LAKE LEAGHUR
ENVIRONMENTAL WATERING PLAN

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

PREPARED FOR THE
GOULBURN-MURRAY WATER CONNECTIONS PROJECT

GOULBURN-MURRAY WATER

Version 9, June 2015

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Front cover photo: Lake Leaghur 2009, North Central CMA

The Lake Leaghur Environmental Watering Plan is a working document, compiled from the best available information. It will be subject to revision in the future as new information becomes available.

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Management agreement

Where consistent with the obligations and responsibilities of the respective agencies, I agree to the management actions and responsibilities as described in this EWP.

NCCMA representative signature:

Print name: EMER CAMPBELL

Date: 24/10/2015

Parks Victoria representative signature:

Print name: 1/12/2015

Date: Daniel McLaughlin

GMW representative signature:

Print name: Ross Plunkett

Date: 22-12-2015

EXECUTIVE SUMMARY

The Lake Leaghur Environmental Watering Plan (EWP) documents the approach to mitigating the potential impacts of the Goulburn-Murray Water Connections Project (GMW Connections Project) due to significant reductions in channel outfalls to the wetland.

The following components are the primary means by which the commitment of no net environmental loss for Lake Leaghur will be achieved for the GMW Connections Project. The main conclusions are summarised below.

Defining the environmental values of Lake Leaghur

Lake Leaghur is a bioregionally important wetland occupying 59 ha of a 79 ha Crown land reserve. It supports significant vegetation communities, flora and fauna species, and provides important breeding habitat.

A water management goal has been developed in light of the current condition of Lake Leaghur, the ecological values the lake supports and potential risk factors that need to be managed.

Lake Leaghur water management goal:
Support a diversity of flora and fauna typical of a deep freshwater marsh, in particular providing key waterbird habitat (breeding and nesting) within a Red Gum Swamp (EVC 292).

Defining the water required to protect the environmental values

A number of ecological objectives are identified and are based on historic and current wetland condition, and water dependent environmental values (habitat, species/communities and processes). The hydrological requirements for each of these objectives were identified, and a desired water regime required to achieve the water management goal is described.

Wetland water regime:
Fill to FSL (1.35 m at 85.85 m AHD) to inundate River Red Gum Swamp (EVC 292) one in three years. Allow natural draw-down over 18 months. Enable variability in depth (flood extent) to facilitate germination of River Red Gum seedlings across the wetland. Ensure water inundates Cane Grass (*Eragrostis australasica*) population for one – six months, one in three years.

The volume of water required to provide the desired water regime for Lake Leaghur has been assessed using a simplified version of the Savings at Wetlands from Evapotranspiration daily Time-Series (SWET) model.

The total volume required to fill the wetland one in three years is 1,319 ML. The maximum volume ever likely to be required in any one year (i.e. the 95% percentile mean annual volume) is 1,377 ML/year.

Assessment of mitigation water requirement

Mitigation water is defined as the volume of water required to ensure no net impacts on high environmental values in waterways and wetlands resulting from GMW Connections Project. Mitigation water may be required where both:

- the waterway or wetland has received incidental irrigation water beneficial and material to high environmental values before the modernisation associated with the Connections Project, and
- where a similar contribution is assessed as being a beneficial part of a water regime which is proposed to continue to support high environmental values following the modernisation.

The assessment for the requirement of mitigation water demonstrates that the **incidental outfall water provides significant benefit to Lake Leaghur and mitigation water is warranted**. In particular, if the volume of outfall water was to be reduced or removed, additional water would need to be secured to maintain the wetland's environmental values (specifically waterbird habitat).

The incidental water at the origin was 174 ML in the baseline year and the annualised baseline mitigation water volume was calculated as 58 ML. The Mitigation Water Commitment

for Lake Leaghur is 33%. This will be used to calculate the interim mitigation water share of any annually calculated water savings.

Potential risks, limiting factors and adverse impacts associated with the recommended water regime

A number of potential risks, limiting factors and adverse impacts are identified that may result from the provision of mitigation water as a portion of the recommended water regime. Currently an adjoining landholder has an opportunistic diversion licence which allows the extraction of 170 ML per year from Lake Leaghur. This licence presents a risk to achieving the identified objectives and goal for the wetland. It is recommended that the conditions of the diversion licence are reviewed and options for alternative supply are investigated.

Infrastructure requirements

Currently, the automated regulator and delivery channel to Lake Leaghur have a capacity of 60 ML/day which equates to a minimum of 11 days to fill the wetland from empty, assuming that no losses occur and operating at full capacity. The current delivery infrastructure is considered adequate to deliver the desired water regime and no infrastructure upgrades are recommended as part of GMW Connections Project.

Lake Leaghur is currently receiving water from the channel 2/2 supply point, however, plans are being developed to provide an alternative supply point, due to rationalisation of channel 2/2. GMW Connections Project will ensure that a suitable alternative supply point will be provided including a reported capacity of 60 ML/day (or an agreed delivery rate).

Adaptive management framework

An adaptive management approach (assess, design, implement, monitor, review and adjust) is incorporated into the EWP to ensure that it is responsive to changing conditions.

The Lake Leaghur EWP has been developed using the best available information. However, a number of information and knowledge gaps are identified in the document which may impact recommendations and/or information presented. These knowledge gaps will be addressed as part of the adaptive management approach outlined within the EWP as additional information becomes available.

Governance arrangements

A summary of the roles and responsibilities (e.g. land manager, environmental water manager, and system operator) relating to the development and implementation of EWPs are defined. A framework for operational management outlining the relevant roles and responsibilities has also been developed to describe the annual decision-making process required to coordinate the implementation of the desired water regime for Lake Leaghur.

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ACKNOWLEDGEMENTS

The information contained in the Lake Leaghur Environmental Watering Plan (EWP) of July 2010 (Version 8) was sourced from a variety of reports and field inspections and from individual knowledge and expertise.

The North Central Catchment Management Authority (CMA) acknowledges the assistance of the following people in preparing this EWP.

- Rob O'Brien (Department of Primary Industries)
- Cherie Campbell, Caitlin Johns, Christine Reid and Dr Todd Wallace (Murray-Darling Freshwater Research Centre)
- Geoff Sainty (Sainty and Associates)
- Shelley Heron (Kellogg Brown and Root)
- Mark Reid (DPI Primary Industries Research Victoria)
- Andrea Joyce (Department of Sustainability and Environment)
- Mark Tscharke (Parks Victoria)
- Paul Haw and Rod Stringer (community representatives)
- Ian Lanyon, Murray Lanyon, Graham Lehmann, Ken Buchanan, Ron Bramley (landholders)
- Laurence Cameron (GMW)
- Pat Feehan (Feehan Consulting)
- Ross Plunkett, Chris Solum and Mark Paganini (NVIRP)
- NVIRP Technical Advisory Committee (listed in Appendix A, Table A1)
- Wetland workshop attendees (listed in Appendix A, Table A2)
- Graham Hall, Bridie Velik-Lord, Rebecca Horsburgh, Peter McRostie, Lyndall Rowley (North Central CMA).

The EWP was updated in March 2015 (Version 9), in consultation and agreement with:

- Emer Campbell and Bree Bisset (North Central CMA)
- Andrea Keleher and Bruce Mathers (Department of Environment, Land, Water and Planning)
- Goulburn-Murray Water Connections Project Environmental Technical Advisory Committee
- Chris Solum, Ross Plunkett and Ed Thomas (Goulburn-Murray Water).

ABBREVIATIONS

AAV	Aboriginal Affairs Victoria
AVW	Atlas of Victorian Wildlife
ANCA	Australian Nature Conservation Agency
AUSRIVAS	Australian River Assessment System
BE	Bulk Entitlement
BONN	Convention on the Conservation of Migratory Species of Wild Animals
CAMBA	China–Australia Migratory Bird Agreement
CMA	Catchment Management Authority
DCFL	Department of Conservation Forests and Lands
DEDJTR	Department of Economic Development, Jobs, Transport and Resources
DELWP	Department of Environment, Land, Water and Planning
DEWHA	Department of Environment, Water, Heritage and the Arts
DPCD	Department of Planning and Community Development
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
EES	Environmental Effects Statement
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
ERP	Expert Review Panel
EVC	Ecological Vegetation Class
EWH	Environmental Water Holder
EWP	Environmental Watering Plan
FFG	*Flora and Fauna Guarantee Act 1988*
FSL	Full Supply Level
GIS	Geographic Information Systems
GL	Gigalitre (one billion litres)
GMID	Goulburn Murray Irrigation District
GMW	Goulburn–Murray Water
JAMBA	Japan–Australia Migratory Bird Agreement
LTCE	Long-term Cap Equivalent
MDFRC	Murray-Darling Freshwater Research Centre
MNES	Matters of National Environmental Significance
North Central CMA	North Central Catchment Management Authority
NVIRP	Northern Victoria Irrigation Renewal Project
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement
SEMP	Site Environmental Management Plan
TAC	Technical Advisory Committee
TIS	Torrumbarry Irrigation System

VEAC	Victorian Environmental Assessment Council
VROTS	Victorian Rare or Threatened Species
WCMF	Water Change Management Framework

1. Goulburn-Murray Water Connections Project

The Goulburn-Murray Water Connections Project (GMW Connections Project), formerly Northern Victoria Irrigation Renewal Project (NVIRP) is a $2 billion works program to upgrade ageing irrigation infrastructure across the Goulburn-Murray Irrigation District (GMID) and to save water lost through leakage, seepage, evaporation and system inefficiencies. Works will include lining and automating channels, building pipelines and installing new, modern metering technology. These combined works will improve the irrigation system's delivery efficiency and recover a long-term average of 429 GL of water per year.

The GMID uses a number of natural carriers, rivers, lakes and wetlands for both storage and conveyance of water. While the water savings generated are from 'losses' within the irrigation system, in some cases the losses from the pre-GMW Connections Project operating regime provides incidental benefits to environmental assets (SKM 2008).

1.1. Decision under the Environmental Effects Act 1978

On the 14 April 2009, the Victorian Minister for Planning made a decision that an Environment Effects Statement (EES) was not required for the NVIRP project, now GMW Connections Project, although this decision was subject to several conditions (DPCD 2009). The conditions that apply to the protection of wetlands and waterways include:

Condition 3: *development of a framework for protection of aquatic and riparian ecological values through management of water allocations and flows within the modified GMID system to the satisfaction of the Minister for Water*

GMW Connections Project has developed a Water Change Management Framework (GMW 2013) in response to this condition. The framework outlines the processes and methods for preparing Environmental Watering Plans (EWPs) to mitigate potential impacts on wetlands and waterways at risk from the implementation of the GMW Connections Project through adaptive water management (GMW 2013).

Condition 5: *Environmental Watering Plans are required for 'at risk' waterways and wetlands before operation of the relevant NVIRP work commences*

1.2. Decision under the Environment Protection and Biodiversity Conservation Act 1999

On the 10 May 2010, the Minister for Environment Protection, Heritage and the Arts approved the NVIRP, now GMW Connections Project, under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), subject to several conditions. The conditions that apply to the protection of wetlands and waterways include:

Condition 3: *This condition applies equally to sites identified through the Water Change Management Frameworks…as requiring the preparation of an environmental watering plan (plan). This includes Johnson Swamp. All plans must be prepared in accordance with the Water Change Management Framework and provided to the Minister for approval. No modified operations potentially impacting on a site to which a plan relates may occur until the plan has been approved by the Minister. All approved plans must be implemented.*

GMW Connections Project has developed this Environmental Watering Plan in accordance with the EPBC Act decision and the Water Change Management Framework (GMW 2013).

1.3. Water Change Management Framework

The Water Change Management Framework (GMW 2013) sets out the overarching principles with respect to environmental management for the operation of the modified GMID. These principles include:

- GMW Connections Project will strive for efficiency in both water supply and farm watering systems.
- GMW Connections Project will design and construct the modernised GMID system to comply with environmental requirements as specified in the no-EES conditions.

- GMW Connections Project will develop management and mitigation measures consistent with established environmental policies and programs in place in the GMID.
- Renewal or refurbishment of water infrastructure will be undertaken to the current best environmental practice, including any requirements to better provide environmental water. Best environmental practice will require irrigation infrastructure required to deliver environmental water to be retained (no rationalisation at these sites) or upgraded to allow for future use.
- Management and mitigation measures will be maintained into the future through establishment of or modification to operating protocols and operational arrangements.

In October 2008, the Food Bowl Modernisation Project Environmental Referrals Report (SKM 2008) assessed Stage 1 (upgrade of the backbone and connections) of the GMW Connections Project in relation to operational impacts on waterways, wetlands and regional groundwater from increased system efficiencies such as changes in channel outfalls, delivery patterns and reductions in leakage and seepage.

SKM (2008) identified 23 wetlands and 17 waterways with significant environmental values which were potentially at risk from the GMW Connections Project, particularly by significant reductions in channel outfalls across the GMID. A wetland shortlisting report undertaken by Hydro Environmental (2009) reduced this number to nine wetlands, for which EWPs needed to be prepared. Feehan Consulting (2009) shortlisted the waterways, resulting in three waterways requiring EWPs.

EWPs have been required for an additional two waterways and one wetland as a result of further information and scope changes.

While GMW Connections Project has been established to implement the modernised works, the project will have no ongoing role in the operation of the modified GMID or environmental management in the region. Therefore GMW Connections Project will need to establish effective management arrangements to ensure that any management or mitigation measures are implemented on an ongoing basis, particularly in the EWPs (GMW 2013).

1.4. Purpose and scope of Environmental Watering Plans

The EWPs are the primary means by which the commitment of no net environmental loss will be achieved for water savings projects (GMW 2013). Each EWP will:

- identify environmental values of the wetland
- identify the water required to protect the environmental values
- define the environmental water regime and the sources of water
- identify if there is a need to provide mitigation water and, if so, determine the quantification of mitigation water
- identify the infrastructure requirements
- identify mitigation measures to minimise the potential risks and impacts associated with the provision of mitigation water
- draft protocols for ongoing water supply
- outline governance arrangements.

This EWP is not a wetland management plan, therefore it is not intended to provide management guidance for wetlands. It is aimed at providing a water supply protocol that can be agreed upon by land, water and catchment managers.

GMW Connections Project is responsible for managing and mitigating the significant environmental effects of its own activities. It is not responsible for managing and mitigating the effects of other activities or circumstances. GMW Connections Project is not responsible for managing and mitigating the environmental effects of activities or circumstances beyond its control such as:

- reduced outfalls due to Government policy initiatives
- water trade
- drought and climate change
- management and modernisation programs carried out by others (GMW 2013)

1.5. Development process

The Lake Leaghur EWP was initially developed in 2010 in collaboration with key stakeholders including Goulburn-Murray Water (GMW), NVIRP (now GMW Connections Project), the Department of Sustainability and Environment (DSE), now Department of Environment, Land, Water and Planning [DELWP]), Parks Victoria and the Department of Primary Industries (DPI), now Department of Economic Development, Jobs, Transport and Resources [DEDJTR]) according to the process outlined in Figure 1. A number of tasks were undertaken to develop the EWP, as follows:

- scoping and collating information
- defining ecological objectives and associated water requirements
- identify if there is a need to provide mitigation water and, if so, determine the quantification of mitigation water
- identifying risks and threats
- assessing infrastructure requirements
- developing recommendations on governance arrangements and adaptive management
- consulting and engaging stakeholders and adjacent landholders.

Following development, EWPs were reviewed by the DSE Approvals Working Group (membership comprised of departmental representatives) and the Expert Review Panel (ERP) prior to consideration by the Victorian Minister for Water and Commonwealth Minister for the Environment.

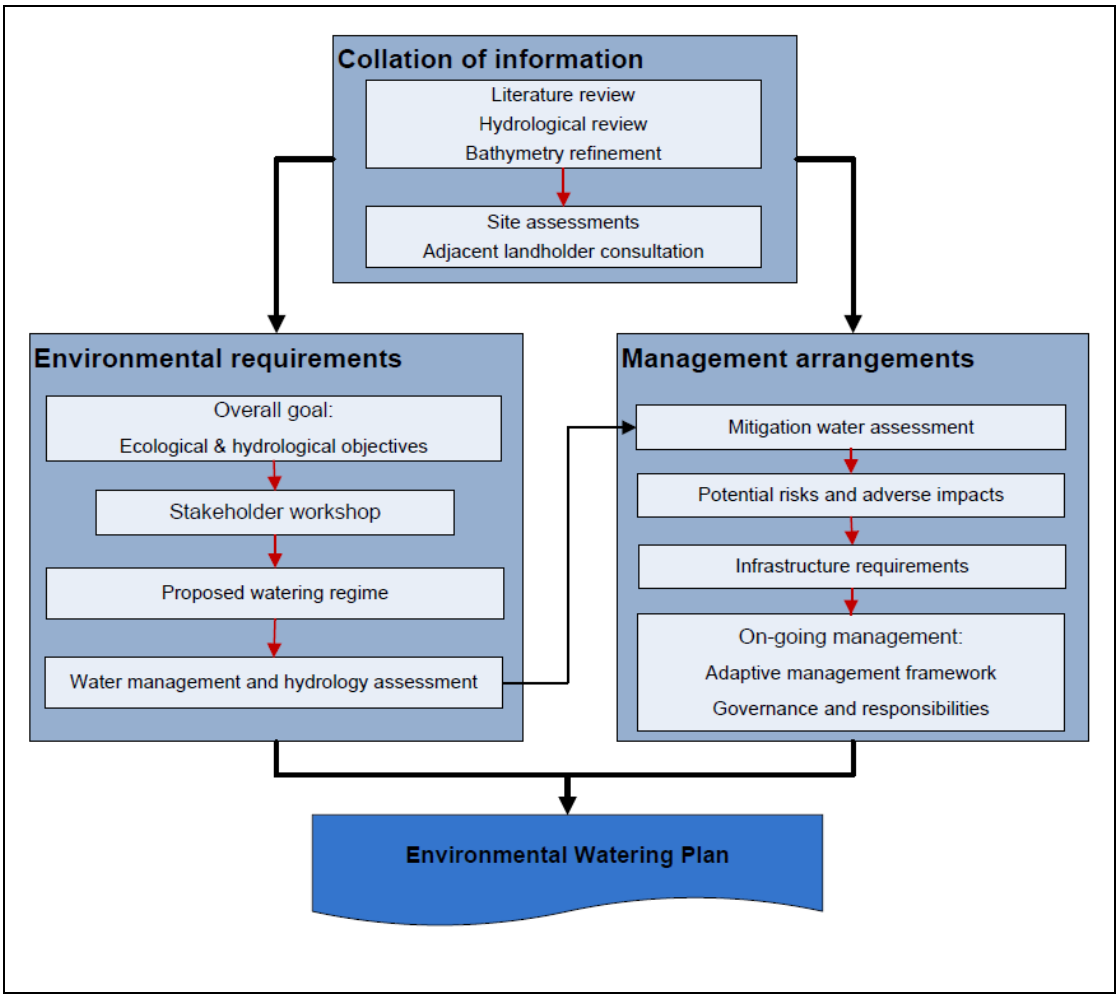

Figure 1: EWP development process

1.5.1. Consultation and engagement

To assist in collating information for the Lake Leaghur EWP (version 8), a targeted community and agency engagement process was undertaken. Key groups consulted were the NVIRP Technical Advisory Committee (now the GMW Connection Project ETAC), agency stakeholders, interest groups and adjoining landholders. An outline of the various groups' involvement is provided below.

