environmental watering events in Lake Cullen. Coupled with drought and the dispersal of the freshwater lens underlying First Marsh meant that saline water (37,000 EC) was observed within 3m of the Marshes during 2001. However, Macumber (2003) also notes that there are an inadequate number of bores between the two wetlands meaning that this conclusion is somewhat unquantified until further work is completed to understand the interactions further.



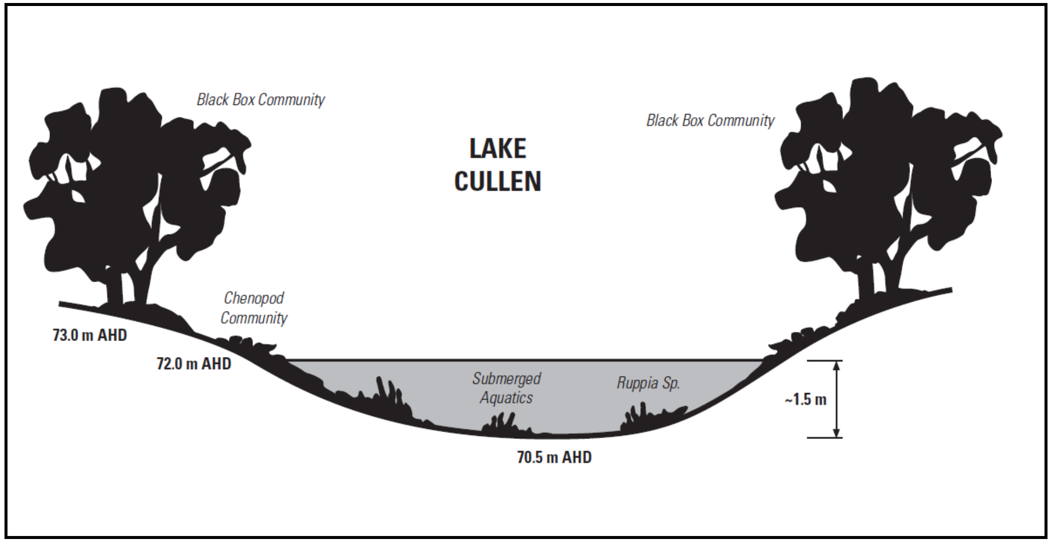


Figure 10. Schematic representation of the ecological components of Lake Cullen.

Table 11. Hydrological objectives for the site

Ecological objective	Water management area	Hydrological objectives						
		Recommended frequency of events (number per 10 years)	Duration of flooding (months)	Preferred timing of inflows	Target supply level (m AHD)	Volume to fill to target supply level[1] (ML)	Volume to maintain at TSL[2] (ML)	Total volume per event[3] (ML)
Maintain submerged aquatic species typical of a saline wetland (e.g. *Ruppia* spp. and *Lepilaena* spp.).	Bed	To achieve vigorous growth of species, a watering frequency of between two and four events per ten years is proposed (ideal number is three events).	Duration of flooding should be 24 to 30 months to allow species to complete their lifecycle and ensure seed is available for following event/s (two full growing seasons).	Winter / Spring	72	7,610 + losses	5,250	12,860 + losses
Maintain Black box communities surrounding the wetland and promote regeneration of species typical of Black Box communities[4].	Riparian zone	To achieve vigorous growth, a watering frequency of between one and two events per ten years is recommended.[4]	Duration of flooding should be between three and six months.[4]	Winter / Spring	73	13,440 + losses	-	13,440 + losses

[1] Based on rating table provided in Nolan-ITU (2000) (refer to Appendix 8); wetland water balance developed by Joyce, A and Velik-Lord, B.
[2] As above.
[3] As above. It is likely that this event will only be provided in years of high water availability and/or in flood events when Lake Cullen is used as a flood mitigation storage wetland. Therefore, the losses expected to occur due to evaporation rates will be highly dependent on the timing of inflows and maximum delivery rate.
[4] Based on information provided in Roberts and Marston (2011)

[4] Nolan-ITU (2001) recommends increasing the recruitment of Black Box trees between the existing level (~75m AHD) toward the wetland. Rogers and Ralph (2011) note that the maintenance of Black Box trees is less reliant on flood inundation than to promote recruitment. Therefore, inundation through the wetland should target at least 73m AHD in order to manage this ecological objective.

6.2.3. Watering regime

The wetland watering regime has been derived from the ecological and hydrological objectives. 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.

The optimal, minimum and maximum watering regimes are described below. The regimes involve between two and three watering events every ten years on average, and the duration of watering varies between the three regimes. Due to the groundwater interactions with neighbouring wetlands, environmental water planning and delivery will need to be adaptive, and informed by climatic and catchment conditions in the region. Specifically, filling Lake Cullen to 73m AHD as proposed below should not be undertaken unless the Avoca Marshes are holding water, or recent flood levels have resulted in the replenishment of the freshwater lens under the Marshes. Both of these cases may prevent the migration of saline groundwater to the Marshes when Lake Cullen is filled.

Conversely, if the Avoca Marshes receive significant flood water, environmental water and/or other water should be sourced to deliver to Lake Cullen to prevent groundwater migration from the Marshes to Lake Cullen.

Due to the inter-annual variability of these estimates (particularly the climatic conditions), determination of the predicted volume requirements in any given year will need to be undertaken by the environmental water manager when watering is planned.

Minimum watering regime

Provide two watering events every ten years.

Fill wetland to between 72m AHD and 73m AHD in spring of year one, targeting the growth and recruitment of submerged aquatic and macrophyte species. Allow water to draw down naturally over the subsequent season, and remain dry for not more than four seasons.

Fill wetland to 72m AHD in spring of year seven, then allow wetland to dry completely (as per previous cycle).

Optimal watering regime

Provide two watering events every ten years.

Fill wetland to 73m AHD in spring of year one to provide water to Black Box areas (dependent on catchment conditions). Ensure inundation period in this region does not exceed two months before allowing water to draw down naturally over the subsequent two seasons (wetland should dry during summer of year three). This will target the growth and recruitment of submerged aquatic and macrophyte species.

Allow wetland to remain completely dry for three seasons (years four to six), then provide water to 72m AHD during spring of year (seven). Provide a top up watering to 72m AHD the following spring (dependent on catchment conditions) to provide opportunities for aquatic plants and macrophyte species, then allow wetland to draw down completely (year nine and ten).

Maximum watering regime

Provide three watering events every ten years.

Fill wetland to 73m AHD in spring of year one to provide water to Black Box areas. Ensure inundation period in this region does not exceed two months before allowing water to draw down naturally over the subsequent two seasons (wetland should dry during summer of year three). This will target the growth and recruitment of submerged aquatic and macrophyte species.

Allow wetland to remain completely dry for one season (year four). Provide water to 72m AHD in spring of year five and top up in spring of year six (depending on catchment conditions).

Allow wetland to dry completely for at least one season before providing another fill event to 72m AHD.

In order to determine the total water volume required per watering event, a basic water balance was developed for Lake Cullen. This water balance focused on the long-term monthly evaporation and rainfall figures recorded at Kerang (sourced from the Bureau of Meteorology). The figures were then converted to wetland deficit (ML) based on the surface area of the wetland (from Nolan-ITU 2001) and roughly checked against real data recorded by DPI in the 2006 wetland fill event. Key inputs to, and assumptions for the relationship include:

- wetted surface area of Lake Cullen at 73m AHD is 660ha (Nolan-ITU 2001; G-MW in Nolan-ITU 2001)
- wetted surface area of Lake Cullen at 72m AHD is 550ha (Nolan-ITU 2001)
- due to the bowl shape of Lake Cullen, gauges cannot read water height below 70.8m AHD, equating to 440ha of wetted area (Nolan-ITU 2001)
- bed level / AHD when Lake Cullen is empty, it is 70.5m AHD.

The optimal watering regime was investigated using the method outlined above. The drawdown curves for a 73m AHD fill event, and a 72m AHD event with a subsequent top up are shown in Figure 11

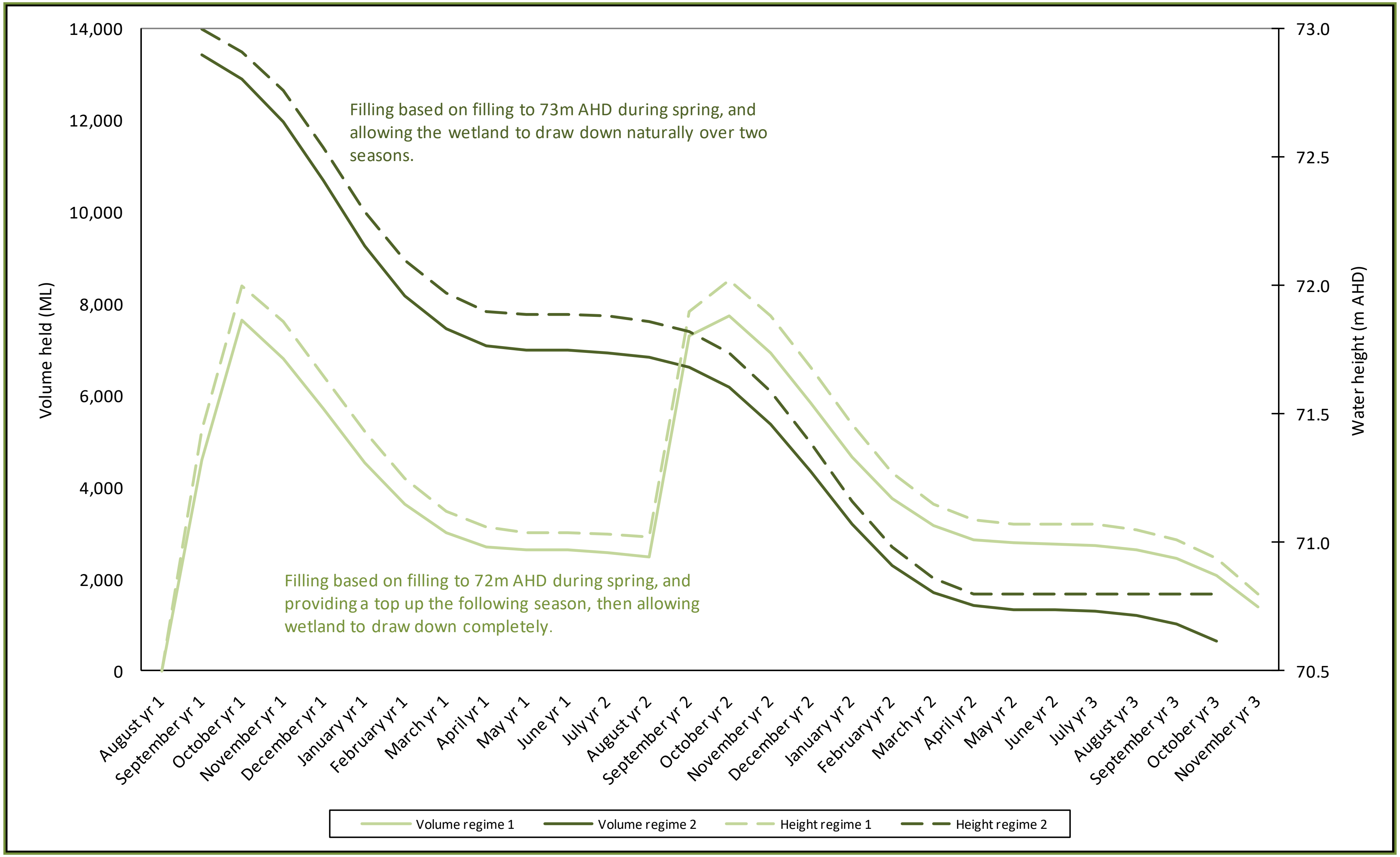


Figure 11. Proposed hydrological regimes based on the optimal watering regime for Lake Cullen.

6.3. Seasonally adaptive approach

Victoria has adopted an adaptive and integrated management approach to environmental management. A key component of this approach for environmental watering is the 'seasonally adaptive' approach, developed through the Northern Region Sustainable Water Strategy (DSE 2009b) and incorporated into the Victorian Strategy for Healthy Rivers, Estuaries and Wetlands.

The seasonally adaptive approach identifies the priorities for environmental watering, works and complementary measures, depending on the amount of water available in a given year. It is a flexible way to deal with short-term climatic variability and helps to guide annual priorities and manage droughts. The approach is outlined in Table 12.

The seasonally adaptive approach has been used to guide the watering regime under various climatic scenarios. In drier periods, restricted water resource availability will potentially limit the number of ecological objectives which can realistically be provided through environmental water management. However, these ecological objectives can be achieved in wetter periods as water resource availability increases.

Due to its large size, Lake Cullen requires a relatively large volume of water to meet its ecological objectives. Further, there is some danger of adversely impacting the wetland function from 'under-filling' of Lake Cullen due to the need to export salt downwards to the water table to prevent salt build up (Nolan-ITU 2001). As such, it is recommended that Lake Cullen be filled to the hydrological target of at least 72m AHD, and there needs to be a degree of certainty that there is sufficient water and delivery time available to achieve this target during any filling event.

In relation to the seasonally adaptive approach, this means that Lake Cullen is unlikely to be a candidate for environmental watering under the drought scenario, but is more likely to receive water in average to wet scenarios (targeting a fill of between 72m AHD and 73m AHD). Its ability to provide a storage role in flood mitigation also means that in wet to very wet scenarios, Lake Cullen can receive surplus water which may be complemented by environmental water to target a fill of 73m AHD.

Table 12. The seasonally adaptive approach to river and wetland management (DSE, 2009b)

	Drought	Dry	Average	Wet to very wet
Long-term ecological objectives	Long-term objectives to move towards ecologically healthy rivers - set through regional river health strategies and sustainable water strategies and reviewed through the 15-year resource review			
Short-term ecological objectives	• Priority sites have avoided irreversible losses and have capacity for recovery	• Priority river reaches and wetlands have maintained their basic functions	• The ecological health of priority river reaches and wetlands has been maintained or improved	• The health and resilience of priority river reaches and wetlands has been improved
Annual management objectives	• Avoid critical loss • Maintain key refuges • Avoid catastrophic events	• Maintain river functioning with reduced reproductive capacity • Maintain key functions of high priority wetlands • Manage within dry-spell tolerances	• Improve ecological health and resilience	• Maximise recruitment opportunities for key river and wetland species • Minimise impacts of flooding on human communities • Restore key floodplain linkages
Environmental water reserve	• Water critical refuges • Undertake emergency watering to avoid catastrophic events • Provide carryover (for critical environmental needs the following year) • If necessary, use the market to sell or purchase water	• In priority river reaches provide summer and winter baseflows • Water high priority wetlands • Provide river flushes where required to break critical dry spells • Provide carryover (for critical environmental needs the following year) • If necessary, use the market to sell or purchase water	• Provide all aspects of the flow regime • Provide sufficient flows to promote breeding and recovery • Provide carryover to accrue water for large watering events • If necessary, use the market to sell or purchase water	• Provide overbank flows • Provide flows needed to promote breeding and recovery • If necessary, use the market to sell or purchase water
River and wetland catchment activities	• Protect refuges (including stock exclusion) • Increase awareness of the importance of refuges • Enhanced monitoring of high risk areas and contingency plans in place • Investigate feasibility of translocations • Environmental emergency management plans in place • Protect high priority river reaches and wetlands through fencing; pest, plant and animal management; and water quality improvement works • Implement post-bushfire river recovery plans	• Protect refuges • Protect high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Environmental emergency management plans in place • Improve connectivity • Implement post-bushfire river recovery plans	• Protect and restore high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Monitor and survey river and wetland condition • Improve connectivity between rivers and floodplain wetlands	• Protect and restore high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Monitor and survey river and wetland condition • Improve connectivity between rivers and floodplain wetlands • Emergency flood management plans in place • Implementation of post-flood river restoration programs

7. POTENTIAL RISKS OF AND MITIGATION MEASURES FOR ENVIRONMENTAL WATERING

A risk identification process has been undertaken to highlight risks associated with environmental water delivery at Lake Cullen.