The TAC was convened by the NVIRP to oversee the development of the EWPs to ensure quality, completeness and practicality. The committee included representation from CMAs, GMW, DPI (now DEDJTR), NVIRP (now GMW Connections Project) and DSE (now DELWP) (Appendix A). A content template for the EWPs was developed and approved by the TAC.

A workshop was held on 17 December 2009 with key agency stakeholders and technical experts (Appendix A) in order to discuss and refine the water management goal, ecological objectives, and water requirements for Lake Leaghur.

Consultation was also undertaken with adjoining landholders (18 January 2010) who have had a long association with the wetland and proven interest in maintaining its environmental value. Other community and agency people were directly engaged to provide technical and historic information, including GMW and various community members. A summary of the information sourced from this process is provided in Appendix B.

1.5.2. 2015 Review

This review has been completed in consultation with the CMAs, GMW, DELWP and Parks Victoria. GMW Connections Project prepared a report (GMW 2015) to review the ecological

data for each EWP site against the stated ecological objectives. The DSE Approvals Working Group has been replaced by the Environmental Technical Advisory Committee (ETAC), comprising departmental representatives (see Appendix A for membership). This report has been reviewed and approved by the GMW Connections Project ETAC. The GMW Connections Project ERP have reviewed this document and provided final advice to the Minister for Water. Outcomes from the ecological objectives review were used in the 2015 review of this EWP. The reviewed EWP has been approved by the GMW Connections Project ETAC.

This document was reviewed in 2015, in accordance with the requirements of the WCMF (GMW 2013). The review considered any new hydrological and ecological knowledge, changes impacting on the mitigation water assessment and changes to project and departmental names. Specific changes to Version 8 are:

- Updating of site ecological information (Section 3)
- Updating of site hydrological information (Section 4)
- Updating roles and responsibilities of agencies (Section 8,9 and 10)
- Administrative changes such as project and departmental name changes (throughout document)

1.5.3. Cessation of GMW Connections Project

The GMW Connections Project is scheduled for completion in June 2018. At this time, as per Section 9.4.4 of the WCMF, the responsibility for delivery of mitigation water will transfer to the designated environmental water manager, operating under the Victorian Environmental Water Management Framework. The entitlement itself will be held by the Victorian Environmental Water Holder. Calculation and confirmation on the LTCE conversion factor will be required from DELWP to finalise mitigation water arrangements prior to handover. This will be decided at or near the end of the GMW Connections Project.

2. Lake Leaghur

Lake Leaghur is situated approximately 16 km north of the township of Boort and 3 km west of the Loddon River (Figure 2). It is located in the Wandella Creek sub-catchment of the Loddon River basin and is of bioregional conservation significance (SKM 2008). It is considered a high value wetland due mainly to the significant vegetation communities and flora and fauna species it supports, particularly threatened waterbirds.

At full supply level (FSL), 85.85 m AHD[1], the wetland has an area of approximately 59 ha within a 79 ha Crown land reserve (DCE 1991). It is oval in shape and has a relatively flat bottom. At FSL it has a capacity of 664 ML and a maximum depth of 1.35 m (Price Merrett Consulting 2006).

Refer to Appendix C for the contour plan prepared for Lake Leaghur by Price Merrett Consulting (2006).

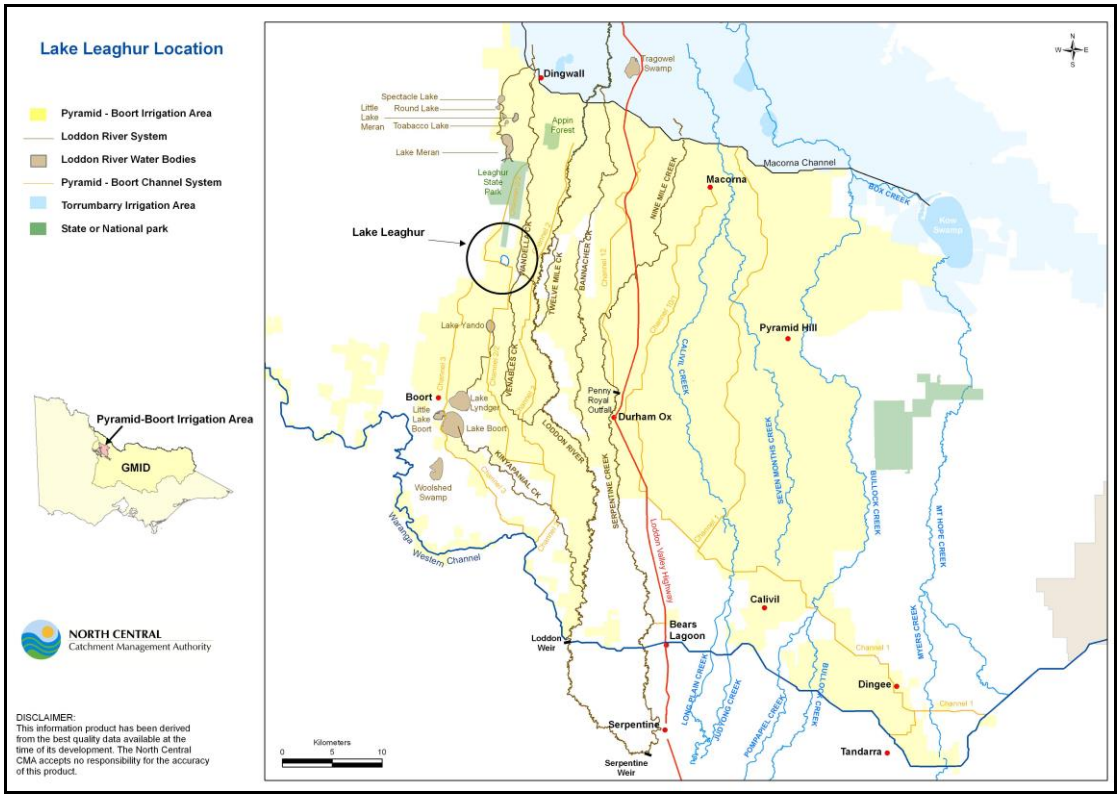

Figure 2: Location of Lake Leaghur

2.1. Wetland context and current condition

Prior to European settlement, Lake Leaghur was as a deep freshwater marsh[2] dominated by large River Red Gums (*Eucalyptus camaldulensis*) scattered across the wetland floor (DSE 2009a; pers. comm. Rob O'Brien [NVIRP], 8 February 2010). Lake Leaghur would naturally have received intermittent Loddon River floodwaters from the Wandella Creek and Venebles Creek and would have been a temporary source of groundwater recharge (Bartley Consulting 2009). The wetland has a lunette on the eastern boundary indicating a historic period of shallow groundwater levels.

The development of the Pyramid–Boort Irrigation System in the 1920s/1930s resulted in a significant change to the hydrology of the wetland. Historically, Lake Leaghur has been a strategic outfall point for the irrigation supply system and has consistently received significant outfalls from channel 2/2, often in excess of 300 ML/year (O'Brien and Joyce 2002). This resulted in a more permanent water regime at Lake Leaghur and a subsequent shift in its

[1] Full supply level (FSL) defined by overflow sill elevation
[2] Deep freshwater marshes are generally less than 2 m deep and are inundated for longer than 8 months of the year (DCFL 1989a)

wetland classification to that of a permanent open freshwater wetland supporting shallow open water (< 5 m), dead timber, reeds and River Red Gum vegetation (DSE 2009b). Permanent open freshwater wetlands retain water for longer than twelve months though they may also experience a drying phase. Until 2001, Lake Leaghur received significant channel outfalls and rarely dried out. It was known to support good fish populations (pers. comm. Rob O'Brien [NVIRP], 8 February 2010). However, it has been predominately dry since 2001 in response to current drought conditions and decreasing outfall volumes (Section 4). The wetland has not flooded naturally since 1996.

Locals have advised that the River Red Gums that once dominated the wetland were removed to facilitate water skiing (Appendix B). Lake Leaghur is now only fringed by the species, regenerating around the margins due to higher, and more permanent, water levels.

In 1993, Lugg *et al*. classified Lake Leaghur as a shallow permanent freshwater lake fringed by River Red Gums, Cumbungi (*Typha* sp.) and Eel Grass (*Vallisneria* sp.).

Field mapping from an assessment conducted on 22 October 2009 indicates that it is currently characterised as a cleared wetland surrounded by a narrow fringe of mature River Red Gums (Plate 1). Saplings have recruited inside of and are expanding the fringe of mature individuals. Although some scattered dead trees exist in the wetland bed (Plate 2), the majority of River Red Gums are reported to be in moderate health (Campbell *et al*. 2009). The base of the wetland is dominated by annual grasses and Prickly Lettuce (*Lactuca serriola*). Patches of live Cumbungi exist near the outfall location and are scattered across the wetland. Extensive beds of dead Cumbungi reflect a much greater distribution when Lake Leaghur was inundated. A patch of Tangled Lignum (*Muehlenbeckia florulenta*) exists near the delivery channel in the southwest, however the species is largely confined to scattered individual plants close to and among the fringing River Red Gums.

A number of moderate to high threat weeds have been observed within Lake Leaghur including: Spear Thistle (*Cirsium vulgare*), Pampas Grass (*Cortaderis* sp.), Sharp Rush (*Juncus acutus* ssp. *acutus*), African Boxthorn (*Lycium ferocissimum*), Horehound (*Marrubium vulgare*), Poppy (*Papaver* sp.), Weld (*Reseda luteola*), Variegated Thistle (*Silybum marianum*) and Tamarisk (*Tamarix ramosissima*).

When inundated, Lake Leaghur would provide important open water, River Red Gum and Tall Marsh habitat. This habitat diversity is likely to continue to attract a variety of waterbirds, reptiles and amphibians for which the wetland is highly valued.

No subsequent condition assessments have been undertaken of the site at this point in time.

A summary of the wetland characteristics is provided in Appendix D.

Plate 1: Fringe of River Red Gums (Source: MDFRC 2009)

Plate 2: Scattered dead River Red Gums (Source: MDFRC 2009)

2.2. Catchment setting

Lake Leaghur is located within the Wandella Creek sub-catchment in the Victorian Riverina bioregion. The surrounding area is low-lying and generally flat. The Leaghur Fault, running north-south, borders the wetland to the west (SKM 2001). The surrounding land use is agricultural dominated by horticulture, particularly tomato growing (SKM 1997a, cited in SKM 2001). Lake Leaghur is connected to a remnant patch of woodland to the southeast and to

Leaghur State Park to the north, although the connection is narrow and fragmented for the first 800 m (Campbell *et al*. 2009).

Rainfall in the Boort region averages 394 mm/year, with May to October being significantly wetter months than November to April (Bureau of Meteorology 2009). Maximum average temperatures range from 31.3°C in January to 13.9°C in July, with mean minimum temperatures falling below 5°C between June and August (Bureau of Meteorology 2009).

Lake Leaghur sits high in the landscape and as such receives little drainage runoff from the surrounding land. Similarly, the construction of levees has further disconnected the wetland from its local catchment (SKM 2001).

Lake Leaghur is directly connected to the Pyramid-Boort Irrigation System and receives outfalls from the 2/2 channel (Figure 3). The outfall channel and structure have a reported capacity of 60 ML/day (Hillemacher and Ivezich 2008). The wetland received significant water from natural events in the 2010/11 and 2012/13 seasons.

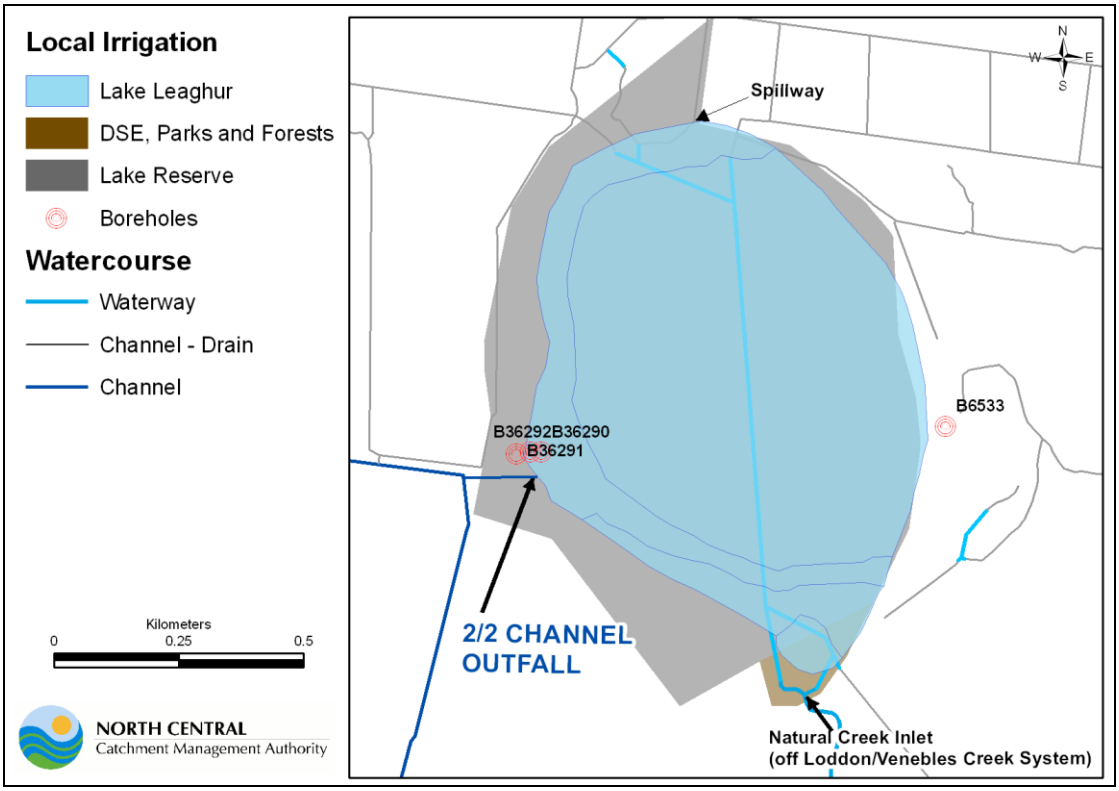

Figure 3: Inflow points at Lake Leaghur

2.3. Land status and management

Lake Leaghur is a Water Supply Reserve under Section 4 of the *Crown Land (Reserves) Act 1978*. It is designated for water supply, regulation and drainage which requires that the wetland is managed for the storage and distribution of irrigation and domestic water, flood mitigation, and disposal of drainage water. Nature conservation and recreation are permitted to an extent consistent with the primary purpose (LCC 1988). The land manager is G–MW.

In 2009, the Victorian Government endorsed (with amendments) the Victorian Environment Assessment Council (VEAC) recommendations for public land management. One of these was that Lake Leaghur be classified as a wildlife reserve under the "state game reserve" classification. A series of VEAC recommendations relating to the establishment of National Parks took effect on 29 June 2010. Wildlife reserves are managed to conserve and protect species, communities or habitats of indigenous animals and plants while permitting recreational (including hunting in season as specified by the land manager) and educational use (VEAC 2008; DSE 2009c).

2.4. Cultural heritage

Cultural heritage values are abundant on productive wetlands throughout the district, including Lake Leaghur (pers. comm. Rob O'Brien [DPI], 8 February 2010). Seven sites of Aboriginal archaeological significance have been recorded and registered with Aboriginal Affairs Victoria (AAV). This includes one hearth, one scar tree, two artefact scatters, and three mounds. Further information can be obtained from AAV.

2.5. Recreation

Lake Leaghur is a valuable wetland within the Boort District Wetlands area. The wetland has historically been a popular location for water skiing (Ecos Environmental Consulting 2007).

The wetland has also been known to support camping, picnicking, fishing and hunting (DCFL 1989a).

2.6. Legislative and policy framework

2.6.1. International agreements

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

- Japan–Australia Migratory Bird Agreement (JAMBA)
- China–Australia Migratory Bird Agreement (CAMBA)
- Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA)
- Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention).

Lake Leaghur is known to support species protected by each of the above international migratory bird agreements (Table 1). As wetland habitat for a number of protected species, Lake Leaghur is required to be protected and conserved in accordance with these international agreements (DEWHA 2009).

2.6.2. Federal legislation

The *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* is the key piece of legislation pertaining to biodiversity conservation within Australia. It aims to control potential impacts on matters of national environmental significance (MNES)[3].

Lake Leaghur is known to support a number of species listed under the *EPBC Act* (Table 1). Similarly, the wetland is known to support protected migratory waterbirds. Actions that may significantly impact any of these MNES are subject to assessment and approval by the Minister for the Environment, Heritage and the Arts. The GMW Connection Project works program is also subject to assessment and approval under the *EPBC Act*.

2.6.3. State legislation

Flora and Fauna Guarantee (FFG) Act 1988

The *Flora and Fauna Guarantee (FFG) Act 1988* aims to protect a number of identified threatened species and communities within Victoria. Lake Leaghur is known to support a number of species both protected[4] and listed under the *FFG Act* (Table 1 and Table 3). Disturbance or collection of any of these threatened species will require a permit from the DELWP.

Environmental Effects Act 1978

Potential environmental impacts of a proposed development are subject to assessment and approval under the *Environmental Effects Act 1978*. As such, the GMW Connections Project

[3] There are seven MNES that are protected under the EPBC Act, these are: World Heritage properties, National Heritage places, wetlands of international importance, listed threatened species and ecological communities, migratory species protected under international agreements, Commonwealth marine areas, and nuclear actions (including uranium mines) (DEWHA 2009).

[4] Includes plant taxa belonging to families or genera protected by the Act (DSE 2014).

works program and any associated environmental impacts are subject to assessment and approval under the Act (as discussed in Section 1.1).

Planning and Environment Act 1987
The removal or disturbance to native vegetation within Victoria is controlled by the implementation of a three-step process of avoidance, minimisation and offsetting under the *Planning and Environment Act 1987*. Any proposed removal or disturbance to native vegetation associated with the GMW Connections Project works program will require the implementation of the three-step process, assessment and approval under the Act.

Water Act 1989
The *Water Act 1989* 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 as part of 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 the *Aboriginal Heritage Act 2006* (DPCD 2007). Lake Leaghur is known to have sites of Aboriginal cultural significance (Section 2.4).

Other - Threatened Species Advisory Lists
Threatened species advisory lists for Victoria are maintained by the DELWP and are based on technical information and advice obtained from a range of experts which are reviewed every one to two years. These advisory lists are not the same as the Threatened List established under the *FFG Act*. There are no legal requirements or consequences that flow from inclusion of a species in advisory lists. However, some of the species in these advisory lists are also listed as threatened under the *FFG Act*. Lake Leaghur is known to support flora and fauna species that are included on advisory lists (Table 1 and Table 3).

3. Lake Leaghur environmental values

The primary purpose of this EWP is to assess and advise on mitigating potential impacts on high environmental values supported by Lake Leaghur. While it is recognised that the wetland provides a number of broader ecological and landscape values (i.e. ecological processes, representativeness and distinctiveness in landscape), high environmental values have previously been defined by the conservation significance of the wetland or species at an international, national or state level (SKM 2008; Hydro Environmental 2009; GMW 2013).

As such, in describing the values supported by the wetland in the sections below, an emphasis is placed on identifying listed flora and fauna species, and vegetation communities followed by the broader ecological and landscape values. All listed values are presented in this section with full species lists provided in Appendix E.

Lake Leaghur is considered a high value wetland due mainly to the significant vegetation communities, flora and fauna species it supports, particularly threatened waterbirds. In addition, when inundated the wetland is known to support a significant diversity and abundance of microorganisms, invertebrates, and other flora and fauna species.

3.1. Fauna

More than ninety bird species have been recorded or are considered likely to occur at Lake Leaghur. Records indicate that of these 33 are listed under international agreements, federal (*EPBC Act*) or state (*FFG Act*) legislation, or are Victorian rare or threatened species (VROTS) (Table 1 and Appendix E). Lake Leaghur is an extremely productive wetland especially for waterbird roosting and breeding. It is known to have provided important breeding habitat for colonially nesting waterbirds (Little Pied Cormorants *Phalacrocorax melanoleucos*) (DCE 1991).

In addition, Striped Legless Lizard (*Delma impar*) and Freshwater Catfish (*Tandanus tandanus*) have been recorded in the wetland (Table 1). Striped Legless Lizard is protected by the federal *EPBC Act*, the Victorian *FFG Act* and is considered endangered within Victoria (DSE 2007). Freshwater Catfish are also protected by the *FFG Act* and are considered endangered within Victoria (DSE 2007).

Table 1: Significant species recorded, or considered likely to occur, at Lake Leaghur

Common Name	Scientific Name	International agreements	EPBC status	FFG status	DELWP status
Australasian Shoveler	*Anas rhynchotis*				VU
Black-chinned Honeyeater	*Melithreptus gularis*				NT
Black-eared Cuckoo[1]	*Chrysococcyx osculans*				NT
Blue-billed Duck	*Oxyura australis*			L	EN
Brown Treecreeper (south-eastern ssp.)	*Climacteris picumnus victoriae*				NT
Clamorous Reed Warbler	*Acrocephalus stentoreus*	B			
Common Greenshank	*Tringa nebularia*	B/C/J/R			
Crested Bellbird	*Oreoica gutturalis*			L	NT
Diamond Firetail	*Stagonopleura guttata*			L	VU
Eastern Great Egret	*Ardea modesta*	C/J		L	VU
Freckled Duck	*Stictonetta naevosa*			L	EN
Freshwater Catfish	*Tandanus tandanus*	-		L	EN
Glossy Ibis	*Plegadis falcinellus*	B/C			NT
Great Egret	*Ardea alba*	C/J		L	EN
Grey-crowned Babbler	*Pomatostomus temporalis*			L	EN
Hardhead	*Aythya australis*				VU
Hooded Robin	*Melanodryas cucullata*			L	NT
Intermediate Egret	*Ardea intermedia*			L	CR
Little Egret	*Egretta garzetta*			L	EN

Common Name	Scientific Name	International agreements	EPBC status	FFG status	DELWP status
Major Mitchell's Cockatoo	*Lophocroa leadbeateri*			L	VU
Marsh sandpiper	*Tringa stagnatilis*	B/C/R			VU
Musk Duck	*Biziura lobata*				VU
Pectoral Sandpiper	*Calidris melanotos*	B/J/R			
Rainbow Bee-eater	*Merops ornatus*	J			
Red-necked Stint	*Calidris ruficollis*	B/C/J/R			
Royal Spoonbill	*Platalea regia*				VU
Ruff (Reeve)	*Philomachus pugnax*	B/C/J/R			
Sharp-tailed Sandpiper	*Calidris acuminate*	B/C/J/R			NT
Speckled Warbler	*Chthonicola sagittata*			L	VU
Striped Legless Lizard	*Delma impar*	-	VU	L	EN
Swift Parrot[1]	*Lathamus discolour*		EN	L	EN
Whiskered Tern	*Chlidonias hybridus*				NT
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	C		L	VU

Conservation Status:

- J/C/R/B: JAMBA/CAMBA/ROKAMBA/Bonn International agreements listed in section 2.4.1
- EPBC listing: EN – Endangered, VU – Vulnerable
- FFG listing: L – Listed as threatened
- DELWP listing: CR – Critically endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened (DEPI 2013)

Note 1: (DSE 2009d) – considered likely to occur

3.2. Flora

Prior to European settlement, according to DSE's pre-1750 Ecological Vegetation Class (EVC) mapping, Lake Leaghur was a Red Gum Swamp (EVC 292) surrounded predominantly by Lignum Swampy Woodland (EVC 823) with Semi-arid Woodland (EVC 97) vegetation to the east, associated with the bordering lunette, and Riverine Grassy Woodland (EVC 295) at slightly higher elevations on the banks of waterways (DSE 2009e). Current EVC mapping (DSE 2009f) for Lake Leaghur suggests that the 1750 EVCs still exist; however the extent of Lignum Swampy Woodland, Semi-arid Woodland and Riverine Grassy Woodland is severely diminished.

DSE's 2005 EVC mapping has been collected via aerial photograph interpretation, biophysical data and selective ground truthing of sites on a project-by-project basis over a number of years (DSE 2007).

However, assessments undertaken by the Murray-Darling Freshwater Research Centre (Campbell *et al*. 2009) on 22 October 2009 identified that the wetland is currently characterised by Red Gum Swamp (EVC 292) vegetation. The results of the assessment show a marked difference to the mapped 2005 EVCs and are based on recently mapped, up to date and field verified information. Therefore, the EVCs reported by MDFRC are included within the EWP as opposed to the mapped 2005 EVCs.

Table 2 shows the conservation status of the observed and mapped EVCs within Lake Leaghur. Refer to Appendix F for a detailed map of EVCs observed in October 2009.

Table 2: Lake Leaghur observed and mapped EVC and bioregional conservation significance (Campbell *et al*. 2009; DSE 2009f)

EVC No.	EVC	Bioregional Conservation Status*
292	Red gum swamp	Vulnerable
823	Lignum swampy woodland	Vulnerable
821	Tall marsh	Depleted
97	Semi-arid woodland	Endangered
295	Riverine grassy woodland	Vulnerable

*Victorian Riverina Bioregion

Six VROTS have been recorded at Lake Leaghur (Table 3 and Appendix E) (SKM 2001; DSE 2005). Cane Grass (*Eragrostis australascia*), Ferny Small-flower Buttercup (*Ranunculus pumilio*, Peppercress (*Lepidium pseudohyssopifolium*), Spiny Lignum (*Muehlenbeckia horrida subsp. Horrida*) and Swamp Buttercup (*Ranunculus undosus*) are all identified as either flood-dependant (VEAC 2008) or as wetland/riparian species (DNRE 2002). An additional six species recorded within Lake Leaghur are protected by the *FFG Act* as they are from the Asteraceae family.

Table 3: Significant flora species recorded at Lake Leaghur

Common Name	Scientific name	EPBC status	FFG status	DELWP status
Branching Groundsel	*Senecio cunninghamii var. cunninghamii*		P	r
Cane Grass	*Eragrostis australasica*			v
Common Everlasting	*Helichrysum apiculatum*		P	
Cotton Fireweed	*Senecio quadridentatus*		P	
Ferny Small-flower Buttercup	*Ranunculus pumilio*			k
Jersey Cudweed	*Helichrysum luteoalbum*		P	
New Holland Daisy	*Vittadinia sp.*		P	
Paper Sunray	*Rhodanthe corymbiflora*		P	
Peppercress	*Lepidium pseudohyssopifolium*			k
Spiny Lignum	*Muehlenbeckia horrida subsp. horrida*			r
Swamp Buttercup	*Ranunculus undosus*			v
Tall Fireweed	*Senecio runcinifolius*		P	

Conservation Status:
- FFG listing: L – listed, P – protected
- DELWP listing: r- rare, v – vulnerable, k – poorly known and suspected, but not definitely known, to belong to one of the categories (x, e, v or r) within Victoria (DELWP 2013).

3.3. Representativeness and distinctiveness

Lake Leaghur is currently classified as a permanent open freshwater wetland supporting shallow water (<5m), dead timber, reed and River Red Gum vegetation (DSE 2009b). However, currently it is considered to be more appropriately described as a deep freshwater marsh (pers. comm. Rob O'Brien [DPI], 8 February 2010). Wetlands supporting healthy and intact River Red Gum Swamp (EVC 292) vegetation are uncommon throughout the area and it is important that these be maintained across the region.

Deep freshwater marshes are often drained to facilitate agricultural activities including grazing or cropping, and have subsequently decreased in extent across the landscape. The area of deep freshwater marshes across Victoria is estimated to have decreased by approximately 70% since European settlement (DNRE 1997). Table 4 illustrates the area and proportion of deep freshwater marshes across various defined landscapes. Lake Leaghur is classified as deep freshwater marsh, which is the most depleted wetland category within Victoria.

Table 4: Current area of deep freshwater marsh wetlands across the landscape

	North Central region	GMID	Victorian Riverina
Deep freshwater marshes (ha)	4,880	7297	6364
Lake Leaghur	1%	<1%	<1%

Lake Leaghur is distinctive as a result of its connectivity to the Loddon River. Other wetlands within the area are completely disconnected from the floodplain (such as Little Lake Meran situated approximately 9 km north of Lake Leaghur). Lake Leaghur remains connected to the Loddon River and has the ability to receive flood flows via a Wandella Creek breakaway under wet conditions.

4. Hydrology

Wetland hydrology is the most important determinant in the establishment and maintenance of wetland types and processes. It affects the chemical and physical attributes of a wetland, which in turn affects the type of values the wetland supports (DSE 2005b). A wetland's hydrology is determined by surface and groundwater inflows and outflows, in addition to precipitation and evapotranspiration (Mitsch and Gosselink 2000 cited in DSE 2005b). Duration, frequency and seasonality (timing of inundation) are the main components of the hydrologic regime for wetlands.

4.1. Natural water regime

Lake Leaghur is located within the Wandella Creek sub-catchment in the Loddon River basin. Its natural water supply would have been from intermittent Loddon River floods with flows provided via a Wandella Creek breakaway that enters the wetland to the south. It is still connected to the Loddon River and maintains the ability to receive flood flows.

Lake Leaghur would have naturally been inundated in winter and spring. The outlet is to the north of the wetland and would have permitted flows north through Leaghur State Park and into Lake Meran. Lake Leaghur is situated relatively high in the landscape. As such, it has historically received little runoff from the surrounding area.

4.2. History of water management

Following development of the irrigation system, Lake Leaghur was a strategic outfall point for the supply system and has consistently received significant volumes of water from channel outfall (O'Brien and Joyce 2002). Locals have advised that it consequently became permanently inundated (Appendix B). Surface water data collected by DELWP between 1990 and 2007 is poor with several gaps in the monitoring record. However, it shows very low but fluctuating water levels from November 1997, and was completely dry by November 2002. Figure 4 illustrates corresponding fluctuating salinity levels recorded within Lake Leaghur between 1990 and 2007. Resourcing constraints have limited data collation since 2008.

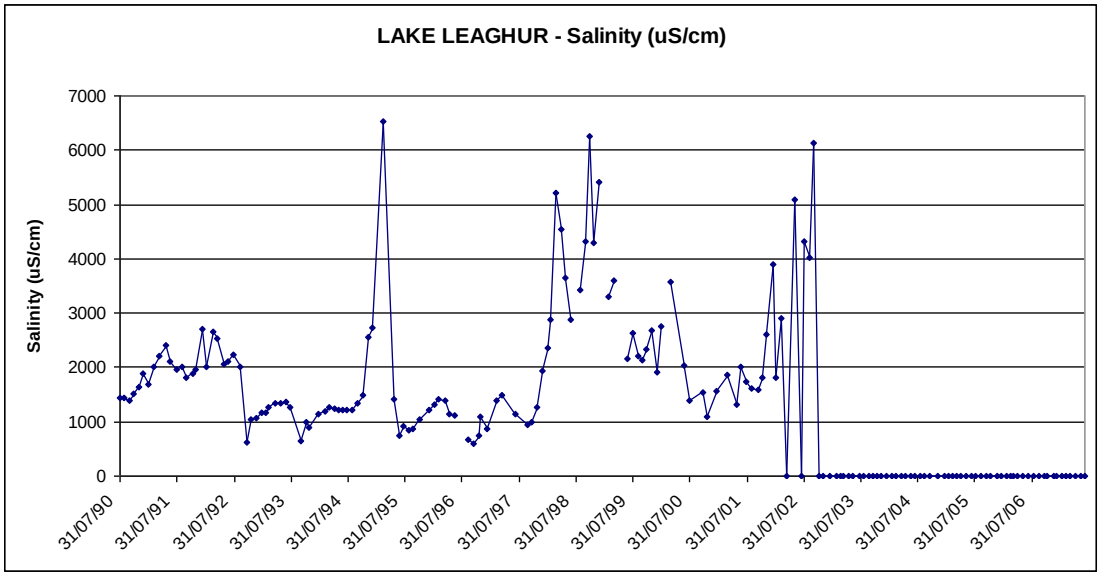

Figure 4: Salinity levels within Lake Leaghur as recorded by DPI between 1990 and 2007

Figure 5 illustrates the volumes of water received from outfalls between 1997/98 and 2008/09. An average of 194 ML/year was recorded between 1997/98 and 2008/09 which equates to 30% of the wetland capacity at FSL. Figure 5 also shows that, up to 2008/2009, Lake Leaghur did not received water from any environmental entitlement.

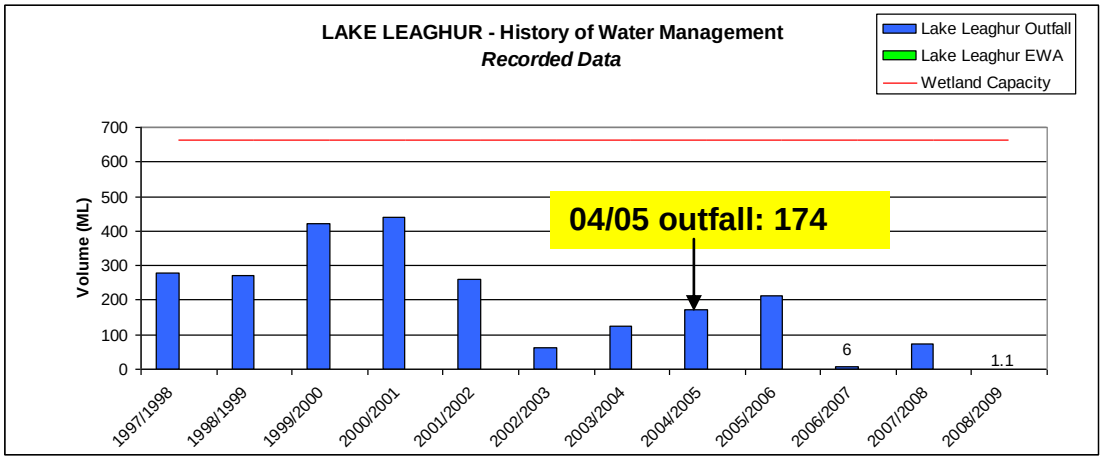

Figure 5: Recorded volumes received by Lake Leaghur from outfalls *Note outfalls recorded from 1997/1998 onwards*

Although the wetland has received small volumes of channel outfalls as shown in Figure 5, Lake Leaghur has been dry since 2000/01 (Table 5). Lake Leaghur received environmental water in Autumn 2010 which was the first time the Lake had been filled and flushed since the last flood in 1996 (pers. comm. Rob O'Brien [DPI], 8 February 2010). Lake Leaghur was filled from regional flooding in August to October 2010 and again in February 2011 and received environmental water again in the 2012/2013 season. The lake has been continuously wet without a drying phase since the 2009/10 season, due to the combination of environmental water deliveries and flood events.

Table 5: Lake Leaghur wetting/drying calendar (Source: NCCMA 2008)

93/94	94/95	95/96	96/97	97/98	98/99	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09
W	W	W	W	W	W/D	D	D	D	D	D	D	D	D	D

09/10	10/11	11/12	12/13	13/14
D	W	W	W	W

4.2.1. Recorded outfalls and GMW Connections Project

Outfall data for Lake Leaghur recorded by GMW from 1997/98 to 2008/09 (Figure 5) indicate that outfall volumes have decreased significantly between 1997/98 (277 ML) and 2008/09 (1.1 ML). Historically, larger outfall volumes sustained a much wetter water regime.

The baseline water year, 2004-2005, has been selected to quantify the savings as part of water savings projects (DSE 2009g). The comparison of estimated water savings with a baseline year is necessary to convert the savings to water entitlements and ensure that there are no impacts on service delivery or reliability for existing entitlement holders (DSE 2008b). This baseline year is used to guide the quantification of mitigation water required for wetlands (discussed in Section 5), taking into account the average annual patterns of availability.

Lake Leaghur received a total of 174 ML of outfall water in 2004-2005. The timing of the outfalls, over the irrigation period of September to May, is shown in Figure 6.

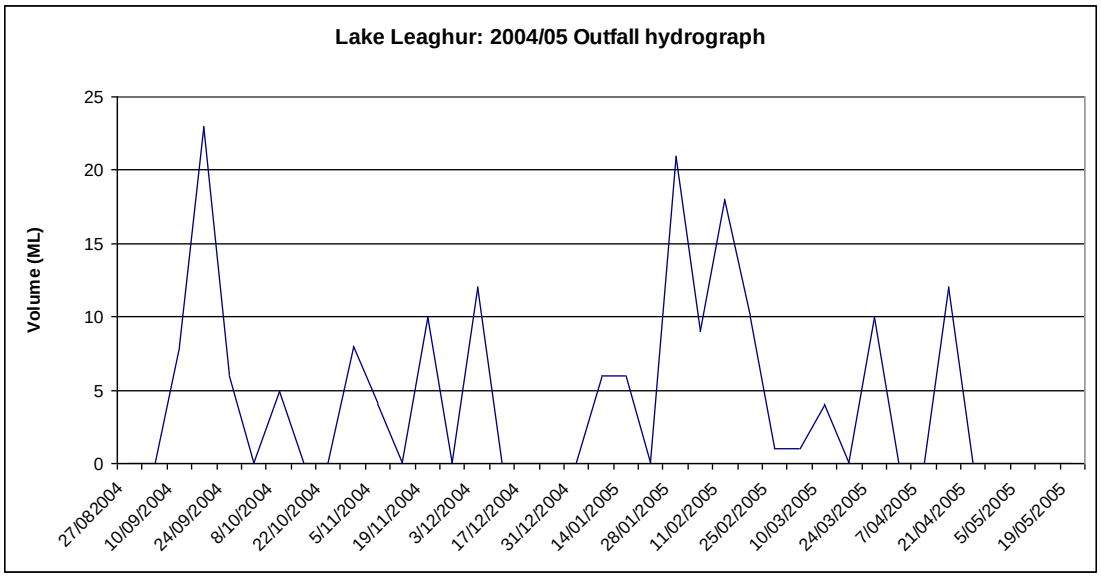

Figure 6: Lake Leaghur outfall hydrograph

4.3. Surface water/groundwater interactions

Lake Leaghur is situated on the Loddon River floodplain on lower floodplain alluvial sediments. It is approximately 3 km west of the Loddon River. Shepparton Formation and Parilla Sand sediments outcrop 2 km west of the wetland, in proximity to the Leaghur Fault. The alluvial/Shepparton Formation sediments comprise sandy clay and clay, and are approximately 35 m thick at the wetland, overlying Parilla Sand and Renmark Group sediments. Groundwater movement beneath the floodplain west of the Loddon River is from the south and southeast toward the northeast, north and northwest.