While the risks described in Table 13 are considered somewhat generic in relation to environmental water management across sites in the North Central region, where they will specifically impact on Lake Cullen is highlighted through the analysis in the impact section of Table 13. In addition, a detailed risk assessment process will be developed prior to delivering environmental water in any given season and will be provided in the site watering proposal.

Table 13. Possible risks and mitigation measures associated with environmental water delivery to Lake Cullen

Risk	Description	Potential Impacts								Potential mitigation measures
		Environmental (Water regime does not support breeding and feeding requirements or vegetation establishment and growth)					Social		Economic	
		Fish	Birds	Amphibians	Invertebrate	Native aquatic flora	Reduced public access and use	Degradation of cultural heritage sites	Flooding of adjacent land	
Required watering regime not met	Flood duration too long or short		✓	✓		✓				• Determine environmental water requirements based on seasonal conditions and to support potential bird breeding events • Monitor flood duration to inform environmental water delivery • Monitor the ecological response of the wetland to flooding (particularly the aquatic macrophyte response – ensure they have flowered prior to drying out)) • Add or allow water to drawdown where appropriate or practical
	Flood timing too late or early		✓	✓		✓	✓			• Undertake a water mass-balance based on seasonal conditions before placing water order • Consult with water authority throughout season. Consider purchasing delivery shares of casual use if need be. • Monitor flood timing to inform environmental water delivery • Monitor the ecological response of the wetland to flooding (particularly the response of aquatic macrophytes – ensure they have flowered prior to drying out)
	Flooding depth too shallow or deep		✓			✓	✓	✓	✓	• Determine environmental water requirements based on seasonal conditions and to support potential bird breeding events • Monitor flood depth to inform environmental water delivery • Liaise with adjoining landowners prior to and during the delivery of environmental water to discuss and resolve potential or current flooding issues • Add or drawdown water where appropriate or practical
	Flood frequency too long or short	✓	✓	✓	✓	✓	✓			• Prioritise water requirements of wetlands in seasonal watering proposals according to their required water regimes and inundation history • Monitor the long-term ecological condition of the wetland to inform future water deliveries • Monitor the ecological response of the wetland to flooding

Continued

Risk	Description	Potential Impacts								Potential mitigation measures
		Environmental (Water regime does not support breeding and feeding requirements or vegetation establishment and growth)					Social		Economic	
		Fish	Birds	Amphibians	Invertebrate	Native aquatic flora	Reduced public access and use	Degradation of cultural heritage sites	Flooding of adjacent land	
Poor water quality	Low dissolved oxygen	✓	✓			✓				• Monitor dissolved oxygen levels and the ecological response of the wetland to flooding • Add or drawdown water where appropriate or practical
	High turbidity	✓				✓				• Monitor turbidity levels and the ecological response of the wetland to flooding • Add or drawdown water where appropriate or practical
	High water temperature	✓				✓				• Monitor water temperature and the ecological response of the wetland to flooding • Add or drawdown water where appropriate or practical
	Increased salinity levels	✓		✓	✓	✓				• Monitor salinity levels and the ecological response of the wetland to flooding • Add or drawdown water where appropriate or practical
	Increased nutrient levels	✓	✓	✓	✓		✓			• Monitor nutrient and Blue Green Algae levels, and the ecological response of the wetland to flooding • Place public warning signs at the wetland if BGA levels are a public health risk • Add or drawdown water where appropriate or practical
Invasive aquatic plant and animal invasion	Introduction of invasive aquatic fauna	✓		✓	✓	✓				• Monitor the ecological response of the wetland to flooding • Install carp screen • Implement an appropriate drying regime
	Growth and establishment of aquatic invasive plants	✓	✓	✓	✓	✓				• Monitor the abundance of native and invasive aquatic plants • Control invasive plants in connected waterways • Spray or mechanically remove invasive plants • Implement an appropriate drying regime
Off-site impacts	Saline groundwater migration	✓[1]		✓[1]	✓[1]	✓[1]	✓[1]			• Fill wetland in accordance with catchment conditions (especially in reference to the conditions in the Avoca Marshes) • Monitor bores to understand groundwater movement and presence of freshwater lens

[1] These potential impacts would be observed at neighbouring wetlands and surrounding land.

8. ENVIRONMENTAL WATER DELIVERY INFRASTRUCTURE

8.1. Constraints

Existing infrastructure constraints to environmental water delivery are considered minimal at Lake Cullen. The existing structure can deliver at a rate up to 300ML/day when there is sufficient channel capacity through the irrigation system (i.e. low irrigation demand), or flood mitigation is required. For environmental purposes, it is likely that a slower delivery rate of 100-200ML is preferable to promote ecological responses. As such, the current delivery infrastructure is considered sufficient for environmental water delivery to Lake Cullen.

From an operational perspective, the middle gate in the outfall structure is a manual door, and the other two bays consist of drop-boards. As such, G-MW is required to access the site to open and close the structure rather than operating it remotely. Additionally the drop-boards are prone to leaking, particularly when they have been removed and then reinstated, resulting in water losses from the system. This leakage seems to support a semi-aquatic plant assemblage directly below the channel structure and a detailed assessment of the environmental benefits this provides will need to be undertaken prior to any modification occurring.

8.2. Irrigation modernisation

The Northern Victorian Renewal Project (NVIRP) is a program which aims to upgrade existing irrigation infrastructure in the Goulburn-Murray Irrigation District to achieve water savings. There are currently no plans to modify the delivery infrastructure to Lake Cullen.

8.3. Infrastructure recommendations

No recommendations for infrastructure modification at Lake Cullen are made at this stage.

9. KNOWLEDGE GAPS AND RECOMMENDATIONS

There are currently a number of knowledge gaps in relation to environmental water management at Lake Cullen. While none of these significantly impact the ability to provide water to the wetland and generate ecological benefit, the addressing of these knowledge gaps would significantly improve the accuracy of environmental water bids, and provide long-term ecological understanding of the site.

Specifically, the following activities are recommended to be undertaken along with long-term investment of environmental water to Lake Cullen:

- review existing wetland capacity table and undertake survey of wetland bed (to be undertaken once site has dried)
- map wetland EVCs across Lake Cullen and undertake a detailed aquatic vegetation survey
- undertake IWC wetland vegetation assessment to monitor condition
- investigate further the association between waterbird numbers and flooding regimes within the Kerang Wetlands Ramsar Site (DSE 2010)
- develop a long and short-term monitoring program to be used in conjunction with environmental watering proposals and delivery plans including the following:
    - identify ecological indicators (based on ecological objectives) for monitoring long-term ecological condition and change
    - Identify decision triggers for managing salinity triggers within, and surrounding Lake Cullen, including monitoring groundwater interactions with Lake Bael Bael and the Avoca Marshes
- undertake detailed assessment of the environmental benefits that the leaky outlet structure provides to the wetland.