Lake Leaghur would have naturally been intermittently filled by floodwaters and would have been a temporary source of groundwater recharge once the local groundwater levels receded following flood events. A lunette borders the wetland to the east and indicates a prior period of shallow groundwater levels.

Groundwater monitoring at Lake Leaghur is conducted by DEDJTR. DEDJTR collect groundwater data from regional bores in the State Observation Bore Network as well as from other bores within the vicinity. Regular monitoring of surface water and electrical conductivity (EC) commenced in 1990 and is also undertaken by DEDJTR.

In the past regional groundwater levels have been shallow; however they have been declining since the 1990s in response to a period of below average rainfall. Figure 7 illustrates groundwater behaviour from bores approximately 1 km east of Lake Leaghur. When the regional groundwater levels were at their highest, groundwater was above the bed of Lake Leaghur. Groundwater discharge into the wetland would have occurred if it did not contain water at the time.

Groundwater levels in the vicinity of the wetland have fluctuated over time. Levels beneath Lake Leaghur began to decline around 1997, which is consistent with the broader regional decline. March 2009 groundwater levels were at least 4 m below the bed of Lake Leaghur. Bores to the east of Lake Leaghur (Figure 8) currently have a higher groundwater level than those located to the west (Figure 9) illustrating a localised impact resulting from channel outfalls.

Groundwater levels rose across all bores during the wet period of 2010/11 (Figure 10) after widespread flooding of the region. Groundwater levels in the region have stabilised since then, based on groundwater data which is only available up until 2013. .

The monitoring record shows a surface water level consistently higher than the groundwater level. Therefore, when Lake Leaghur is inundated, it would be a source of groundwater recharge.

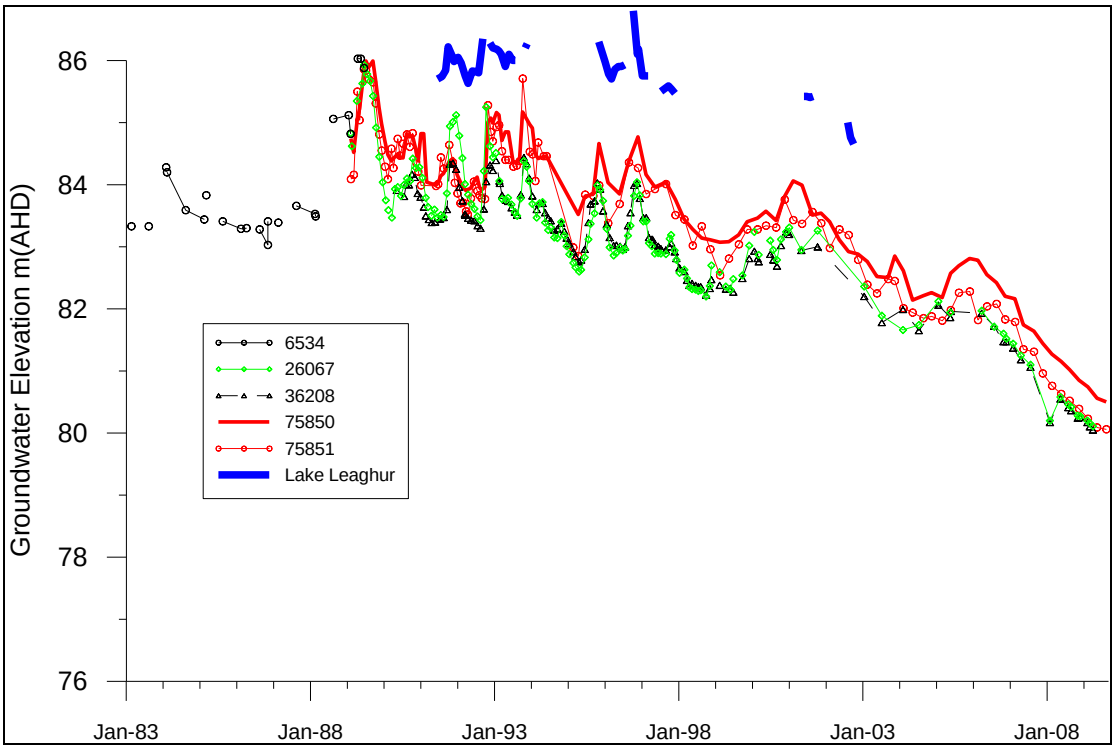

Figure 7: Groundwater level for bores 1 km east of the wetland and Lake Leaghur surface water level (Bartley Consulting 2009)

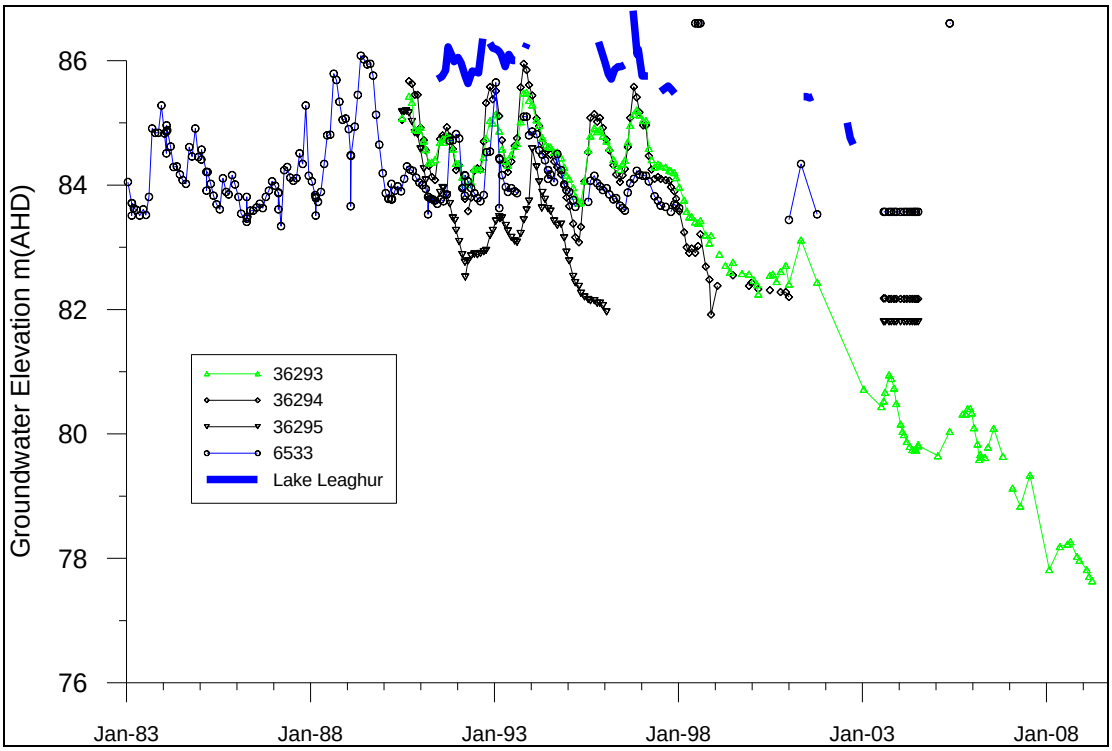

Figure 8: Groundwater level (east) and Lake Leaghur surface water level (Bartley Consulting 2009)

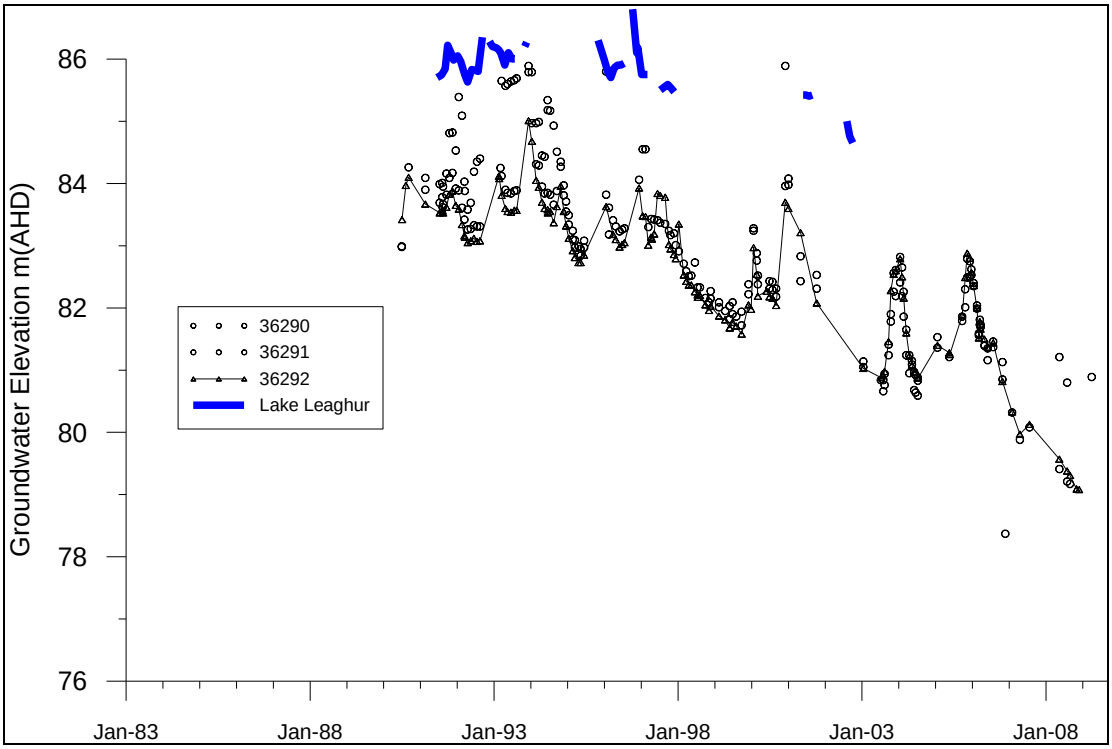

Figure 9: Groundwater level (southwest) and Lake Leaghur surface water level (Bartley Consulting 2009)

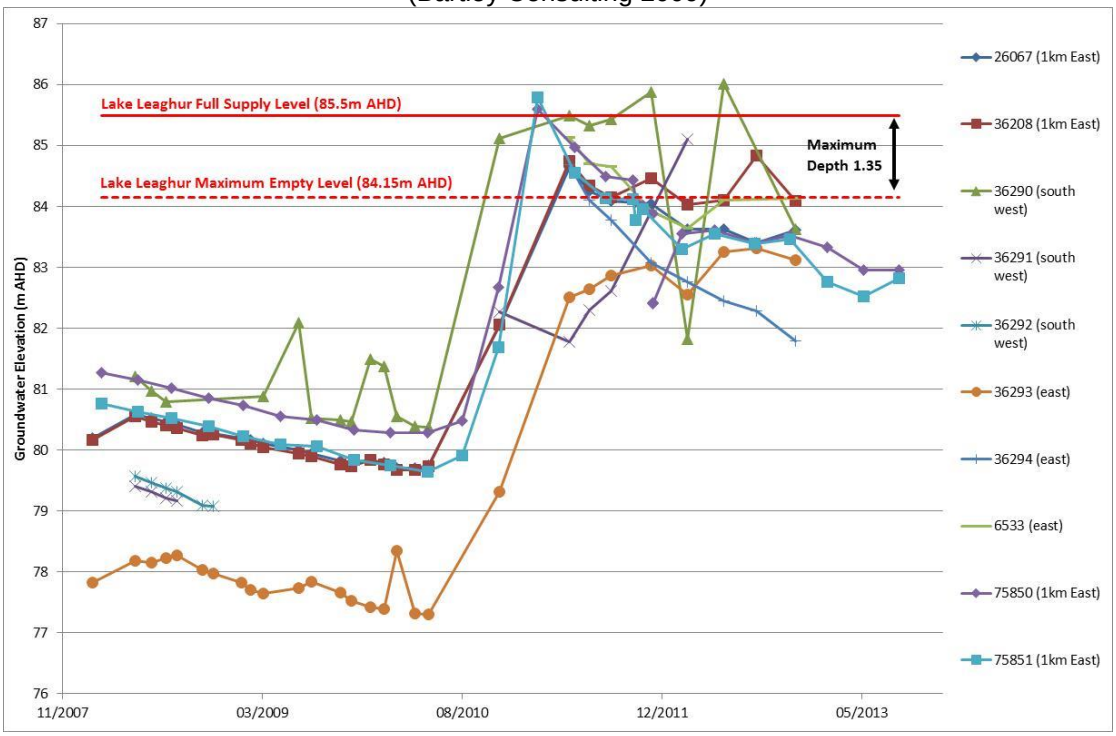

Figure 10: Groundwater level and Lake Leaghur full supply level (Victorian Water Measurement Information System)

Data from bores within the vicinity of Lake Leaghur show fluctuating EC levels with mean values ranging from 5,289 µS/cm to 33,681 µS/cm in the northwest. Mean EC levels are the lowest at bores adjacent channel no. 2/2. Overall, the bores closer to Lake Leaghur show lower EC levels than in areas further west. Similarly, surface water EC levels have fluctuated over time from 600 uS/cm to 6,540 uS/cm, with a median of 1,655 uS/cm (116 readings). The

data suggests that as the water levels decline in Lake Leaghur salinity increases through evapoconcentration[5].

Based on trends in groundwater levels:

- Intermittent watering of Lake Leaghur is likely to result in localised groundwater mounding. However, as the level is below the capillary zone (>4m) there is no significant risk of adverse impact on the wetland or neighbouring land through watertable rise.
- Inundation while groundwater levels are so low increases the opportunity for salts to move down the profile into the groundwater.
- There would be a small risk of saline groundwater discharge to low-lying areas on neighbouring land if Lake Leaghur was permanently inundated. The risk would increase if regional groundwater levels were to rise (Bartley Consulting 2009).

4.4. Surface water balance

A daily surface water balance has been modelled in order to identify the hydrological attributes of Lake Leaghur. The model used is a simplified version of the Savings at Wetlands from Evapotranspiration daily Time-Series (SWET) (Gippel 2005a, Gippel 2005b, Gippel 2005c).

This model has been approved by the Murray Darling Basin Authority for estimating the wetland surface water balance. Modelling the daily water balance enables managers to quantify the volumes required in providing the desired water regime. It also allows for consideration of variability in climatic conditions and wetland phase.

A surface water balance and associated calculations to define the hydrological characteristics of Lake Leaghur was undertaken as part of the development of the EWP. Components are discussed in brief below. Actual figures are provided in Appendix G. This information is utilised for the estimation of volumes required for the desired water regime (Section 5.3).

The main components of the model are outlined below:

- **Time Series:** the daily time step is set up to run from May 1891 to end of 2009.
- **Wetland capacity:** volume required to fill the wetland to the targeted supply level. At 85.85 m AHD[6], the wetland has a capacity of 664 ML (Price Merrett Consulting 2006).
- **Infiltration:** volume required to fill the underlying soil profile. Calculation of this volume has been adapted from measurements undertaken by GMW (GMW 2008a). The following assumptions were included in the application of the SWET model for Lake Leaghur (Gippel 2005a, Gippel 2005b, Gippel 2005c):
    - Infiltration (ML) = Soil cracking (%) x area of wetland (ha) x depth (mm))/100
    - Soil cracking – 25% of surface area
    - Average depth of 300mm
    - Ongoing losses via infiltration are considered negligible due to the low permeability of the underlying soil (GMW 2008b)
- **Rainfall/runoff:** this includes rainfall directly falling onto the wetland and surface run-off. Surface water inflows/run-off: an average volumetric figure of 0.2 ML/ha/year for the Kerang area (DPI and HydroEnvironmental 2007). Lake Leaghur has virtually no local catchment area as it is high in the landscape and has been disconnected via the construction of levees across the landscape. The contributing volume is dependent on the rainfall intensity (15-40%).
- **Climate data:** SILO DataDrill including wind data (Bureau of Meteorology)
- **Evaporation data:** a modelled approach (combination of the Penman-Monteith method with a deBruin adjustment; recommended by the CSIRO) to assessing evaporation at the wetland has been incorporated into the water balance (McJannet *et al*. 2009).

[5] Concentration of salts by evaporation
[6] FSL defined by overflow sill elevation

Please note:

- *Groundwater is not included in the model (Gippel 2010). While groundwater may contribute in some circumstances it is not readily quantifiable or not easily factored into the model.*
- *In addition, the modelling does not consider water diversion/extraction from Lake Leaghur as part of the overall surface water balance.*
- *The model has been set up so as to manage water levels at a single target level (85.85 m AHD). Therefore, it is not possible to model fluctuating water levels (different target levels) over time in order to test various management scenarios.*

The modelling produces a range of volumes required to operate the wetland in accordance with the optimal regime specified in Section 5.3. The modelling results for Lake Leaghur are presented in Section 5.3 and Appendix G.

4.5. Operational uses

Lake Leaghur has in the past been designated for water supply, regulation and drainage in accordance with the Land Conservation Council's recommendations for the use of public land (LCC 1988). This designation requires that the wetland is managed for storage and distribution of irrigation and domestic water, flood mitigation, and disposal of drainage water. The wetland was previously used as an operational outfall.

Water levels in Lake Leaghur are determined by the height of the overflow sill situated to the north of the wetland which is at 85.85 m AHD (Price Merrett Consulting 2006). At this height, the maximum depth of Lake Leaghur is 1.35 m. Above 85.85 m, water quality would be maintained by through flow. Below this height, water is lost predominately through evaporation.

An opportunistic diversion licence is held by a landholder adjoining Lake Leaghur. This licence permits the extraction of 170 ML per year from Lake Leaghur (NCCMA 2008). The conditions of the diversion licence are discussed further in Sections 6 and 7.

No operational plans or guidelines exist for Lake Leaghur. However, an Environmental Assessment prepared by SKM in 2001 made recommendations for the management of the wetland in association with using it as a buffer storage (reharvesting outfalls).

4.5.1. Flood mitigation

Lake Leaghur maintains an ability to receive flood flows from the Loddon River and Wandella Creek via a breakaway that enters the wetland to the south (Figure 3). In addition, it can receive flood flows from the Lake Lyndger floodway during larger floods (approximately one in 15 year events or bigger based on floods prior to the onset of current drought conditions such as those that occurred in 1993, 1983 and 1975) (pers. comm. Graham Hall [NCCMA], 14 January 2010).

Like many of the districts wetlands the height of the outlet was initially raised to increase the retention capacity of the wetland and access to stock and domestic water. In 1996, the outlet was lowered by approximately 20 to 30 cm to mimic the natural FSL as part of the Boort West of Loddon Land and Water Management Plan (Appendix B).

4.5.2. Drainage

Lake Leaghur is situated relatively high in the landscape and is surrounded by constructed levees. As such, it virtually has no local catchment area except for irrigation run-off after rainfall. However, as there is very little irrigation in the area it is anticipated that there is little to no runoff from local rainfall (pers. comm. Graham Hall [NCCMA], 14 January 2010).