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APPENDIX 1: CORRICK AND NORMAN CLASSIFICATION OF WETLAND CATEGORIES

Source: DSE 2007b

Category	Sub-category	Depth (m)	Duration of inundation
Flooded river flats These include many areas of agricultural land that become temporarily inundated after heavy rains or floods. Water may be retained in local depressions for just a few days or for several months.		< 2	
Freshwater meadow These include shallow (up to 0.3 m) and temporary (less than four months duration) surface water, although soils are generally waterlogged throughout winter.	1 Herb-dominated 2 Sedge-dominated 3 Red gum- dominated 4 Lignum dominated	< 0.3	< 4 months/year
Shallow freshwater marsh Wetlands that are usually dry by mid-summer and fill again with the onset of winter rains. Soils are waterlogged throughout the year and surface water up to 0.5 m deep may be present for as long as eight months.	1 Herb-dominated 2 Sedge-dominated 3 Cane grass dominated 4 Lignum dominated 5 Red gum-dominated	< 0.5	< 8 months/year
Deep freshwater marsh Wetlands that generally remain inundated to a depth of 1 – 2 m throughout the year.	1 Shrub-dominated 2 Reed-dominated 3 Sedge-dominated 4 Rush-dominated 5 Open water 6 Cane grass dominated 7 Lignum-dominated 8 Red gum-dominated	< 2	permanent
Permanent open freshwater Wetlands that are usually more than 1 m deep. They can be natural or artificial. Wetlands are described to be permanent if they retain water for longer than 12 months, however they can have periods of drying.	1 Shallow 2 Deep 3 Impoundment	<2 >2	permanent
Semi-permanent saline These wetlands may be inundated to a depth of 2 m for as long as eight months each year. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the whole year.	1 Salt pan 2 Salt meadow 3 Salt flat 4 Sea rush-dominated 5 Hypersaline lake	< 2	< 8 months/year
Permanent saline These wetlands include coastal wetlands and part of intertidal zones. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the whole year.	Shallow Deep Intertidal flats	< 2 > 2	permanent
Sewage oxidation basin These include artificial wetlands used for sewage treatment.	Sewage oxidation basin		
Salt evaporation basin These include artificial wetlands used salt concentration.	Salt evaporation basin		

APPENDIX 2: ENVIRONMENTAL WATER SOURCES

Commonwealth Environmental Water Holder (CEWH)

Under *Water for the Future* the Commonwealth Government committed $3.1 billion to purchase water in the Murray-Darling Basin over 10 years. The Commonwealth Environmental Water Holder will manage their environmental water.

The Commonwealth Water Act 2007 identified that "the Commonwealth Environmental Water Holder must perform its functions for the purpose of protecting or restoring environmental assets so as to give effect to relevant international agreements". Wetlands listed as of International Importance (Ramsar) are considered priority environmental assets for use of the commonwealth environmental water (DEWHA 2008).

Victorian Environmental Water Holder (VEWH)

The VEWH (when established in June 2011) will be responsible for holding and managing Victorian environmental water entitlements and allocations and deciding upon their best use throughout the State. The environmental entitlements held by the VEHW that could potentially be made available to this site include:

- Bulk Entitlement (River Murray – Flora and Fauna) Conversion Order (incl. Amendments Orders and Notices 2005, 2006, 2007 and 2009); and
- Environmental Entitlement (River Murray Environmental Water Reserve) 2010.

In 1987 an annual allocation of 27,600 ML of high security water was committed to flora and fauna conservation in Victorian Murray wetlands. In 1999, this became a defined entitlement for the environment called the Victorian River Murray Flora and Fauna Bulk Entitlement.

The Northern Victoria Irrigation Renewal Project (NVIRP) water savings are predicted to provide up to 75 GL as a statutory environmental entitlement, which will be used to help improve the health of priority stressed rivers and wetlands in northern Victoria (DSE, 2008). The entitlement will have properties which enable the water to be used at multiple locations as the water travels downstream (provided losses and water quality issues are accounted for); meaning that the water can be called out of storage at desired times to meet specific environmental needs.

River Murray Unregulated Flow (RMUF)

Unregulated flows in the River Murray system are defined as water that cannot be captured in Lake Victoria and is, or will be, in excess of the required flow to South Australia. If there is a likelihood of unregulated flow event in the River Murray system, the Authority provides this advice to jurisdictions The Upper States then advise the Authority on altered diversion rates and environmental releases within their existing rights to unregulated flows.

Based on the information received from Jurisdictions, the Authority reassesses the event and, if necessary, limits Upper States' access to ensure that the unregulated flow event is not over committed. The Authority then issues formal unregulated flow advice to jurisdictions including any limits to States access.

Depending on the volume of water remaining, the Authority advises EWG and the Water Liaison Working Group (WLWG) on the availability and volume of RMUF. Whilst there is a range of measures that can be undertaken by Upper States as part of their 'prior rights' during unregulated flows, RMUF events are prioritised solely for the environment.

APPENDIX 3: LEGISLATIVE FRAMEWORK

International agreements and conventions

Ramsar Convention on Wetlands (Ramsar)

The Australian Government is a Contracting Party to the convention, which is an inter-governmental treaty whose mission is “the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".

Bilateral migratory bird agreements

Australia is a signatory to the following international bilateral migratory bird agreements:

- Japan-Australia Migratory Bird Agreement (JAMBA);
- China-Australia Migratory Bird Agreement (CAMBA); and
- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

These agreements require that the parties protect migratory birds by:

- limiting the circumstances under which migratory birds are taken or traded;
- protecting and conserving important habitats;
- exchanging information; and
- building cooperative relationships.

Convention on the Conservation of Migratory Species of Wild Animals (Bonn)

This convention (known as the Bonn Convention or CMS) aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental treaty, concluded under the aegis of the United Nations Environment Programme, concerned with the conservation of wildlife and habitats on a global scale. The Convention was signed in 1979 in Bonn, Germany, and entered into force in 1983.

Commonwealth legislation

Environment Protection and Biodiversity Conservation Act 1999 (EPBC)

This is the key piece of legislation pertaining to biodiversity conservation within Australia. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places - defined in the EPBC Act as matters of national environmental significance.

Water Act 2007 (Commonwealth Water Act)

This establishes the Murray-Darling Basin Authority (MDBA) with the functions and powers, including enforcement powers, needed to ensure that Basin water resources are managed in an integrated and sustainable way.

Aboriginal and Torres Straight Islander Heritage Protection Act 1984

This aims to preserve and protect areas and objects in Australia and Australian waters that are of particular significance to indigenous people from injury or desecration.

State legislation and listings

Flora and Fauna Guarantee Act 1988 (FFG)

This is the key piece of Victorian legislation for the conservation of threatened species and communities and for the management of potentially threatening processes.

Advisory lists of rare or threatened species in Victoria (DSE)

Three advisory lists are maintained by DSE for use in a range of planning process and in setting priorities for actions to conserve biodiversity. Unlike other threatened species lists, there are no legal requirements or consequences that flow from inclusion of a species on an advisory list. The advisory lists comprise:

- Advisory List of Rare or Threatened Plants In Victoria – 2005
- Advisory List of Threatened Vertebrate Fauna in Victoria - 2007
- Advisory List of Threatened Invertebrate Fauna in Victoria - 2009

Environmental Effects Act 1978

Potential environmental impacts of a proposed development are subject to assessment and approval under this Act. A structural works program and any associated environmental impacts would be subject to assessment and approval under the Act.

Planning and Environment Act 1987

This controls the removal or disturbance to native vegetation within Victoria by implementation of a three-step process of avoidance, minimisation and offsetting.

Water Act 1989 (Victorian Water Act)

This is the key piece of legislation that governs the way water entitlements are issued and allocated in Victoria. The Act also identifies water that is to be kept for the environment under the Environmental Water Reserve. The Act provides a framework for defining and managing Victoria's water resources.

Aboriginal Heritage Act 2006

All Aboriginal places, objects and human remains in Victoria are protected under this Act.

Other relevant legislation

The preceding legislation operates in conjunction with the following other Victorian legislation to influence the management and conservation of Victoria's natural resources as well as outline obligations with respect to obtaining approvals for structural works:

- Environment Protection Act 1970
- Catchment and Land Protection Act 1994
- Heritage Act 1995
- Conservation, Forests and Lands Act 1987
- Land Act 1958
- Heritage Rivers Act 1992
- Wildlife Act 1975
- Murray Darling Basin Act 1993
- National Parks Act 1975
- Parks Victoria Act 1998
- Forests Act 1958

APPENDIX 4: ECOLOGICAL VEGETATION CLASSES

Figure 12 shows the Ecological Vegetation Classes mapped at Lake Cullen.

Freshwater Lake Aggregate (EVC 718) is shown in dark purple; Riverine Chenopod Woodland (EVC 103) is shown in pink hash; Semi-arid Woodland (EVC 97) is shown in light green hash.

Table 14 shows the list of 22 possible EVCs considered under Freshwater Lake Aggregate (EVC 718).

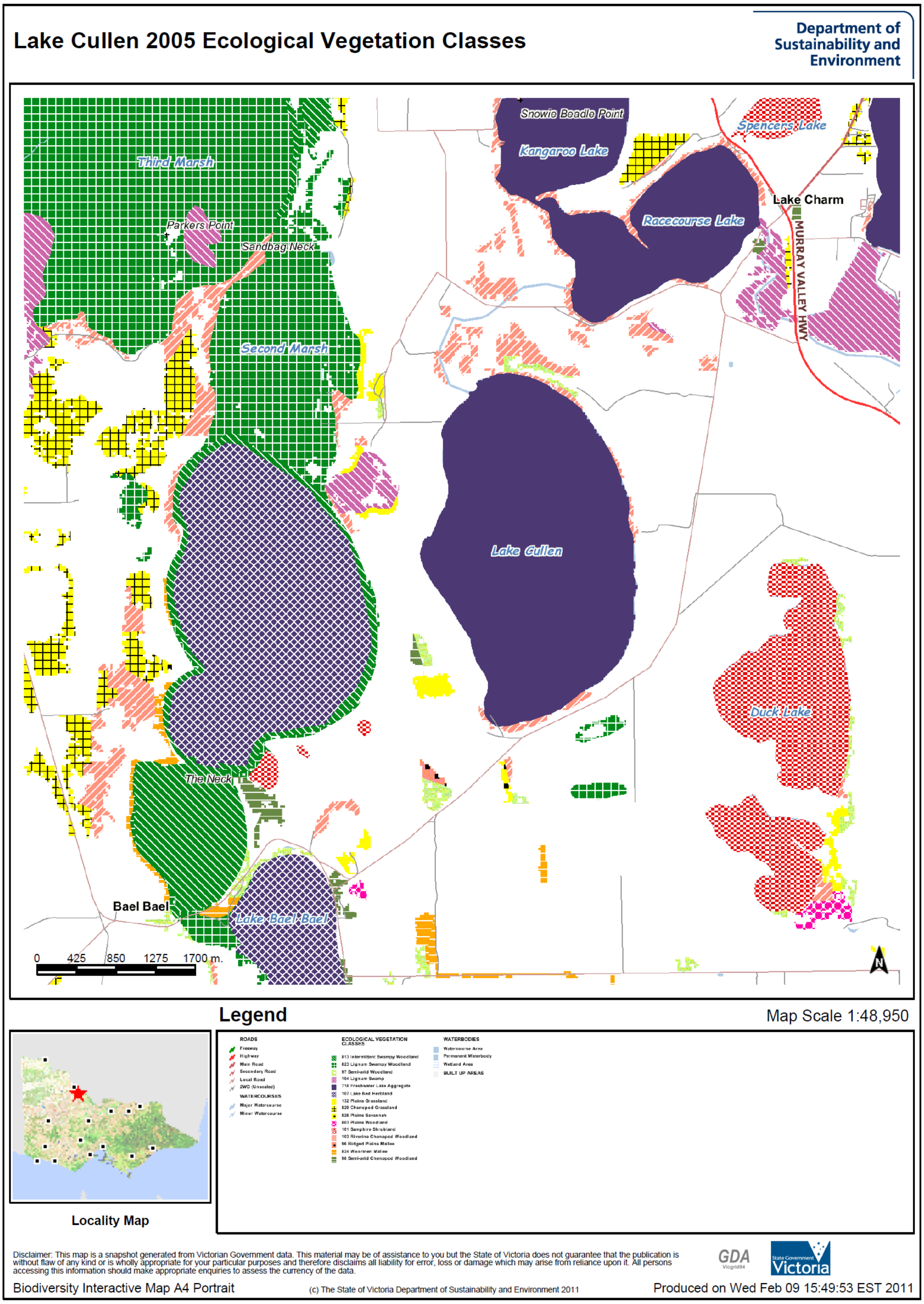

Figure 12. EVCs recorded at Lake Cullen, and their location

Table 14. Main component EVCs that are considered under the Freshwater Lake Aggregate.

Aggregate EVC mapping unit no.	Aggregate EVC mapping unit	EVC No.	Main component EVCs
718	Freshwater Lake Aggregate	11	Coastal Lagoon Wetland
718	Freshwater Lake Aggregate	107	Lake Bed Herbland (Mallee)
718	Freshwater Lake Aggregate	291	Cane Grass Wetland
718	Freshwater Lake Aggregate	308	Aquatic Sedgeland
718	Freshwater Lake Aggregate	334	Billabong Wetland
718	Freshwater Lake Aggregate	602	Cane Grass Wetland/Aquatic Herbland Complex
718	Freshwater Lake Aggregate	647	Plains Sedgy Wetland
718	Freshwater Lake Aggregate	651	Plains Swampy Woodland
718	Freshwater Lake Aggregate	653	Aquatic Herbland
718	Freshwater Lake Aggregate	755	Plains Grassy Wetland/Aquatic Herbland Complex
718	Freshwater Lake Aggregate	767	Plains Grassy Wetland/Brackish Herbland Complex
718	Freshwater Lake Aggregate	806	Alluvial Plains Semi-arid Grassland (Mallee)
718	Freshwater Lake Aggregate	809	Floodplain Grassy Wetland (minor)
718	Freshwater Lake Aggregate	810	Floodway Pond Herbland
718	Freshwater Lake Aggregate	819	Spike-sedge Wetland
718	Freshwater Lake Aggregate	821	Tall Marsh (including Reed Swamp)
718	Freshwater Lake Aggregate	857	Stony Rises Pond Aggregate
718	Freshwater Lake Aggregate	918	Submerged Aquatic Herbland
718	Freshwater Lake Aggregate	920	Sweet Grass Wetland
718	Freshwater Lake Aggregate	932	Wet Verge Sedgeland
718	Freshwater Lake Aggregate	949	Dwarf Floating Aquatic Herbland
718	Freshwater Lake Aggregate	963	Sedge Wetland/Aquatic Sedgeland Complex

Note: the EVCs listed in Table 14 are those listed in generic Freshwater Lake Aggregates. To determine which of these are present at Lake Cullen, detailed EVC mapping will need to be completed.

Department of Sustainability and Environment

EVC/Bioregion Benchmark for Vegetation Quality Assessment

Victorian Riverina bioregion

EVC 103: Riverine Chenopod Woodland

Description:
Eucalypt woodland to 15 m tall with a diverse shrubby and grassy understorey occurring on most elevated riverine terraces. Confined to heavy clay soils on higher level terraces within or on the margins of riverine floodplains (or former floodplains), naturally subject to only extremely infrequent incidental shallow flooding from major events if at all flooded.

Large trees:

Species	DBH(cm)	#/ha
Eucalyptus spp.	50 cm	5/ha

Tree Canopy Cover:

%cover	Character Species	Common Name
10%	*Eucalyptus largiflorens*	Black Box

Understorey:

Life form	#Spp	%Cover	LF code
Immature Canopy Tree		5%	IT
Understorey Tree or Large Shrub	1	5%	T
Medium Shrub	3	30%	MS
Small Shrub	5	25%	SS
Prostrate Shrub	1	1%	PS
Medium Herb	5	5%	MH
Small or Prostrate Herb*	5	10%	SH
Medium to Small Tufted Graminoid	2	5%	MTG
Soil Crust	na	10%	S/C
* Largely seasonal life form			
Total understorey projective foliage cover		**65%**	

LF Code	Species typical of at least part of EVC range	Common Name
T	*Acacia stenophylla*	River Coobah
MS	*Atriplex nummularia*	Old-man Saltbush
MS	*Chenopodium nitrariaceum*	Nitre Goosefoot
MS	*Eremophila divaricata* ssp. *divaricata*	Spreading Emu-bush
SS	*Sclerolaena tricuspis*	Streaked Copperburr
SS	*Enchylaena tomentosa* var. *tomentosa*	Ruby Saltbush
SS	*Atriplex lindleyi*	Flat-top Saltbush
SS	*Rhagodia spinescens*	Hedge Saltbush
PS	*Sclerochlamys brachyptera*	Short-wing Saltbush
MH	*Einadia nutans* ssp. *nutans*	Nodding Saltbush
MH	*Calocephalus sonderi*	Pale Beauty-heads
MH	*Senecio glossanthus*	Slender Groundsel
MH	*Brachyscome lineariloba*	Hard-head Daisy
SH	*Disphyma crassifolium* ssp. *clavellatum*	Rounded Noon-flower
SH	*Maireana pentagona*	Hairy Bluebush

Recruitment:
Continuous

Organic Litter:
5% cover

Logs:
5 m/0.1 ha.