5. Management objectives

Previously, Lake Leaghur has been managed as a water supply reserve with the primary objective of storing and distributing water for irrigation and domestic purposes. However, numerous recommendations have been made in order to provide a water regime that protects and enhances environmental values supported by the wetland (Ecos Environmental Consulting 2007).

Table 6 provides information on the proposed management objectives and water regime outlined in previous reports for Lake Leaghur.

Table 6: Previous management recommendations

Source	Objectives	Duration	Timing	Frequency
Ecos Environmental Consulting 2007	River Red Gum Open water habitat Waterbirds	4 months.	Late winter/ spring	Every 2 to 3 years flood Lake Leaghur to the upper part of the River Red Gum zone.

5.1. Water management goal

The water management goal for Lake Leaghur has been derived from a variety of sources including previous management goals, local expertise and knowledge and has been appraised by agency stakeholders and technical experts (wetland workshop, Appendix A, Table A2). In determining the water management goal, consideration has also been given to water availability, feasibility of delivery and additional limitations. The goal takes into consideration the values the wetland supports and potential risks that need to be managed.

Lake Leaghur water management goal:
Support a diversity of flora and fauna typical of a deep freshwater marsh[7], in particular providing key waterbird habitat (breeding and nesting) within a Red Gum Swamp (EVC 292).

5.2. Ecological objectives and hydrological requirements

Ecological objectives and hydrological requirements have been identified in determining a desired water regime to support high environmental values supported by Lake Leaghur (Table 7). The process for identifying ecological and hydrological objectives closely follows that recommended in FLOWs: a method for determining environmental flow requirements in Victoria (DNRE 2002). The ecological objectives outline the outcomes desired from delivery of the desired water regime.

Water dependent environmental values including habitat, species/communities and processes were identified from local anecdotal information, relevant reports, condition assessments, and records (such as the Flora Information System and Atlas of Victorian Wildlife databases).

Objectives were identified for each of the values in terms of the physical conditions (habitat objectives), species and/or biota (biodiversity objectives), and biological processes (process objectives) needed in order to achieve the water management goal.

Habitat objectives identify habitat components considered critical in achieving the water management goal. While it is recognised that each habitat component will attract an array of fauna species, examples of previously recorded listed species, whose habitat requirements closely align with a specific component, have been provided as potential indicator species. Those species and communities of international, national and state conservation significance were given highest priority as were those that are indicative of integrated ecosystem functioning.

The objectives are expressed as one of four types of target, which are related to the present condition/functionality of the value:

- Reinstate – no longer considered to occur
- Restore/rehabilitate – severely impacted and only occur to a reduced extent

[7] Deep freshwater marshes are generally less than 2 m deep and are inundated for longer than 8 months of the year (DCFL 1989b)

- Maintain – not severely impacted but are desirable as part of the ecosystem
- Reduce – have increased undesirably at the expense of other values.

Hydrological requirements describe the water regimes required for achieving ecological outcomes (ecological objectives) (DNRE 2002). All values identified have components of their life-cycle or process that are dependent on particular water regimes for success e.g. colonially nesting waterbirds require certain timing, duration and frequency of flooding to successfully breed and maintain their population. Requirements for the three characteristics of a water regime[8] were identified and described for all of the ecological values (Campbell, Cooling & Hogan 2005).

The ecological objectives and hydrological requirements for Lake Leaghur were developed in conjunction with agency stakeholders and technical experts at the Wetland Workshop held on 17 December 2009. The ecological objectives and hydrological requirements were reviewed in 2015 in consultation with GMW, the CMAs, DELWP and Parks Victoria. The review found that the ecological objectives and hydrological requirements were still appropriate for Lake Leaghur (GMW 2015).

Table 7: Lake Leaghur proposed ecological objectives and hydrological requirements

Ecological objective	Justification	Hydrological requirement
1. Habitat objectives		
1.1 Maintain the health and restore the distribution of River Red Gum vegetation (EVC 292) • Maintain health of existing trees • Provide opportunities for recruitment across a greater range of elevations	River Red Gum trees provide hollows, fallen branches and shading for habitat, and provide a source of seed for recruitment.	Inundate to FSL (85.85 m AHD) one in three years for three to six months[9].
1.2 Maintain emergent aquatic plant community (EVC 821) persisting at the channel outfall	Provides habitat for waterbirds (e.g. Clamorous Reed Warbler), frogs and macro- and micro-invertebrates	Inundate one in three years for three to six months. Note If a one in three year inundation period is unfeasible, consideration should be given to providing small pulse flows every year to maintain this aquatic refuge
1.3 Restore diverse aquatic and amphibious plant communities	Aquatic and amphibious plants provide habitat and food sources for birds (e.g. Hardhead, Musk Duck), frogs and invertebrates.	Aquatic and amphibious plants are likely to respond to the one in three years inundation provided for Objective 1.1
2. Species/community objectives		
2.1 Restore Cane Grass populations	Listed as a vulnerable species in Victoria. Only a very small population was evident to the south of the wetland amongst the River Red Gum	Expand Cane Grass populations by inundating one in three years for one to six months
2.2 Establish breeding opportunities for waterbirds, frogs and invertebrates: • e.g. Little Pied Cormorants, Ducks, Great Egret[10]	Linked to habitat objectives. Providing a variety of habitat types and high productivity of micro and macro-invertebrates and plant species through a wetting and drying cycle should enable breeding opportunities.	Fill in spring and provide top-ups (where necessary) to extend duration to seven to ten months if breeding is observed.

[8] Timing, frequency and duration

[9] Refer to Appendix K: for comparison of bathymetric information and vegetation mapping.

Ecological objective	Justification	Hydrological requirement
2.3 Maintain a viable seed and egg bank	Seed and egg banks provide a source of survival for invertebrates and macrophytes in temporary wetlands during dry periods. These habitat and food sources in turn support higher order consumers such as waterbirds, frogs and fish.	Enable the establishment of aquatic and amphibious plant communities and micro and macro-invertebrate communities and maintain suitable habitat long enough to complete life cycles. Duration variable and seasonally dependent, but maintaining inundation for at least three to six months, one in three years is recommended.
3. Process objectives		
3.1 Restore connectivity between river, floodplain and wetland	Connectivity facilitates dispersal and movement of plant propagules, micro and macro-invertebrates and fish, as well as nutrient and carbon cycling.	During times of 'natural' flood provide 'top-up' environmental water to inundate the floodplain remnants to the southeast and north (extending into Leaghur State Park to reach stands of Black Box)

5.3. Desired water regime

A desired water regime has been defined for Lake Leaghur and is presented below. This regime is based on the ecological objectives and hydrological requirements outlined in Section 5.2.

Figure 10 illustrates the various components of the wetland (e.g. River Red Gum, aquatic refuge of tall marsh vegetation, open water, aquatic and amphibious plant species) that are being targeted by the water regime.

Timing: Winter/spring

Frequency of wetting: Minimum: one in five years

Optimum: one in three years

Maximum: one in two years

Note: consideration should be given to providing small pulse flows every year to maintain the aquatic refuge currently existing at the channel outfall (refer to objective 1.2)

Duration: Fill in winter/spring; allow to evaporate and dry completely over 18 months

Variable duration: three to six months in Red Gum Swamp (EVC 292) and aquatic plant communities. Inundate Cane Grass population to the south of the wetland for one to six months. Where possible flood the Lignum Swampy Woodland (EVC 823) to the south and north (into Leaghur State Park) for two to three months ideally one in six years though frequency may be dependent on availability of water and delivery method.

Extent and depth: Fill to FSL (1.35 m at 85.85 m AHD) in winter/spring and allow natural draw-down.

Variability: High. Variability in flood extent may assist in distribution of Red Gum seed across the wetland to allow for germination of seedlings across a greater range of elevations and avoid the 'fringe' effect.

Wetland water regime
Fill to FSL (1.35 m at 85.85 m AHD) to inundate River Red Gum Swamp (EVC 292) one in three years. Allow natural draw-down over 18 months[11]. Enable variability in depth (flood extent) to facilitate germination of River Red Gum seedlings across the wetland. Ensure water inundates Cane Grass population for one – six months, one in three years.

[10] Known to breed in Leaghur State Park (Parks Victoria 1998)

[11] This corresponds with the regime described for deep freshwater marshes which are less than 2 m deep and are inundated for longer than 8 months of the year (and can be permanent)

Please refer to the figures in Appendix G for the modelled desired water regime.

Encourage natural flooding and, where a delivery method is available, inundate the remnant floodplain woodland to the south and inundate into Leaghur State Park to the north to support Lignum Swampy Woodland (EVC 823) communities and restore connectivity between the wetland and floodplain. Ensure no blockages or interference occurs in feeder creeklines.

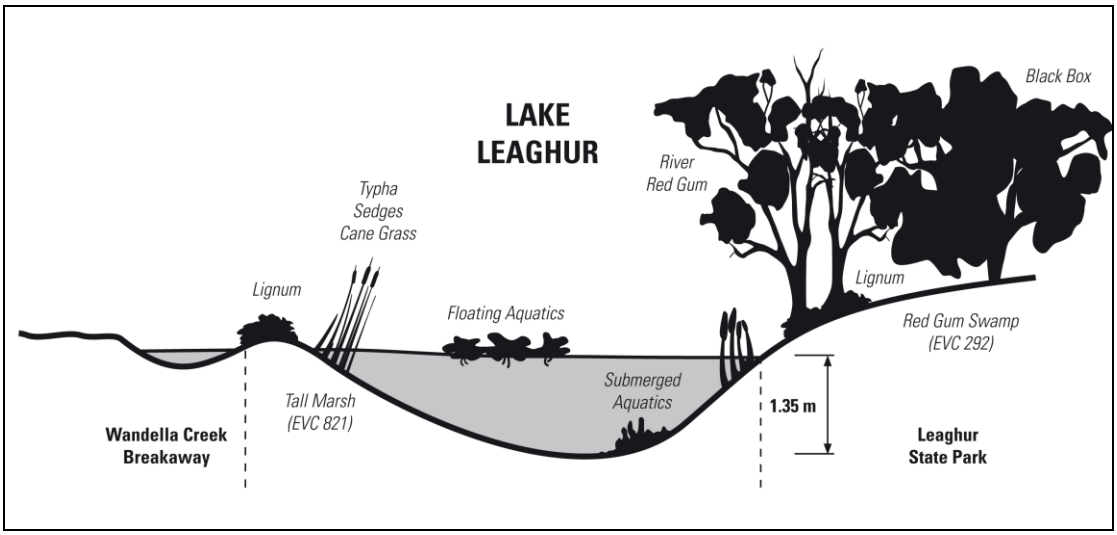

Figure 11: Schematic of wetland areas to be targeted (not to scale)

The volumes of water required to provide the desired water regime for Lake Leaghur are presented in Table 8. These volumes reflect the results from the SWET modelling (model described in Section 4.4 and results presented in Appendix G) are based on filling Lake Leaghur to 85.85 m AHD.

Table 8: Volumes required to provide the desired water regime for Lake Leaghur (SWET modelling output)

Result	
Mean long-term (LT) annual controlled inflow requirement	447 ML/year
95th percentile of mean LT annual controlled inflow requirement	1,377 ML/year
Average LT controlled inflow requirement for filling periods	1,319 ML
Record length	118
No. of periods	40
Years with no inflow	78 in 118
No. of draw downs over record	40
No. of draw downs not fully drawn down	0
% of draw downs not fully drawn down	0%
95th percentile duration of full period (months)	5.5
50th percentile duration of full period (months)	4.9

A brief description of each the main results follows:

- **Mean long-term annual controlled inflow requirement**: the total amount of water required to be delivered into the wetland annually in a controlled fashion to achieve the specified level and the desired regime (excluding natural inflows from rainfall and local catchment runoff). This is the average over the modelled period, which may include years with zero water required (e.g. for a one in three year water regime, water is only required in year one). A mean long term annual volume of 447 ML to fill Lake Leaghur to 85.85 m AHD.
- **95th percentile of mean long-term annual controlled inflow requirement**: an estimate of the maximum volume ever likely to be required over any 12 month period (1,377 ML).
- **Average long-term controlled inflow requirement for filling period:** the total amount of water required to be delivered to the wetland in a controlled fashion to achieve the desired water level regime for the recommended cycle (i.e. every year).

This excludes natural inflows from rainfall and local catchment runoff. Therefore, the volume required to fill Lake Leaghur to 85.85 m AHD would be approximately 1,319 ML.

Please note: due to the variability of inflows to the wetland, particularly in response to current climate conditions, determination of inflows from local rainfall and runoff in any one year will need to be undertaken by the environmental water manager when watering is planned. Surface water inflows to Lake Leaghur and rainfall will vary considerably from year to year, depending on seasonal conditions.

5.4. Mitigation water

The volume of water that is required to offset the impact of the GMW Connections Project on wetlands that have become reliant on this water to support high environmental values is termed 'mitigation' water. The potential impact of the GMW Connections Project considered in the Lake Leaghur EWP is related mainly to a reduction in outfalls. Other potential impacts to the wetland will be managed in accordance with the Water Change Management Framework and Site Environmental Management Plans.

Guiding principles for mitigation water based on government policy were defined by the Water Change Management Framework and are:

1. Water savings are the total (gross) volumes saved less the volume of water required to ensure no net impacts due to the project on high environmental values
2. Using the same baseline year (2004–05) as that used to quantify savings, taking into account the long-term average annual patterns of availability.
3. The mitigation water will be deployed according to the EWP.
4. Sources of mitigation water will be selected to ensure water can be delivered in accordance with the delivery requirements as specified in the EWPs. Water quality will need to be considered for all sources of water to ensure it is appropriate.

In the majority of cases, actual outfall volumes are less than what is required to support all water-dependent environmental values of a particular wetland. Therefore, the outfall water only forms part of the overall volume required to provide the water regime of the wetland. The water regime supports processes and systems which in turn provide suitable conditions for defined ecological values (e.g. breeding of waterbirds).

A process for calculating mitigation water based on the best available information involves the application of a series of steps that includes:

Step 1: Describe the desired water or flow regime

Step 2: Determine the baseline year incidental water contribution

Step 3: Assess dependency on baseline incidental water contributions

Step 4: Calculate the annualised baseline mitigation water volume (BMW)

Step 5: Calculate the mitigation water commitment

Step 6: Calculate the LTCE mitigation water volume

5.4.1. Lake Leaghur mitigation water

Step 1: Describe the desired water or flow regime

The desired water regime for Lake Leaghur is filling to FSL one in three years. Further detail is provided in Section 5.3.

The total volume required to provide this three year cycle is 1,319 ML. The 95% percentile mean annual volume required equates to 1,377 ML.

Step 2: Determine the baseline year incidental water contribution[12]

[12] Incidental water contributed in the baseline year for each hydrological connection i.e. outfall water, seepage and leakage of a supply channel within 200m of the wetland.

This step determines the baseline year incidental water for each hydrological connection assessed (e.g. outfalls, leakage and seepage) and the incidental water contribution both as it leaves the irrigation system and as it arrives at the wetland.

Leakage and seepage have not been accounted for within the following steps. Preliminary calculations to estimate the potential contributions to Lake Leaghur from leakage and seepage from the no. 2/2 channel were completed based on the localised impact assessment method outlined in the Water Change Management Framework (GMW 2013). The results indicate that a range of 2 ML/year to 7 ML/year may be received by Lake Leaghur (Appendix H). However, any future GMW Connections Project actions to address leakage and seepage (i.e. lining the main supply channel or decommissioning any channels within 200 m of the wetland), will trigger a re-calculation in accordance with the Water Change Management Framework (GMW 2013).

Therefore, only one hydrological connection (outfalls) is included within the mitigation water calculations and the potential contributions from leakage and seepage are excluded.

The baseline year (2004-05) outfall volume recorded at the regulating structure was 174 ML, refer to Section 4.1. Lake Leaghur received outfall water directly, via a short delivery channel supporting Tangled Lignum and Black Box vegetation. Therefore, 100% of this outfall is estimated as having contributed to the wetland's water balance in 2004-05.

The determination of the baseline year incidental water contribution is provided in Table 9.

Table 9: Determination of the baseline year incidental water contribution determination

Hydrological connection or incidental water source (e.g. Outfall #)	Baseline year incidental water at origin (Gross) (ML)	Estimated losses between origin (irrigation system) and wetland (for baseline year) (ML)	Baseline year incidental water contribution at the wetland (Net) (ML)
Outfall #ST025235	174	0	174

Step 3: Assess dependency on baseline incidental water contributions

The Water Change Management Framework (GMW 2013) specifies the criteria (Table 10) to be applied in assessing whether mitigation water is required for a wetland or waterway with high environmental values. The criteria have been assessed for Lake Leaghur with the results presented in Table 10.

Table 10: Mitigation water dependency assessment

Criteria by which mitigation water may be assessed as not required	Link between incidental (losses) and environmental values
1. Mitigation water may be assessed as not required where:	
1.1 There is no hydraulic connection (direct or indirect) between the irrigation system and the wetland or waterway	Outfall water is received directly by Lake Leaghur.
1.2 The water does not reach the wetland or waterway with environmental values (e.g. the outfall is distant from the site and water is lost through seepage and evaporation before reaching the area with environmental values)	There are no impediments or diversions to the outfall water being received by the wetland. 100% of the outfall recorded in 04/05 contributed to the surface water balance of the wetland.
2. Mitigation water may be assessed as not required where the wetland or waterway receives water from the irrigation system:	
2.1 That is surplus to the water required to support the environmental values (e.g. changing from a permanently wet to an intermittently wet or ephemeral regime is beneficial or has no impact)	In the years that qualify for mitigation water (i.e. one out of three), the wetland does not have more water than is required to support the desired state of the environmental values, even if operated under a drier regime. It is currently dry.
2.2 That occurs at a time that is detrimental to the environmental values	Losses generally occur between September and May. The proposed water regime recommends inundation and draw-down over an 18 month period. Losses are not considered to have detrimental impacts on the high environmental values at Lake Leaghur.
2.3 That is of poor quality (or results in water of poor quality entering a site e.g.	Losses (Irrigation outfalls) are of acceptable water quality, although the turbidity of water could be an issue for aquatic

Criteria by which mitigation water may be assessed as not required	Link between incidental (losses) and environmental values
seepage resulting in saline groundwater intrusions to wetlands) and the removal of which would lead to an improvement in the environmental values	plant growth.
3. Mitigation water may be assessed as not required where the environmental values:	
3.1 Do not directly benefit from the contribution from the irrigation system (e.g. River Red Gums around a lake may not directly benefit from an outfall and may be more dependent on rainfall or flooding)	The losses reach the wetland (direct outfall) and maintain a refuge for aquatic plants (e.g. *Typha* sp.), which enhances opportunities for recolonisation of the wetland when filled to FSL.
4. Mitigation water may be assessed as not required where the removal of the contribution from the irrigation system does not:	
4.1 Increase the risk of reducing the environmental values (e.g. outfalls form a very small proportion of the water required to support the environmental values and their removal will not increase the level of risk)	If outfall volumes were reduced or removed, additional water would need to be secured for: • Filling the wetland to FSL • Providing pulse flows to maintain the aquatic refuge if greater volumes of water are not available (e.g. environmental entitlement)
4.2 Diminish the benefits of deploying any environmental water allocations (over and above the contribution from the irrigation system)	If outfall volumes were reduced or removed, additional water would need to be secured for: • Filling the wetland to FSL • Providing pulse flows to maintain the aquatic refuge if greater volumes of water are not available (e.g. environmental entitlement)

The assessment process for the calculation of mitigation water for Lake Leaghur demonstrates that the **incidental outfall water provides benefit to the wetland and that the provision of mitigation water is warranted**. Outfalls in the baseline year equate to 39% of the of the mean long term annual inflows required to provide the desired water regime (447 ML). If the volume of outfall water was to be reduced or removed additional water would need to be secured to maintain the wetland's environmental values (specifically waterbird habitat). At Lake Leaghur mitigation water is required one in three years in order to maintain the environmental values. When the wetland is in a dry phase, no mitigation water is required.

Step 4: Calculate the annualised baseline mitigation water volume (BMW)

The BMW volume is expressed as the baseline incidental water contributions divided by the number of years in the cycle of the desired water regime.

As there are no losses associated with transmission, the annualised baseline mitigation water volume has been calculated at Outfall #ST025235 (gross).

Gross BMW

$$= \frac{\text{Baseline year incidental water contribution at origin}_{(Gross)} \text{ (Step 2)}}{\text{The inherent cycle (years) of the desired water regime (Step 1)}}$$

= 174 ML / 3 (one in three years)

= 58 ML

Step 5: Calculate the mitigation water commitment

The MWC expresses the BMW (Step 4) as a percentage of the baseline incidental water contribution. It is used to calculate the share of annual water savings. These are calculated each year in accordance with the Water Savings Protocol and the associated Technical Manual (DSE 2009g) and will become available in any following year.

MWC (%)

$$= \frac{\text{BMW}_{\text{(Lake Leaghur 2004/05)}} \text{ (Step 4)}}{\text{Baseline incidental water contributions at origin}_{(Gross)} \text{ (Step 2)}}$$

= (58/174) x 100

= 33%

The overall MWC for Lake Leaghur is 33%.

Step 6: Calculate the LTCE mitigation water volume

The LTCE mitigation water volume is used to account for mitigation water when reporting against the net savings target. This volume is calculated by multiplying the mitigation water commitment (Step 5) by the baseline mitigation water volume (Step 4) and the LTCE conversion factor.

Please note: Calculation and confirmation on the LTCE conversion factor is required from DELWP. This will be decided at or near the end of the GMW Connections Project.

5.5. Other water sources

The annualised baseline mitigation water volume only represents 13% of the mean long-term annual volume of water required to deliver the desired water regime (447 ML). GMW Connections Project is only accountable for mitigating any potential impact from the project i.e. for provision of mitigation water as a proportion of the total outfall, seepage and leakage volumes received by the wetland if they are supporting high environmental values. As such, it is important that the environmental water holder secures additional sources of water in years when water is proposed to be filled. The most likely additional sources of water will be existing and future environmental entitlements.

Potential sources of environmental water to provide the desired water regime to Lake Leaghur are discussed below.

5.5.1. Murray flora and fauna bulk entitlement

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 (DSE 2006). Each year, a prioritisation process is used to decide on the best use of the available water (based on River Murray allocations). An annual distribution program identifies wetlands that will receive a portion of the entitlement utilising a decision flowchart (DSE 2006). As of 2011, the Victorian Environmental Water Holder is responsible for allocating water to environmental assets where required.

5.5.2. 75 GL environmental entitlement

Water savings generated by GMW Connections Project will provide up to 75 GL to be vested in the Victorian Environmental Water Holder as an Environmental Water Entitlement. This environmental water is in addition to Government's commitments to provide water for the Living Murray process and will be used to help improve the health of stressed wetlands and waterways in Northern Victoria and the River Murray (NVIRP 2010).

In addition, Stage 2 of GMW Connections Project will generate up to 200 GL of water savings, which will be allocated to the environment. This water will be available for use across the Murray Darling Basin.

5.5.3. Commonwealth environmental water

Under Water for the Future the Australian Government has committed to purchase water in the Murray-Darling Basin over 10 years. The program will complement a range of other measures to address sustainable water management in the Basin. The Commonwealth Environmental Water Holder, in DoE, will manage the Commonwealth's environmental water.

The *Water Act 2007* provides 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 of International Importance (Ramsar wetlands) are considered priority environmental assets for use of the Commonwealth environmental water (DEWHA 2008). Whilst Lake Leaghur is not a wetland of international importance, it is a refuge for species listed under other international conventions. A case for the receipt of Commonwealth environmental water could be made.

6. Potential risks or adverse impacts

An important component of the EWPs is the identification of potential risks, limiting factors and adverse impacts associated with the delivery of the desired water regime. The annualised baseline mitigation water volume represents 13% of the mean annual volume of water required (447 ML). Awareness of the potential risks and impacts will influence future intervention and long-term condition monitoring undertaken at Lake Leaghur, and will inform adaptive management of the water regime and the provision of mitigation water (Section 8).

Table 11 outlines the risks, limiting factors and potential impacts associated with the provision of mitigation water as a component of the desired water regime that need to be considered by GMW Connections Project and the environmental water manager.

Appendix I outlines a range of additional risks and limiting factors identified which may arise as a direct result of, or in association with, implementing the desired water regime at Lake Leaghur. It is envisaged that these additional risks and limiting factors will be considered in the future management of the lake (i.e. management plan).

Mitigation measures are recommended to minimise the likelihood or the risk occurring and/or its potential impact.

Table 11: Potential risks, impacts and mitigation measures associated with provision of mitigation water at Lake Leaghur

Risks/limiting factors	Impacts	Mitigation measures
Limited water availability (i.e. other water sources are unable to be secured to provide the desired water regime)	Failure to achieve identified objectives and goal Loss of water dependent species at outfall point	Consider using mitigation water to provide small pulse flows to maintain aquatic refuge in times where the optimal regime is limited by water availability.
Ineffective delivery	Inability to deliver water in order to achieve objectives and water management goal	Ensure capacity of 60 ML/day (or suitable agreed delivery rate) is maintained if an alternative outfall point is established through rationalisation. Ensure that the delivery capacity is sufficient to facilitate delivery of required volumes at critical times (e.g. delivery share).
Opportunistic diversions (equating to 170 ML)	Artificial lowering of water level threatening achievement of identified objectives and goal. Using environmental water for consumptive use.	Investigate options for alternative supply.
Future irrigation modernisation actions inhibit significant leakage and seepage loss contributions	Loss of high environmental values. Failure to achieve identified objectives and overall water management goal	If future actions are likely to impact seepage and leakage loss contributions (i.e. lining or decommissioning any channels within 200 m of the wetland) detailed analysis of the loss contributions is required and incorporated into the mitigation water recommendations.

7. Water delivery arrangements

Lake Leaghur receives outfalls from channel 2/2 via a short outfall delivery channel (Figure 11). The outfall channel has a capacity of 60 ML/day. The outfall regulating structure is fully automated and also has a capacity of 60 ML/day (Hillemacher and Ivezich 2008).

The outlet is characterised by an overflow sill located to the north of Lake Leaghur. It has an elevation of 85.85 m AHD which determines the storage capacity at FSL of 664 ML (Price Merrett Consulting 2006). From the outlet, water travels north along Stringers Lane, through Leaghur State Park and into Lake Meran via natural inlets (SKM 2001).

At a flow rate of 60 ML/day it would take approximately 11 days to fill Lake Leaghur from empty, assuming that there are no losses and operating at full capacity (Hillemacher and Ivezich 2008).

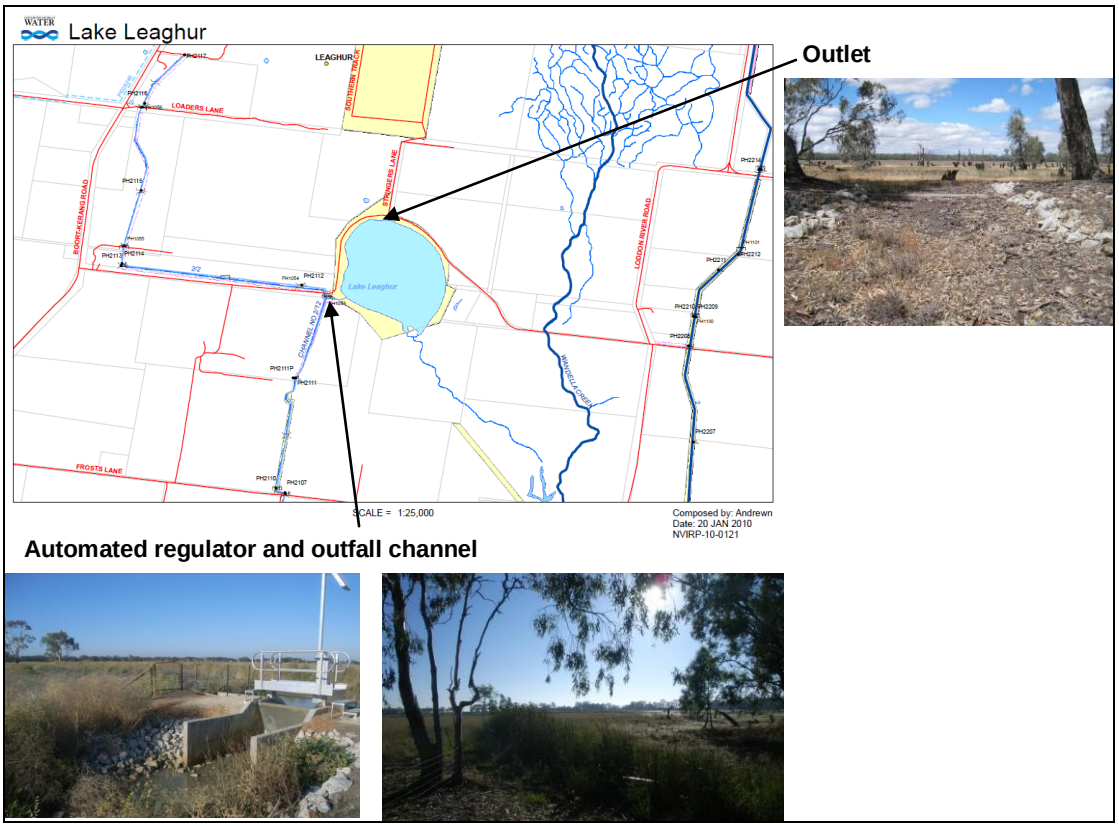

Figure 12: Lake Leaghur Infrastructure

7.1. GMW Connection Project works program – channel 2/2

The Stage 1 GMW Connections Project works program includes delivering an automated backbone for the water distribution system, rationalising spur channels, connecting farm water supply to the backbone and upgrading metering on up to 50% of customer supply points in the GMID.

The Pyramid-Boort No. 2/2 channel is the backbone within the vicinity of Lake Leaghur. GMW Connections Project is currently investigating the rationalisation of 9 km of Channel 2/2 as part of the Connections Program. GMW Connections Project is responsible for "retain(ing) infrastructure and improving where practicable, where it will be required for delivering environmental water…." (GMW 2013). Lake Leaghur is currently receiving water from the channel 2/2 supply point, however, plans are being developed to provide an alternative supply point, due to rationalisation of channel 2/2. GMW Connections Project will ensure that a suitable alternative supply point will be provided including a reported capacity of 60 ML/day (or an agreed delivery rate).

Alternative supply options currently being considered include:

- Diverting water from channel 2 (which has a capacity of 350 ML/day) approximately 2-3 km west towards Lake Leaghur. The alternative option would cross the Wandella Creek (bore underneath) and outfall into the breakaway that feeds into the wetland to the south. The estimated cost for these works is $800,000. Please refer to Figure 13.

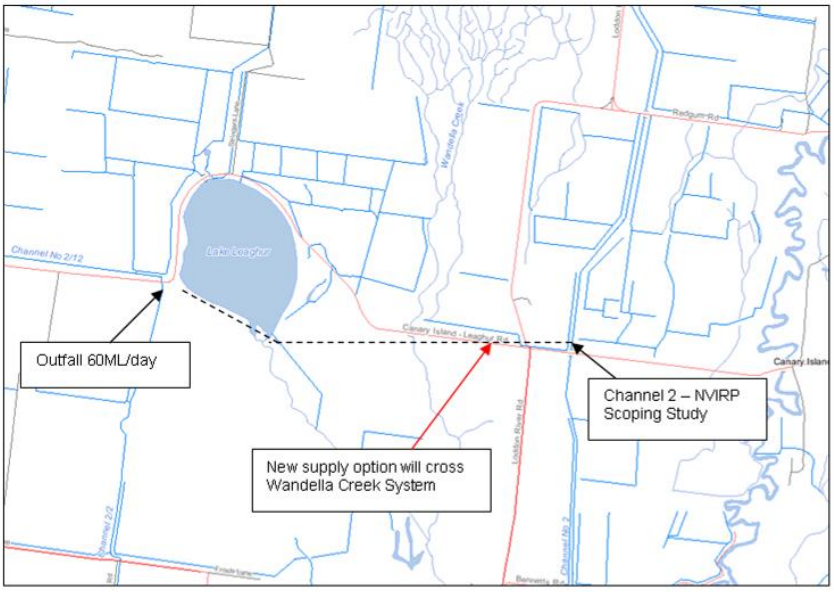

Figure 13: Lake Leaghur potential alternative supply option

7.2. Infrastructure requirements

Under the current infrastructure arrangements Lake Leaghur can receive up to 60 ML/day from channel 2/2 via a fully automated regulator. However this is dependent on sufficient capacity being available within channel 2/2. At a rate of 60 ML/day it would take 11 days to fill Lake Leaghur, not accounting for any losses. The desired water regime recommends filling the wetland to FSL one in three years and providing top-ups when required to support waterbird breeding events. Therefore:

- The current delivery infrastructure is considered adequate to deliver the desired water regime and no infrastructure upgrades are recommended as part of GMW Connections Project.

However, if channel 2/2 is rationalised GMW Connections Project will be responsible for providing suitable alternative supply arrangements including:

- The reported capacity of 60 ML/day (or an agreed suitable delivery rate) is to be provided if a new supply point is adopted.

Additional infrastructure upgrades may be required depending on the agreed option and will need to be readdressed once alternative supply and governance arrangements are agreed upon.

In addition, Common Carp (*Cyprinus carpio*) are abundant within the GMW channel system and there is currently no carp screen between the channel system and Lake Leaghur. Carp are known to have significant detrimental impacts on wetlands by increasing the turbidity of the water, preventing the establishment of aquatic vegetation and competing with native species.

It is recommended that a carp screen is installed to prevent larger carp entering the wetland. A screen with a spacing size of 50 mm would minimise blockage while restricting the passage of large breeding sized carp (SKM 2005). Although it would not totally exclude the passage of carp it will significantly reduce the population size, facilitating regeneration of wetland vegetation. A carp screen is seen as a beneficial upgrade to Lake Leaghur, particularly as the desired water regime encourages a dry phase of approximately 18 months rather than permanent inundation.

The following should be considered prior to installation:

- The screen should be positioned to prevent fish entrainment.
- It should be designed to rotate about a vertical axis (to clear any weed or debris accumulating).
- It should be fitted so it can be easily removed and readily accessible.
- Regular maintenance will be required during regulator operation to prevent blockages.
- Installation will reduce the hydraulic capacity of the regulator (SKM 2005).

Costs for a carp screen range from $5,000 to $20,000 depending on size, functionality and installation requirements. These additional works are outside the scope of GMW Connections Project.

8. Adaptive management framework

A key GMW Connections Project principle is that an adaptive management approach is adopted to ensure an appropriate response to changing conditions (Section 9.4, GMW 2013).

Adaptive management is a continuous management cycle of assessment and design, implementation, monitoring, review and adjustment. Table 12 shows how the adaptive management approach will be applied in the context of this EWP.

Table 12: Adaptive management framework

Adaptive management phase	Application to this EWP (Responsible agency)	When (Sections 15 and 19, GMW 2013)
Assessment and design	Assessment identifies environmental values, their water dependencies, and the potential role of incidental water. Design determines the desired water regime to support environmental values and determines any mitigation water commitment. Details of both these phases are documented in this EWP. (GMW Connections Project)	2010
Implementation	Implementation is the active management of environmental water, of which mitigation water may form a portion, consistent with this EWP. (North Central CMA)	Continuous
Monitoring (and reporting)	Monitoring is gathering relevant information to facilitate review and enable any reporting obligations to be met. Two types of monitoring are required. Compliance monitoring is checking that the intended water regime is applied. Performance monitoring is used to inform the review of the effectiveness of the mitigation water contribution to achieving the water management goal by monitoring individual ecological objectives. (North Central CMA).	Annual
Review	Review is evaluating actual results against objectives and identifying any improvement opportunities which may be needed. (GMW Connections Project, until responsibilities transferred to other agencies)	2015, 2020, 2025, etc
Adjustment	Adjustment is determining whether changes are required following review or after considering any new information or scientific knowledge and making any design changes in an updated version of the EWP. (GMW Connections Project, until responsibilities transferred to other agencies, adjustment is limited to the extent that the new information relates to the impact of the GMW Connections Project at the time of the impact occurred, and only insofar as the new information could change the mitigation outcomes).	2015, 2020, 2025, etc

8.1. Monitoring and reporting

It is assumed that if mitigation water is supplied in accordance with the desired water regime proposed within the EWP then environmental values potentially impacted by GMW Connections Project will be maintained. GMW Connections Project will report, annually, on the contribution, or provision, of "GMW Connections Project Mitigation Water" towards achieving the water regime (Section 18, GMW 2013). This will be done through liaison with other agencies in relation to monitoring and then reporting whether:

- Mitigation water was available for delivery to the wetland or waterway

- A decision was made that water was required for the wetland or waterway for that year
- Mitigation water was delivered to the wetland or waterway in accordance with the desired water regime proposed within the EWP (i.e. quantity, timing, duration, frequency)
- The ecological objectives were achieved or are being achieved

It is expected the CMA will monitor environmental water delivery (i.e. quantity, timing, duration and frequency). GMW Connections Project will not implement a detailed monitoring program. It is beyond the scope of this EWP to provide a detailed monitoring program to determine the effectiveness of the desired water regime in achieving ecological objectives and the water management goal.

However, Appendix J provides some suggested components identified during the preparation of this EWP to be considered in preparing a monitoring program for the wetland.

8.2. Review

Periodic reviews provide the opportunity to evaluate monitoring results in terms of compliance, ecological objectives and to learn from implementation.

As per the requirements of the WCMF, it is expected this EWP will be reviewed in 2015, 2020 and every five years thereafter, or at any time, if requested by the Victorian Minister for Water or Commonwealth Minister for the Environment (Sections 15 and 19, GMW 2013). The GMW Connections Project is responsible for reviews until such time as responsibility is transferred.

8.3. Adjustment

Adjustments may be made to:

- operational management
- management hypotheses and, perhaps, to ecological objectives
- cope with unexpected issues.

These adjustments will be incorporated into the EWP.

9. Governance arrangements

A summary of the roles and responsibilities of the various bodies relating to the delivery and review of management and mitigation measures is provided in Table 13 (GMW 2013). The table outlines the roles and responsibilities before and during the implementation of GMW Connections Project in the modified GMID.