EVC 103: Riverine Chenopod Woodland - Victorian Riverina bioregion

Weediness:

LF Code	Typical Weed Species	Common Name	Invasive	Impact
T	*Olea europaea* subsp. *europaea*	Olive	low	high
MS	*Lycium ferocissimum*	Boxthorn	low	high
LH	*Sisymbrium erysimoides*	Smooth Mustard	high	high
LH	*Critesion* spp.	Barley-grass	high	low
LH	*Gazania linearis*	Gazania	high	high
LH	*Opuntia* spp.	Prickly Pear	low	high
LH	*Sisymbrium irio*	London Mustard	high	high
LH	*Psilocaulon granulicaule*	Noon-flower	high	high
MH	*Limonium sinuatum*	Notch-leaf Sea-lavender	high	high
MH	*Limonium lobatum*	Winged Sea-lavender	high	high
MH	*Trifolium arvense* var. *arvense*	Hare's-foot Clover	high	low
MH	*Mesembryanthemum nodiflora*	Ice-plant	high	high
MH	*Carrichtera annua*	Ward's Weed	high	high
MH	*Marrubium vulgare*	Horehound	high	high
MH	*Carpobrotus aequilaterus*	Angled Pigface	low	high
MH	*Silene apetala* var. *apetala*	Sand Catchfly	high	low
MH	*Medicago* spp.	Medic	high	low
MH	*Oxalis pes-caprae*	Soursob	high	high
MH	*Silene gallica*	French Catchfly	high	low
MH	*Silene nocturna*	Mediterranean Catchfly	high	low
SH	*Mesembryanthemum crystallinum*	Common Ice-plant	high	high
MTG	*Vulpia bromoides*	Squirrel-tail Fescue	high	high
MTG	*Lolium rigidum*	Wimmera Rye-grass	high	low
MTG	*Asphodelus fistulosus*	Onion Weed	high	high
MNG	*Bromus rubens*	Red Brome	high	high
MNG	*Vulpia myuros*	Rat's-tail Fescue	high	low
MNG	*Bromus* spp.	Brome	high	high
MNG	*Schismus barbatus*	Arabian Grass	high	low
SC	*Asparagus asparagoides*	Bridal Creeper	high	high

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For more information contact: Customer Service Centre, 136 186

www.dse.vic.gov.au

Department of Sustainability and Environment

EVC/Bioregion Benchmark for Vegetation Quality Assessment

Victorian Riverina bioregion

EVC 97: Semi-arid Woodland

Description:
Non-eucalypt woodland or open forest to 12 m tall, of low rainfall areas. Occurs in a range of somewhat elevated positions not subject to flooding or inundation. The surface soils are typically light textured loamy sands or sandy loams.

Large trees:

Species	DBH(cm)	#/ha
Allocasuarina spp.	40 cm	20 / ha
Callitris spp.	40 cm	
Myoporum platycarpum	35 cm	

Tree Canopy Cover:

% cover	Character Species	Common Name
20%	*Allocasuarina luehmannii*	Buloke
	Callitris gracilis ssp. *murrayensis*	Slender Cypress-pine
	Myoporum platycarpum	Sugarwood

Understorey:

Life form	#Spp	%Cover	LF code
Immature Canopy Tree		5%	IT
Medium Shrub	5	15%	MS
Small Shrub	5	20%	SS
Large Herb*	2	5%	LH
Medium Herb*	7	5%	MH
Small or Prostrate Herb*	2	5%	SH
Medium to Small Tufted Graminoid	2	10%	MTG
Medium to Tiny Non-tufted Graminoid	1	1%	MNG
Bryophytes/Lichens	na	10%	BL
Soil Crust	na	20%	S/C

* Largely seasonal life form

Total understorey projective foliage cover **75%**

LF Code	Species typical of at least part of EVC range	Common Name
MS	*Alectryon oleifolius* ssp. *canescens*	Cattle Bush
MS	*Acacia oswaldii*	Umbrella Wattle
MS	*Hakea tephrosperma*	Hooked Needlewood
MS	*Hakea leucoptera* ssp. *leucoptera*	Silver Needlewood
SS	*Enchylaena tomentosa* var. *tomentosa*	Ruby Saltbush
SS	*Sclerolaena diacantha*	Grey Copperburr
SS	*Olearia pimeleoides*	Pimelea Daisy-bush
SS	*Rhagodia spinescens*	Hedge Saltbush
MH	*Einadia nutans* ssp. *nutans*	Nodding Saltbush
MH	*Vittadinia dissecta* s.l.	Dissected New Holland Daisy
MH	*Calandrinia eremaea*	Small Purslane
MH	*Crassula colorata*	Dense Crassula
SH	*Actinobole uliginosum*	Flannel Cudweed
MTG	*Austrodanthonia caespitosa*	Common Wallaby-grass
MTG	*Austrostipa* spp.	Spear-grass
MNG	*Austrostipa elegantissima*	Feather Spear-grass

Victoria The Place To Be

EVC 97: Semi-arid Woodland - Victorian Riverina bioregion

Recruitment:
Continuous

Organic Litter:
20% cover

Logs:
20 m/0.1 ha.

Weediness:

LF Code	Typical Weed Species	Common Name	Invasive	Impact
LH	*Brassica tournefortii*	Mediterranean Turnip	high	high
LH	*Reichardia tingitana*	Reichardia	high	low
MH	*Silene* spp.	Catchfly	high	high
SH	*Medicago minima*	Little Medic	high	high
MTG	*Schismus barbatus*	Arabian Grass	high	high
MTG	*Pentaschistis airoides* ssp. *airoides*	False Hair-grass	high	high
MNG	*Bromus rubens*	Red Brome	high	high
MNG	*Vulpia myuros*	Rat's-tail Fescue	high	high
MNG	*Critesion murinum* subsp. *glaucum*	Blue Barley-grass	high	high
SC	*Asparagus asparagoides*	Bridal Creeper	high	high

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APPENDIX 5: RECENT WATERING HISTORY

Wetland		1990-1991	1991-1992	1992-1993	1993-1994	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001
Lake Cullen	Status *	W	W	W	W-D	D	W	W	W	W-D	D	W
	Water source #	C	C	C	-	-	F	E	E	-	-	E
	Volume delivered (if available)	U	U	U	-	-	U	U	U	-	-	10,026
	Comment	Water reached 73m AHD in 1988, and the wetland retained water from two top up events (to ~72m AHD and ~71.5m AHD) during this time.					Water height varied between ~72m AHD and ~71.5m AHD during this period, before drying completely.					Water delivery delayed due to minor Loddon flood (water delivered 4/12/00 – 10/2/01); delivery rate constrained due to irrigation demand; high evaporation losses occurred (up to 50ML/day); water level reached 71.48m AHD (16cm below target level).

Wetland		2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
Lake Cullen	Status [1]	W-D	D	D	D	D	W	W-D	D	D	W	W	W-D
	Water source [2]	-	-	-	-	-	E	-	-	-	E,T,F	-	-
	Volume delivered (if available)	-	-	-	-	-	7,998	-	-	-	15,659	-	-
	Comment										Water provided in association with Loddon system floods between September 2010 and January/February 2011. Water level reached 73m AHD in January 2011. Additional 4.5GL was provided in late January – early February G-MW as flood mitigation.		

[1] Water present / dry wetland
[2] Environmental water allocation / Torrumbarry irrigation system / Flood mitigation / Unknown / Channel outfall / na
Source: Joyce and Turner in DSE (2010); R. Stanton, G-MW; DSE (2001); Mcumber (2001).

Appendix 6: Index of Wetland Condition Method

Sub-indices

The table below shows what is measured for each of the six sub-indices and how each sub-index is scored. The sections below describe this in greater detail. Further information can be found on the IWC website (www.dse.vic.gov.au/iwc).

IWC sub-indices and measures

Sub-index	What is measured	How it is scored
Wetland catchment	The intensity of the land use within 250 metres of the wetland	The more intensive the landuse the lower the score
	The width of the native vegetation surrounding the wetland and whether it is a continuous zone or fragmented	The wider the zone and more continuous the zone, the higher the score
Physical form	Whether the size of the wetland has been reduced from its estimated pre-European settlement size	A reduction in area results in a lowering of the score
	The percentage of the wetland bed which has been excavated or filled	The greater the percentage of wetland bed modified, the lower the score
Hydrology	Whether the wetland's water regime (i.e. the timing, frequency of filling and duration of flooding) has been changed by human activities	The more severe the impacts on the water regime, the lower the score
Water properties	Whether activities and impacts such as grazing and fertilizer run-off that would lead to an input of nutrients to the wetland are present	The more activities present, the lower the score
	Whether the wetland has become more saline or in the case of a naturally salty wetland, whether it has become more fresh	An increase in salinity for a fresh wetland lowers the score or a decrease in salinity of a naturally salty wetland lowers the score
Soils	The percentage and severity of wetland soil disturbance from human, feral animals or stock activities	The more soil disturbance and the more severe it is, the lower the score
Biota	The diversity, health and weediness of the native wetland vegetation	The lower the diversity and poorer health of native wetland vegetation, the lower the score
		The increased degree of weediness in the native wetland vegetation, the lower the score

Scoring method

Each subindex is given a score between 0 and 20 based on the assessment of a number of measures as outline above. Weightings are then applied to the scores as tabulated below. The maximum possible total score for a wetland is 38.4. For ease of reporting, all scores are normalised to an integer score out of 10 (i.e. divide the total score by 38.4, multiply by 10 and round to the nearest whole number).

IWC sub-index	Weight
Biota	0.73
Wetland catchment	0.26
Water properties	0.47
Hydrology	0.31
Physical form	0.08
Soils	0.07

Five wetland condition categories have been assigned to the sub-index scores and total IWC scores as tabulated over page. The five category approach is consistent with the number of categories used in other condition indices such as the Index of Stream Condition. Biota sub-index score categories were determined by expert opinion and differ to those of the other sub-indices.

Non-biota sub-index score range	Biota sub-index score range	Total score range	Wetland condition category
0-4	0-8	0-2	Very poor
5-8	9-13	3-4	Poor
9-12	14-16	5-6	Moderate
13-16	17-18	7-8	Good
16-20	19-20	9-10	Excellent
N/A	N/A	N/A	Insufficient data

APPENDIX 7: WORKSHOP OUTCOMES

Key discussion points from the local technical group workshop held on 16 June 2011 are provided below. Members of the local technical group present at the workshop were Mark Tscharke (Parks Victoria), Shelley Heron (Kellogg Brown and Root), Emer Campbell (North Central Catchment Management Authority) and Ross Stanton (Goulburn-Murray Water).

Lake Cullen overview and recommendations:

- Lake Cullen is considered to be a highly productive wetland for waterbird use.
- Historically the community was against filling the wetland above about 73m AHD due to flooding on private land through the lower section of the wetland (at 74m AHD, there may be some localised flooding and if this was proposed, a targeted community consultation process should be undertaken). The recommendations provided for environmental water management at this stage does not target inundation above 73m AHD.
- The group does not want to have a permanent water regime for this wetland, an intermittent wetland is more preferable (but need to consider the Limits of Acceptable Change as this is part of the Kerang Wetlands Ramsar Site).
- There are two main ecological objectives for the wetland – one focusing on the submerged aquatics, and the second focusing on the Black Box community surrounding the wetland (at the higher level in the wetland ~73m AHD).
- Current flood reached greater than 73m AHD, and has inundated some Black Box trees. While no recruitment has been observed yet, the trees have been flowering.
- The *Ruppia* has responded very well in this flood event with the species being prevalent through the wetland margins.
- There seems to be more of a reliance on inundation of Black Box to achieve recruitment, as opposed to watering the area surrounding the trees (without inundation as such) which has outcomes for improved condition.
- The lack of obvious recruitment may be due to browsing by rabbits, or they may have not grown yet. Weeds/thick vegetation (including grasses) in this wetland may also be an issue for Black Box regeneration as they would have to come up in between the existing vegetation.
- Impact of rabbits and weeds on potential for regeneration should not be underestimated, and should be investigated at Lake Cullen (e.g. undertaking a rabbit exclusion plot).
- The Black Box community is considered a reasonable ecological objective to target, but should have associated complementary works undertaken in association with environmental water delivery.
- The aquatic vegetation community is also an important ecological component to target as this will be the basis for the high productivity of the wetland for waterbird feeding.
- Salinity is considered to be a major consideration for the management of this wetland, and the potential for salt exporting from the wetland to other important environments (e.g. Lake Bael Bael and the Avoca Marshes) needs to be considered during every proposal for environmental water use.
- Need to manage the wetland with the knowledge that it is a saline wetland, but need to ensure that there is sufficient salt pushed downwards during events so that we are not just promoting an increasing saline wetland over time.
- Need to consider the upper limits of salinity tolerances of *Ruppia* being a target species, and what are the requirements for it to 'bounce back' next time it is flooded – these questions need to be investigated further.
- Long-term monitoring data available for the wetland water quality is very patchy and unfortunately could not be used with any great certainty.
- It may also be worth investigating which species of *Ruppia* are present in Lake Cullen as different

species will have different salinity requirements.

- The group discussed whether there would be benefits of filling the wetland and then topping it up, or allow only one delivery and then allow the wetland to draw down completely.
- The group felt that with a filling of the wetland to 73m AHD, there would be no need to provide an additional top up. If the wetland is only filled to about 72m AHD, there may be an opportunity to top up the wetland which should be considered to prolong the duration of flooding if required (particularly targeting the *Ruppia*).
- Other aquatic species such as *Potamogeton* spp. and *Lepilaena* spp. also need to be considered alongside *Ruppia* as these other species are also important.
- The group supported the environmental water regime provided below:

Year	Optimal watering regime
One	Fill wetland to 73m AHD in spring.
Two	Allow wetland to drawdown to ~72m AHD.
Three	Allow wetland to drawdown completely.
Four	Allow wetland to remain dry.
Five	Allow wetland to remain dry.
Six	Allow wetland to remain dry.
Seven	Fill wetland to ~72m AHD in spring.
Eight	Provide top up (dependent on catchment conditions).
Nine	Allow wetland to drawdown.
Ten	Allow wetland to remain dry.