Table 13: Roles and responsibilities

Agency	Assess and develop management and mitigation measures	Deliver and review management and mitigation measures during GMW Connections Project implementation
GMW Connections Project (until such time as responsibility is transferred)	• identify and account for water savings, subject to audit by DELWP accredited auditor • Lead the assessment and development processes for management and mitigation measures including developing and gaining approval to the WCMF (which guides the development of EWPs and the assessment of mitigation water). • Maintain short-list of all wetlands, waterways and groundwater dependent ecosystems for mitigation. • Identify and source mitigation water required to implement management and mitigation measures including the adaptive development of EWPs. • Retain or provide infrastructure to deliver water to wetlands and waterways. • Convene and chair the Environmental Technical Advisory Committee. • Convene the Expert Review Panel	• Apply, review and, as necessary, develop amendments and gain approval to updated versions of the WCMF. • Provides resources to enable monitoring and review of management and mitigation measures • Establish protocols for transfer of responsibility to relevant agencies. • Coordinate with other agencies to deliver management and mitigation measures. • Arrange for the provision of delivery and measurement infrastructure including capacity and operational flexibility for mitigation water.
Catchment Management Authority	• Identify and inform GMW Connections Project of opportunities for best practice. • Inform GMW Connections Project of its infrastructure requirements to deliver environmental water.	• Advise Environmental Water Holder and system operator on priorities for use of environmental entitlements (including mitigation water) in line with recommendations outlined in the EWPs • Implement the relevant components of Environmental Watering Plans.

Agency	Assess and develop management and mitigation measures	Deliver and review management and mitigation measures during GMW Connections Project implementation
	• Participate in the Environmental Technical Advisory Committee. • Agree to implement relevant components of Environmental Watering Plans. • Agree to implement other relevant regional management and mitigation measures required due to the implementation of GMW Connections Project.	• Operate, maintain and replace, as agreed, the infrastructure required for delivery of mitigation water, where the infrastructure is not part of the GMW irrigation delivery system. • Report on environmental outcomes (e.g. wetland or waterway condition) from the delivery of the water, in the course of normal reporting on catchment condition. • Where agreed conduct the periodic review of EWPs and report results to GMW Connections Project. • Manage and report on other relevant catchment management and mitigation measures required due to the implementation of GMW Connections Project.
Land Manager (Public and private as relevant)	• Identify and inform GMW Connections Project of opportunities for best practice. • Participate in the Environmental Technical Advisory Committee. • Agree to implement relevant components of Environmental Watering Plans. • Agree to implement other relevant regional management and mitigation measures required due to the implementation of GMW Connections Project.	• Implement the relevant components of Environmental Watering Plans. • Operate, maintain and replace, as agreed, the infrastructure required for delivery of mitigation water, where the infrastructure is not part of the GMW irrigation delivery system. • Where agreed, participate in the periodic review of relevant EWPs. • Manage and report on other relevant catchment management and mitigation measures required due to the implementation of GMW Connections Project.
System Operator	• Identify and inform GMW Connections Project of opportunities for best practice. • Participate in the Environmental Technical Advisory Committee. • Agree to implement relevant components of Environmental Watering Plans.	• Implement the relevant components of Environmental Watering Plans, namely delivery of mitigation water. • Operate, maintain and replace, as needed, the infrastructure required for delivery of mitigation, or other, water, where the infrastructure is part of the GMW irrigation delivery system. • May negotiate transfer of ownership of infrastructure to the environmental water/land manager for provision of mitigation water if it is no longer required for the public distribution system, in accordance with the principles set out in the WCMF.

Agency	Assess and develop management and mitigation measures	Deliver and review management and mitigation measures during GMW Connections Project implementation
		• Where the infrastructure assets are due for renewal or refurbishment, the water corporation will undertake the upgrade to the best environmental practice, including any requirements to better provide Environmental Water Reserve, and to remain consistent with current WCMF. • Report annually on the availability and delivery of water for mitigating environmental impacts as part of reporting upon meeting obligations under its bulk entitlement. In some instances, it will be appropriate to measure mitigation flows to ensure mitigation volumes of water are delivered.
DELWP	• Identify and inform GMW Connections Project of opportunities for best practice. • Participate in the Environmental Technical Advisory Committee. • Arrange funding to enable environmental water manager, catchment manager and land manager to deliver agreed measures.	• Participate in the periodic review of the Water Change Management Framework and relevant EWPs.
Environmental Water Holder		• Hold and manage environmental entitlements, including mitigation water that becomes a defined entitlement. • Consult with CMAs in identifying priority wetlands, waterways and groundwater systems for environmental watering. Plan and report on the use of environmental entitlements. • Negotiate with Commonwealth Environmental Water Holder to arrange delivery of Commonwealth environmental water.

9.1. Framework for operational management

The obligation to annually reserve and supply mitigation water will be established by amendment to the River Murray and Goulburn System Bulk Entitlements held by GMW. This arrangement is legally binding and reflects the commitments of the GMW Connections Project to provide water to mitigate potential impacts to high value environmental assets. The arrangements require GMW to set aside water in the Goulburn and Murray Systems to meet the mitigation water needs, calculated in accordance with the methods in the Water Change Management Framework, for future use at wetlands and waterways that have an approved EWP.
Mitigation water will be able to be carried over in line with other entitlements and will only be supplied to those wetlands where a mitigation water requirement has been identified. The specification of the volume and use of mitigation water will be the same regardless of whether it is established via bulk entitlement or contract.

Delivery of environmental water to Lake Leaghur requires the coordination of information, planning and monitoring among a number of agencies.

A framework for operational management outlining the relevant roles and responsibilities is presented in Figure 13. This has been developed to describe the decision-making process required to coordinate implementation of the recommended water regime for Lake Leaghur. The various government bodies and their roles will change over time. Therefore, this framework should be taken as a guide only.

The main components are:

- assessment of current conditions i.e. wetland phase, climatic conditions, etc.
- identification of potential water sources and preparation of relevant information for submission of water bid
- coordination of the environmental water delivery and adaptive management process.

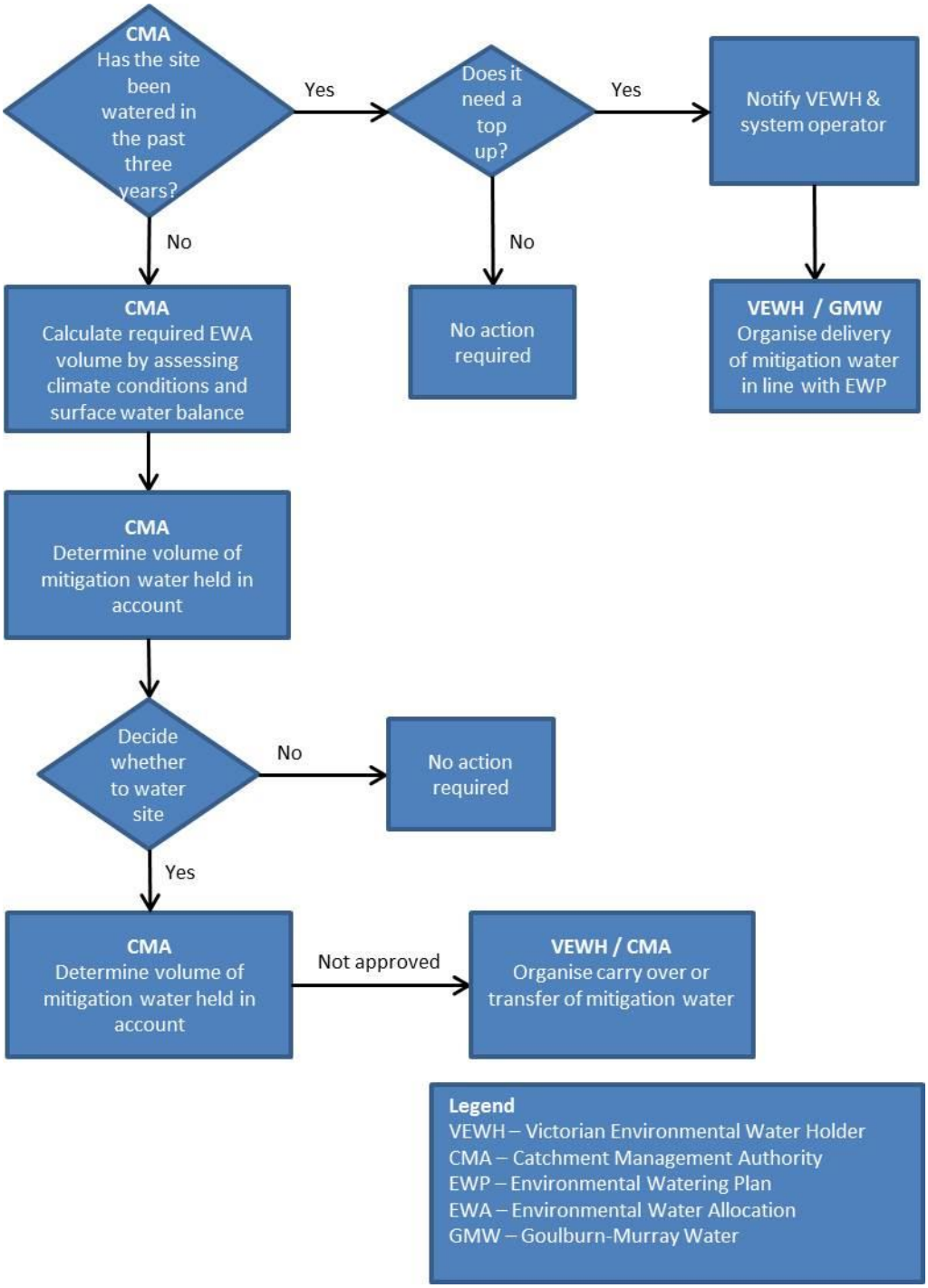

Figure 14: Operational management framework

10. Knowledge gaps

The Lake Leaghur EWP has been developed using the best available information. However, a number of information and knowledge gaps exist which may impact on recommendations and/or information presented in the EWP. These are summarised below.

10.1. Works program

Further information on the GMW Connections Project works program in the vicinity of Lake Leaghur needs to be confirmed to more specifically assess the potential impacts on the wetland, particularly:

- the potential rationalisation of Channel 2/2, on which the Lake Leaghur outfall structure is located
- the potential impact and ecological response to providing an alternative supply point.

Refer to Section 7 for details on the potential changes to current infrastructure arrangements and supply points.

10.2. Lake Leaghur

- Continued monitoring and evaluation of groundwater and surface water data is recommended to ensure no detrimental impacts from implementation of the water regime.
- The relationships between hydrology and ecological response in wetlands are complex. Therefore, it will be important that monitoring and adaptive management is undertaken to enable decisions to be made based on the best available information.

10.3. Roles and responsibilities

- GMW Connection Project is responsible for addressing knowledge gaps associated with the GMW Connections Project works program in the vicinity of Lake Leaghur listed under Section 10.1.
- North Central CMA in its capacity as environmental water manager is responsible, where funding and resourcing allow, for addressing the knowledge gaps listed under Section 10.2.

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Appendix A: NVIRP TAC, Wetland workshop participants and GMW Connections Project ETAC

Table A1: NVIRP TAC members - 2009

Name	Organisation and Job title
Anne Graesser	Manager – Natural Resources Services Goulburn Murray Water
Carl Walters	Executive Officer SIR Goulburn Broken CMA
Emer Campbell	Manager – NRM Strategy North Central CMA
Jen Pagon	Catchment and Ecosystem Services Team Leader Department of Primary Industries
John Cooke	Manager Sunraysia Department of Sustainability and Environment
Ross Plunkett	Executive Manager Planning NVIRP
Tamara Boyd	State Parks and Environmental Water Coordinator Parks Victoria
Observers	
Andrea Joyce	Program Leader – Wetlands and Environmental Flows Department of Sustainability and Environment
Bruce Wehner	Ranger Parks Victoria
Caroline Walker	Executive Assistant to Executive Manager Planning NVIRP
Chris Solum	Environmental Program Manager NVIRP
Michelle Bills	Strategic Environmental Coordinator North Central CMA
Pat Feehan	Consultant Feehan Consulting
Paulo Lay	Senior Policy Officer Department of Sustainability and Environment
Rebecca Lillie	Project Officer North Central CMA

Table A2: Wetland workshop participants – 17 December 2009

Name	Organisation and Job title
Andrea Joyce	Program Leader – Wetlands and Environmental Flows Department of Sustainability and Environment
Anne Graesser	Manager – Natural Resources Services Goulburn Murray Water
Bridie Velik-Lord	Environmental Flows Officer North Central CMA
Cherie Campbell	Senior Ecologist Murray Darling Freshwater Research Centre
Chris Solum	Environmental Program Manager NVIRP
Emer Campbell	Manager – NRM Strategy North Central CMA
Geoff Sainty	Wetland Specialist Sainty and Associates Pty Ltd
Karen Weaver	Biodiversity and Ecosystem Services Department of Sustainability and Environment
Mark Tscharke	Senior Ranger Parks Victoria
Michelle Bills	Strategic Environmental Coordinator North Central CMA
Pat Feehan	Consultant Feehan Consulting
Rebecca Lillie	Project Officer North Central CMA
Rob O'Brien	Senior Environmental Officer Department of Primary Industries
Shelley Heron	Manager – Water Ecosystems Kellogg Brown and Root

Table A3: GMW Connections Project ETAC members - 2015

Name	Organisation and Job title
Aaron Gay	Regional Manager, Environment and Natural Resources Department of Environment, Water, Land and Planning
Andrea Keleher	Program Manager – Healthy Landscapes Department of Environment, Water, Land and Planning
Bruce Wehner	Ranger Parks Victoria
Carl Walters	Executive Officer SIR Goulburn Broken CMA
Emer Campbell	Manager – NRM Strategy North Central CMA
Neil McLeod	Irrigation Officer – Dairy and Irrigation Department of Economic Development, Jobs, Transport and Resources
Ross Plunkett	Manager Environment and Water Savings GMW Connections Project
Observers	
Chris Solum	Environmental Project Manager GMW Connections Project
Josie Lester	Environmental Project Officer GMW Connections Project

Appendix B: Community Interaction/Engagement

Community Engagement purpose

An important component of the EWPs involves identifying the goal, underlying environmental objectives and wetland type for each of the wetlands being assessed for the GMW Connections Project. This requires an understanding of physical attributes, the history and the main biological processes associated with each of the wetlands.

In many cases adjoining landholders have had a long association with a wetland and have developed a good understanding that is useful to include in the development of the EWPs. This is particularly important if only limited monitoring records exist.

Method

A targeted community/agency engagement process was developed for the first round of EWPs developed in early 2009. A list of people with a good technical understanding of the wetland was developed by the technical working group (DPI, DSE and North Central CMA representatives).

This list included key adjoining landholders that have had a long association with the wetland and proven interest in maintaining its environmental value. A minimum of 2 landholders were invited to provide input for each wetland.

Other community and agency people that can provide useful technical and historic information include GMW water bailiffs, duck hunters (Field & Game Association), bird observers and field naturalists. These people often possess valuable information across several of the wetlands currently being studied.

The method of obtaining information was informal and occurred at the wetland (e.g. oral histories, interviews). The information has been captured in brief dot point form and only technical information and observations are to be noted that will add value to the development of the EWP.

A list of participants has been recorded however all the comments have been combined for each of the wetlands so individual comments are not referenced back to individuals.

List of community and agency participants (Lake Leaghur)

- Laurence Cameron (GMW)
- Ian Lanyon (landholder)
- Murray Lanyon (landholder)
- Graham Lehmann (landholder)
- Paul Haw (community member)
- Rod Stringer (community member)
- Ken Buchanan (landholder)
- Ron Bramley (Manager of Tony Sawer's farm)

Note: the results below document the comments received from the community members approached as part of the community engagement process. However, if new information comes to light this can be amended and redistributed accordingly.

Information provided to the community

It is important that the people approached for this information have a brief, straight summary of the purpose of the EWPs and type of information that will be useful to include in the planning process. Refer to summary below (adapted from Rob O'Brien, DPI 2009):

We are currently completing a study for NVIRP Northern Victoria Irrigation Renewal Project. It involves completing plans for Lake Leaghur, McDonalds Swamp, Little Lake Meran, Lake Meran, Little Lake Boort, Round Lake and Lake Yando.

As part of this it would be valuable to gather information that is broadly described below with a focus on the water regime and associated wetland values. It's recognised that these wetlands have been altered significantly since European settlement and the expansion of irrigated agriculture.

Providing information on these changes and how these influenced and altered the wetlands is important. It is particularly important to collate information or observations over more recent times, such as the last 30 - 50 years.