APPENDIX 8: CAPACITY TABLE

Lake Cullen Rating Table

Gauge Heights in metres

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
70.8	1,410	1,460	1,510	1,560	1,610	1,660	1,710	1,760	1,810	1,860
70.9	1,910	1,960	2,010	2,060	2,110	2,160	2,210	2,260	2,310	2,360
71.0	2,410	2,460	2,510	2,560	2,610	2,660	2,700	2,750	2,800	2,850
71.1	2,900	2,950	3,000	3,050	3,100	3,150	3,200	3,250	3,300	3,350
71.2	3,400	3,450	3,500	3,540	3,590	3,640	3,690	3,740	3,790	3,840
71.3	3,890	3,940	3,990	4,040	4,080	4,130	4,180	4,230	4,280	4,330
71.4	4,380	4,430	4,490	4,540	4,590	4,640	4,690	4,740	4,790	4,850
71.5	4,900	4,950	5,000	5,060	5,110	5,160	5,220	5,270	5,320	5,380
71.6	5,430	5,480	5,540	5,590	5,650	5,700	5,760	5,810	5,870	5,920
71.7	5,970	6,030	6,080	6,140	6,190	6,250	6,300	6,360	6,410	6,470
71.8	6,520	6,570	6,630	6,680	6,740	6,790	6,850	6,900	6,950	7,010
71.9	7,060	7,120	7,170	7,230	7,280	7,340	7,390	7,440	7,500	7,550
72.0	7,610	7,660	7,720	7,770	7,830	7,890	7,940	8,000	8,050	8,110
72.1	8,170	8,220	8,280	8,330	8,390	8,450	8,500	8,560	8,620	8,680
72.2	8,730	8,790	8,850	8,910	8,960	9,020	9,080	9,140	9,190	9,250
72.3	9,310	9,370	9,420	9,480	9,540	9,600	9,660	9,710	9,770	9,830
72.4	9,890	9,940	10,000	10,060	10,120	10,170	10,230	10,290	10,350	10,400
72.5	10,460	10,520	10,580	10,640	10,690	10,750	10,810	10,870	10,930	10,980
72.6	11,040	11,100	11,160	11,220	11,270	11,330	11,390	11,450	11,510	11,570
72.7	11,630	11,690	11,750	11,810	11,870	11,930	11,990	12,050	12,110	12,170
72.8	12,230	12,290	12,350	12,410	12,470	12,530	12,590	12,650	12,710	12,770
72.9	12,830	12,890	12,950	13,010	13,070	13,130	13,190	13,250	13,310	13,370
73.0	13,440	13,500	13,560	13,620	13,680	13,740	13,800	13,860	13,920	13,980
73.1	14,040	14,100	14,160	14,220	14,280	14,340	14,400	14,460	14,520	14,580
73.2	14,640	14,700	14,760	14,830	14,890	14,950	15,010	15,070	15,130	15,190
73.3	15,250	15,310	15,380	15,440	15,500	15,650	15,620	15,690	15,750	15,810
73.4	15,870	15,930	16,000	16,060	16,120	16,180	16,250	16,310	16,370	16,430
73.5	16,500	16,560	16,620	16,690	16,750	16,810	16,870	16,940	17,000	17,060
73.6	17,120	17,180	17,250	17,310	17,370	17,430	17,500	17,560	17,620	17,680
73.7	17,750	17,810	17,870	17,930	18,000	18,060	18,120	18,180	18,240	18,310
73.8	18,370	18,430	18,490	18,560	18,620	18,680	18,740	18,810	18,870	18,930

APPENDIX 9: TARGETED COMMUNITY CONSULTATION – SUMMARY REPORT

Method

Community Consultation for the Lake Cullen Environmental Water Management Plan (EWMP) has been undertaken via telephone interviews during the week of the 8th April 2013. To finalise the EWMP local knowledge and input was required. The interviews were focussed on collecting information from the community in relation to the wetland, its values and the draft environmental watering regime recommendations. The information collected has been summarised below and will be used to update, revise and complete the plan. The community consultation component of developing the plan is essential in ensuring that the plan is meaningful and robust into the future.

Community representatives interviewed

Charlie Gillingham, Mark Daley, Shane Cummins, Simon Starr, Stuart Simms and Tom Lowe

1. Wetland information (general)

- When the wetland is dry it is a dust bowl. The north-west winds escalate the issue, living 4 kilometers away and looking south towards the wetland it looked like there was a bush fire but it was actually Lake Cullen. Need to consider this issue when looking at drying out the Kerang Lakes (G-MW bypass project), dust will impact on towns, houses and roads, therefore being a health and safety hazard.
- Lake Cullen was part of the irrigation system, however as only small volumes were being taken out of the wetland it became more saline over time. Forty years ago a channel was dug around the wetland and the wetland eventually dried out.
- Dust blowing is a real negative, Brown Bothers Vineyard have complained in the past.
- A real issue for this lake has been the rising salinity levels due to evaporation of saline water and groundwater intrusion.
- Prior to the establishment of the Torrumbarry Irrigation System the wetland was a freshwater lake. Once it was abandoned as an irrigation carrier it became a saline wetland.
- Lake Cullen was a freshwater wetland that would have been flushed via flood events (part of a flood corridor – Lake Meran and Lake Elizabeth).
- Water salinity in the lake is a problem, it is also an issue for the surrounding environment.
- Lake Cullen was naturally an intermittent wetland (lunette on the eats side of the wetland), in 1925 permanent water was supplied to the wetland. This appendix to the Kerang Lakes system eventually became saline.

2. Wetland values

Environmental

- Cullens Lake is a highly valued wetland, its main value is when it has water and provides important feeding and resting area for waterbirds.
- Wetland has noxious weeds and rabbit problems.
- Birds are good at the wetland, therefore the food chain is working.
- Professor John Scarred did a study into the Ducks, Swans and Geese of the world in the 1960s and counted 1300 Blue Billed Ducks in the Kerang Lakes, 500 Musk Ducks and 270 Freckled Ducks at Lake Cullen.

- When the wetland was permanent large Murray Cod existed, fishing competitions were a popular occurrence at the wetland.
- Coots, Ducks, Waders, including the international Sharp-tailed Sandpiper use to be in very high numbers at the wetland.
- Dr Sue Briggs has done work on River Red Gum Swamps on the Lachlan River and assessed the nutrients locked up in the wetlands. It was found that the utilisation of nutrients did not occur until drying the wetland and re-flooding.
- In the recent floods there was a big population of Ducks, Coots, Swans, Avocets, small Grebes and Stilts.
- Would love to see Duck Hunting stopped.
- Reeds at the outfall (some leakage from the structure maintains an aquatic assemblage) is seen to be of benefit and providing refuge for native fauna (e.g. Frogs).
- Lake Cullen was a tremendous refuge for Migratory birds, it is still a good refuge for water birds in its semi saline condition.

Cultural Heritage

- The northern plains have been embraced as home for many thousands of years by the first peoples.

Recreation

- Historically, there used to be fishing competitions at Lake Cullen (Murray Cod).
- Duck hunting is a popular activity at this wetland when it has water in it.
- Some community members would like to see duck hunting stopped.

3. Draft environmental watering regime

- North end of the entry point, the boards still leak water into the wetland and this trickle is maintaining an aquatic plant assemblage. Crakes, Bitterns and frogs use this drought refuge.
- It the regulator that delivers water to the wetland is upgraded, some additional water would be required to maintain the vegetation that relies on the current leakage.
- Reeds at the outfall are important, currently maintained to due to leaking drop boards in the structure.
- 2010/11 Floods didn't get to the Black Box trees (private fences).
- The wetland was too full for too long approximately 15 years ago. Fluctuations in the wetland were due to irrigation practices.
- Don't want the wetland filled all the way to full supply, you will lose birds (e.g. Stilts).
- Stilts and Plovers will not turn up in 20 metres of water, you need a buffer of salty dirt.
- Need to consider the water pressure to the Avoca Marshes and Lake Cullen. What we do to one wetland will affect another.
- You need twice as much water now to get the same result due to the water table now being at 5 metres. For example: Two year dams are now only lasting eight months.
- The recommended watering regime in the plan will not put pressure onto the Avoca Marshes.
- Need to be careful with the level you fill the wetland to, for example not drowning the Black Box (they will not stand in water like River Red Gums do).
- The two in ten year watering regime is probably adequate, the wetland is about dry now. Need to let the wetland dry right out, when watering need to add one metre of water quickly as this will force salinity to move to Duck Lake (need to create that pressure to enable this movement). The bed of Duck Lake is one metre lower than Cullens Lake.