- *What was the original (pre-European settlement) condition of the wetland, including any details of the water regime and values (environmental, cultural)?*
- *What broad changes to the wetlands have occurred, particularly changed water regimes, as agricultural development influenced the floodplains and wetland?*
- *What connection does the wetland have to the floodplain to provide floodwater, or local catchment runoff?*
- *To what extent does the current irrigation supply channel have on the water regime over time?*
- *During more recent times (last 50yrs?) how did the productivity of the wetland vary with the altered water regimes?*
- *Describe the health of the wetland and notable plants and animals (both aquatic/terrestrial) associated with its water management.*
- *Comment on pest plants (boxthorn, willows, cumbungi etc)*
- *What influence has grazing domestic stock had on the reserve, both positive and negative effects?*
- *Given the history and current condition what type of water regime would be needed to achieve the best environmental results for the wetland?*
- *What other management practices could be adopted to improve the environmental value of the wetland?*

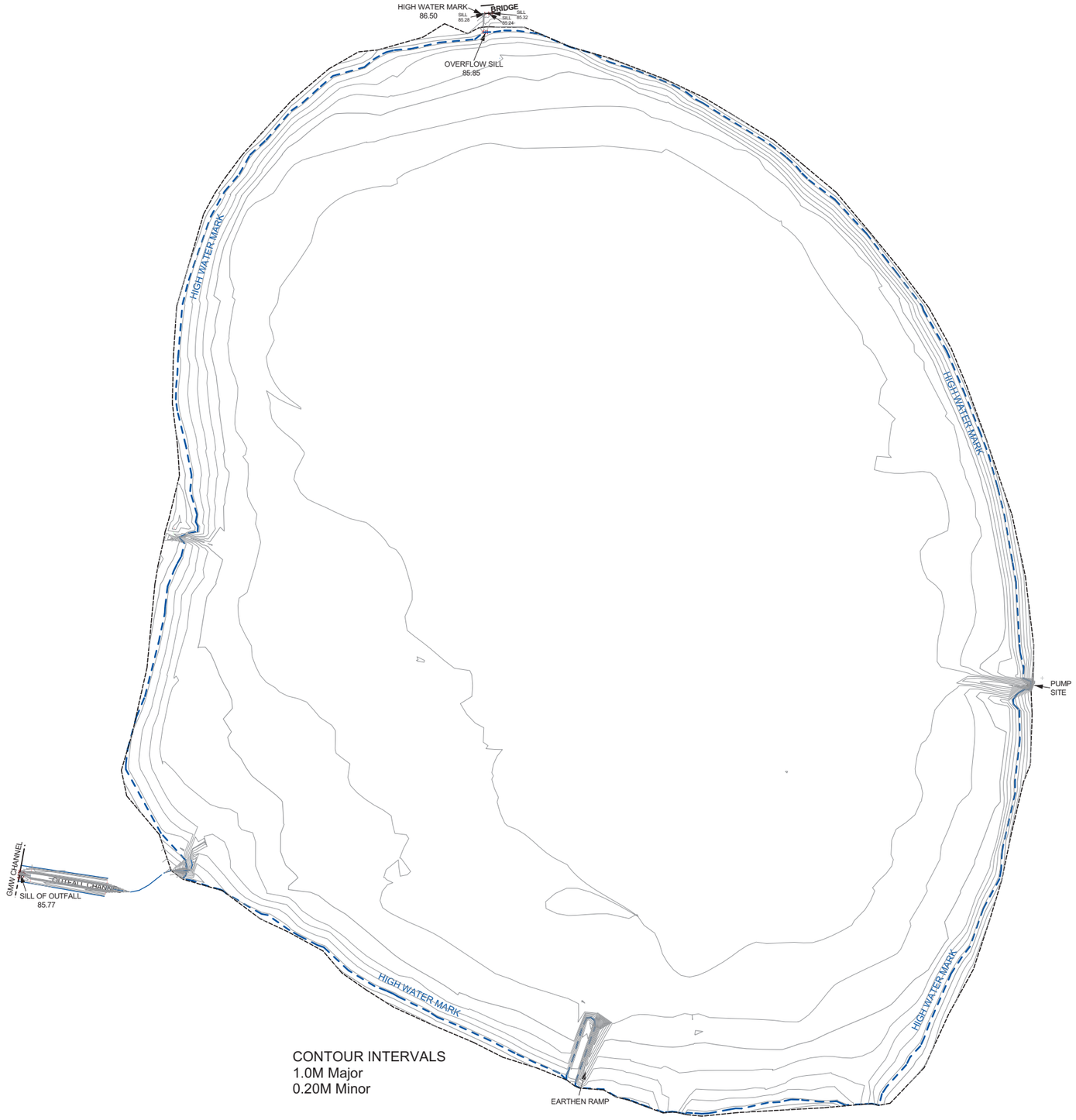
Comments and feedback from participants for Lake Leaghur

- Lake Leaghur is the first wetland to fill after the occurrence of a Loddon Flood
- It historically had the best duck hunting in the region (with approximately 500 shooters observed out at the lake)
- It was a "pristine" lake due to it being periodically flushed from Loddon flood flows. It was considered to have crystal clear water.
- Ribbon weed grew around the edges of the lake as well as Twiggy Lignum.
- There was a natural predator of Cumbungi that ensured it never threatened the wetland with encroachment. It was also too deep (about 8ft when at the sill height).
- Vegetation at the southern end of the lake is of high value (e.g. Sea eagles and Black Coots). There was a fire here back in the 1990s but it was never a major threat.
- When it was full it used to back up into the trees at the south of the wetland.
- There used to be a weir in Wandella Creek.
- The Leaghur State Park has not been grazed for around 15 years. It is changing to dryland plants. You would need a 12/13ft flood for 10 days to get through the park.
- Great lake to observe birdlife (open water). Used to support countless thousands of Ibis. Teal and Musk Ducks were also remembered to occur in great numbers.
- The lake used to, and still supports, carpet pythons.

- Fish species that lake was known to support include: Redfin, Tench, Yellow Belly, River Blackfish and Eels
- The introduction of Common Carp, murky water from the channel system and increased salinity levels due to the lack of flooding changed the ecology of the lake. The lake depended on irrigation outfalls in response to water level dropping (evaporation).
- The Venebles Creek (which feeds into the Lake) use to run twice a year (July and October/November) and was generally wet all summer.
    - In 1996 locals could not access the surrounding landscape because it was too wet, except for approximately 2-3 months.
    - We use to have to travel to the school bus stop by boat (1970s)
    - At one stage the only way I could access my house was by using a tractor
- Boort West of Loddon Salinity Management Plan lowered the sill level of the lake (actioned in November 1996). Aboriginal cooking mounds indicated the level for the concrete sill.
- Loddon Floods are seen as the best way to fill the lake, this will provide opportunities for regeneration of River Red Gums (the lake use to be covered with River Red Gums). Putting environmental flows may be required to maintain values through dry spells. There was agreement on an overall 1 in 3/5 year water regime.
    - Trees near the outfall currently look in healthy condition
    - The reeds and rushes need water every 5-6 years
    - The lake needs a drying cycle
    - In the 70s the lake received good wetting cycles with bigger floods flush the lake in between.
- The last wetting cycle for the lake only reach 1/3 full and the lake was full of Carp
- Carp exclusion is essential for the management of the lake
- Foxes are probably the biggest pest for this area. You don't see a lot of rabbits in the area, however there are more hares in recent times.
- The watertable and salt levels have dropped substantially due to the drought.
- At full flood level, Lake Leaghur seeps like a sieve
- The land use around Lake Leaghur use to be predominantly stocking country (covered in lignum), which has changed to intensive agriculture (tomato country).
- There is no local catchment for the lake (confirming Graham Hall's statement). Runoff contributes very little to the water balance of the wetland.
- There was a general discussion about Little Lake Boort:
    - The value of this Lake to the surrounding community (social and economic)
    - Great education tool for the community in improving the health of the lake
    - Tourist attraction
    - Discussion on how the community can secure water for the Lake

Please note: these issues will be addressed further in the development of the Little Lake Boort EWP

Appendix C: Contour Plan and Capacity Table Price Merrett Consulting (2006)



REV	DATE	ORIGINAL CREATED	DRN	CHKD
		REVISIONS		

JOB DETAILS

DESIGNED :	
DRAWN :	R.J.MACLEAN
SURVEY DATE :	26/07/2006
DATUM :	A.H.D.
GRID INTERVAL :	RANDOM
LEVEL BOOK :	-
FIELD BOOK :	F022

SCALE OF METRES

30 0 60 120

ORIGINAL DRAWING SCALE
1 IN 3000 (A2 SHEET SIZE)

MGA ZONE 54

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NORTH CENTRAL CATCHMENT MANAGEMENT AUTHORITY

LAKE LEAGHUR CONTOUR SURVEY

HUNTLY

CROWN ALLOTMENT	SECTION	PARISH	FILE NUMBER	SHEET NUMBER	DRAWING No.	REVISION	SHEET SIZE
		LEAGHUR	F3958	1 of 1	2176	0	A2

LAKE LEAGHUR

RATING CURVE TABLE

ELEVATION AHD	SURFACE AREA (Ha)	VOLUME STORED MEGALITRES	
84.50	8.587	1.67	
84.60	30.557	23.57	
84.70	38.281	58.02	
84.80	43.540	99.00	
84.90	47.349	144.55	
85.00	50.027	193.24	
85.10	51.859	244.18	
85.20	53.384	296.82	
85.30	54.602	350.84	
85.40	55.607	405.96	
85.50	56.426	461.99	
85.60	57.174	518.79	
85.70	57.889	576.32	
85.80	58.590	634.57	
85.85	58.925	664.24	OUTFALL SILL ELEVATION
85.90	59.248	693.49	
86.00	59.797	753.02	
86.10	60.186	813.03	
86.20	60.601	873.36	
86.30	61.085	933.90	
86.40	61.590	994.54	
86.50	62.060	1055.52	HIGH WATER MARK ON GUAGE

Note - volumes are cumulative volumes

Appendix D: Wetland characteristics

Characteristics	Description
Wetland Name	Lake Leaghur
Wetland ID	7626 524142
Wetland Area	59 ha at 85.85 m AHD in a 79 ha Crown land reserve
Conservation Status	Bioregionally Important Wetland
Land Manager	G–MW
Surrounding Land Use	Horticulture
Water Supply	Natural: Wandella Creek and Loddon River Current: Channel outfall 2/2 (approx. 22 days to fill).
1788 Wetland Classification	Category: Deep Freshwater Marsh (>8 months per year, <2m depth) Sub-category: n/a
1994 Wetland Classification	Category: Permanent Open Freshwater Subcategories: Shallow (<5 m), Dead Timber, Reed, Red Gum
Wetland Capacity	664.24 ML, *FSL 85.85 m AHD* (Price Merrett Consulting 2006)
Outfall Volumes	174 ML (04/05) ~211.1 ML (98/99 to 07/08) average

Appendix E: Flora and fauna species list

Compiled: September 2009

Sources:

Campbell *et al*. (2009)

DSE (2009h)

Ecos Environmental Consulting (2007)

Lugg *et al.* (1993)

Saddlier *et al.* (2009)

SKM (2001)

Data Source: 'Threatened Fauna 100' © The State of Victoria, Department of Sustainability and Environment.

Data Source: 'Threatened Flora 100' © The State of Victoria, Department of Sustainability and Environment.

Data Source: 'Aquatic Fauna Database', Copyright - The State of Victoria, Department of Sustainability and Environment.

Updated: March 2015

Sources:

eBird Website (2014)

North Central Catchment Management Authority bird monitoring records (2014)

Common Name	Scientific Name
Fauna - native	
Australasian Grebe	*Tachybaptus novaehollandiae*
Australasian Shoveler	*Anas rhynchotis*
Australian Magpie	*Gymnorhina tibicen*
Australian Pelican	*Pelecanus conspicillatus*
Australian Raven	*Corvus coronoides*
Australian Reed-warbler	*Acrocephalus australis*
Australian Shelduck	*Tadorna tadornoides*
Australian White Ibis	*Threskiornis molucca*
Australian Wood Duck	*Chenonetta jubata*
Black Kite	*Milvus migrans*
Black Swan	*Cygnus atratus*
Black-chinned Honeyeater	*Melithreptus gularis*
Black-eared Cuckoo	*Chrysococcyx osculans*
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
Black-fronted Dotterel	*Elseyornis melanops*
Black-shouldered Kite	*Elanus axillaris*
Black-tailed Native Hen	*Gallinula ventralis*
Black-winged Stilt	*Himantopus himantopus*
Blue-billed Duck	*Oxyura australis*
Brown Treecreeper (south-eastern ssp.)	*Climacteris picumnus victoriae*
Brown Falcon	*Falco berigora*
Brown Quail	*Coturnix ypsilophora*
Chestnut Teal	*Anas castanea*
Clamorous Reed Warbler	*Acrocephalus stentoreus*
Cockatiel	*Nymphicus hollandicus*
Collared Sparrowhawk	*Accipiter cirrocephalus*
Common Greenshank	*Tringa nebularia*
Common Long-necked Turtle	*Chelodina longicollis*
Crested Bellbird	*Oreoica gutturalis*
Crested Pigeon	*Ocyphaps lophotes*
Darter	*Anhinga novaehollandiae*
Diamond Firetail	*Stagonopleura guttata*
Dusky Moorhen	*Gallinula tenebrosa*
Dusky Woodswallow	*Artamus cyanopterus*

Common Name	Scientific Name
Eastern Great Egret	*Ardea modesta*
Eastern Rosella	*Platycercus eximius*
Eurasian Coot	*Fulica atra*
Flat-headed Gudgeon	*Philypnodon grandiceps*
Freckled Duck	*Stictonetta naevosa*
Freshwater Catfish	*Tandanus tandanus*
Galah	*Eolophus roseicapilla*
Glossy Ibis	*Plegadis falcinellus*
Golden Whistler	*Pachycephala pectoralis*
Great Cormorant	*Phalacrocorax carbo*
Great Crested Grebe	*Podiceps cristatus*
Great Egret	*Ardea alba*
Grey Shrike-thrush	*Colluricincla harmonica*
Grey Teal	*Anas gracilis*
Grey-crowned Babbler	*Pomatostomus temporalis*
Hardhead	*Aythya australis*
Hoary-headed Grebe	*Poliocephalus poliocephalus*
Hooded Robin	*Melanodryas cucullata*
Intermediate Egret	*Ardea intermedia*
Laughing Kookaburra	*Dacelo novaeguineae*
Little Black Cormorant	*Phalacrocorax sulcirostris*
Little Egret	*Egretta garzetta*
Little Grassbird	*Megalurus gramineus*
Little Pied Cormorant	*Microcarbo melanoleucos*
Little Raven	*Corvus mellori*
Magpie-lark	*Grallina cyanoleuca*
Major Mitchell's Cockatoo	*Lophocroa leadbeateri*
Marsh Sandpiper	*Tringa stagnatilis*
Masked Lapwing	*Vanellus miles*
Musk Duck	*Biziura lobata*
Nankeen Kestrel	*Falco cenchroides*
Noisy Miner	*Manorina melanocephala*
Pacific Black Duck	*Anas superciliosa*
Peaceful Dove	*Geopelia striata*
Pectoral Sandpiper	*Calidris" melanotos*
Pink-eared Duck	*Malacorhynchus membranaceus*
Purple Swamphen	*Porphyrio porphyrio*
Rainbow Bee-eater	*Merops ornatus*
Red-capped Plover	*Charadrius ruficapillus*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Red-necked Stint	*Calidris ruficollis*
Red-kneed Dotterel	*Erythrogonys cinctus*
Red-rumped Parrot	*Psephotus haematonotus*
Royal Spoonbill	*Platalea regia*
Ruff	*Philomachus pugnax*
Rufous Whistler	*Pachycephala rufiventris*
Sacred Kingfisher	*Todiramphus sanctus*
Sharp-tailed Sandpiper	*Calidris acuminata*
Silver Gull	*Chroicocephalus novaehollandiae*
Speckled Warbler	*Chthonicola sagittata*
Spotted Marsh Frog (race unknown)	*Limnodynastes tasmaniensis*
Straw-necked Ibis	*Threskiornis spinicollis*
Striated Pardalote	*Pardalotus striatus*
Superb Fairy-wren	*Malurus cyaneus*
Swamp Harrier	*Circus approximans*
Swift Parrot	*Lathamus discolor*
Tree Martin	*Hirundo nigricans*
Water Rat	*Hydromys chrysogaster*
Wedge-tailed Eagle	*Aquila audax*
Welcome Swallow	*Hirundo neoxena*
Whiskered Tern	*Chlidonias hybridus*
Whistling Kite	*Haliastur sphenurus*

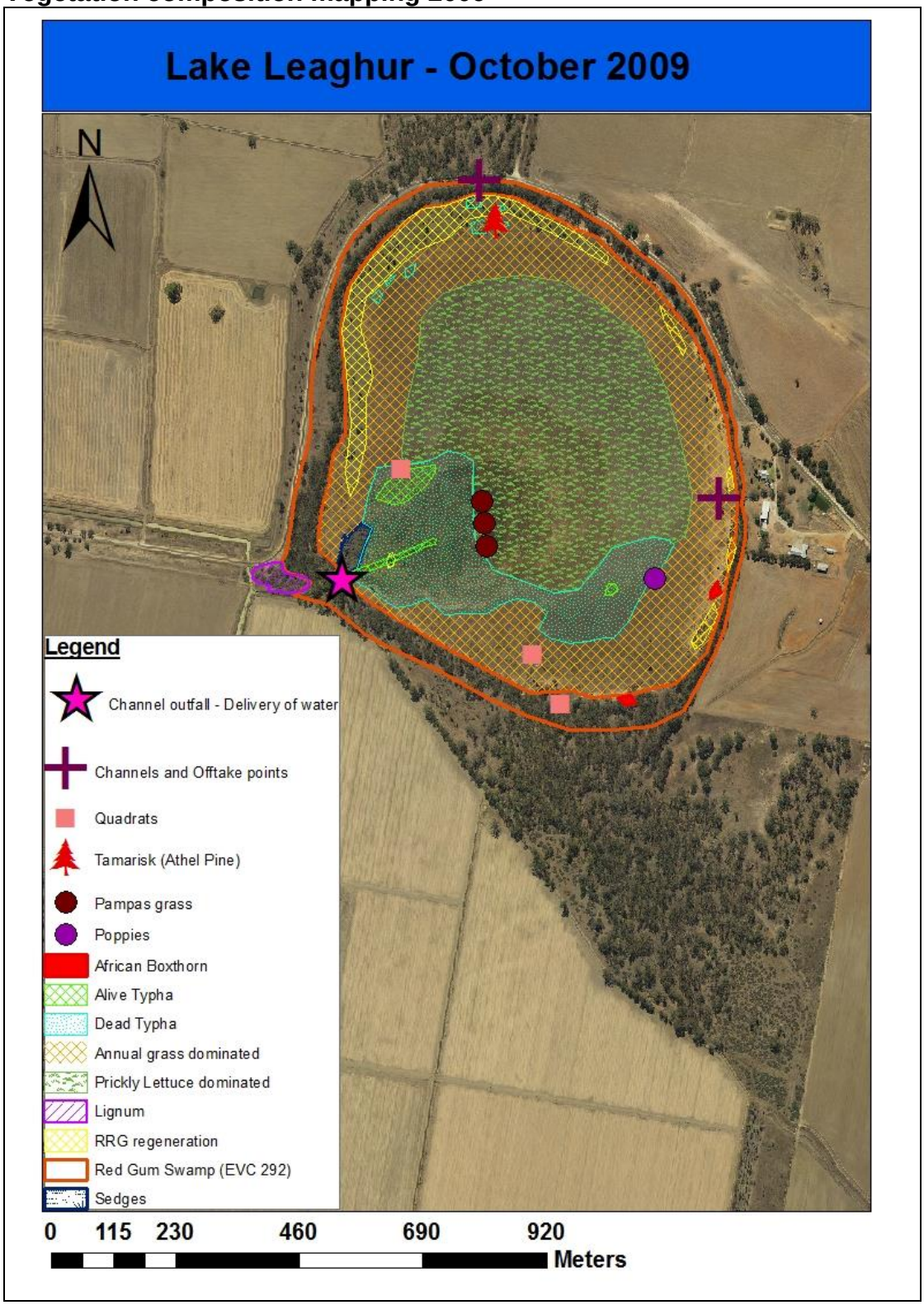
Common Name	Scientific Name
White-bellied Sea-Eagle	*Haliaeetus leucogaster*
White-breasted Woodswallow	*Artamus leucorynchus*
White-faced Heron	*Egretta novaehollandiae*
White-necked Heron	*Ardea pacifica*
White-plumed Honeyeater	*Lichenostomus penicillatus*
Willie Wagtail	*Rhipidura leucophrys*
Yellow-billed Spoonbill	*Platalea flavipes*
Fauna - exotic	
Common Carp	*Cyprinus carpio*
Common Starling	*Sturnus vulgaris*
Goldfish	*Carassius auratus*
House Sparrow	*Passer domesticus*
Mosquito fish	*Gambusia holbrooki*
Redfin Perch	*Perca fluviatilis*
Tench	*Tinca tinca*
Flora - native	
Barren Cane Grass	*Eragrostis infecunda*
Berry Saltbush	*Atriplex semibaccata*
Blown Grass	*Lachnagrostis filiformis*
Blunt Pondweed	*Potamogeton ochreatus*
Branching Groundsel	*Senecio cunninghamii var. cunninghamii*
Bristly Wallaby-grass	*Austrodanthonia setacea* s.l.
Brown-back Wallaby-grass	*Austrodanthonia duttoniana*
Cane Grass	*Eragrostis australascia*
Chenopod	*Chenopodium sp.*
Cherry Ballart	*Exocarpus cupressiformis*
Clammy Goosefoot	*Chenopodium pumilo*
Common Blown-grass	*Agrostis avenacea*
Common Blown-grass	*Lachnagrostis filiformis var.1*
Common Everlasting	*Helichrysum apiculatum*
Common Nardoo	*Marsilea drummondii*
Common Spike-sedge	*Eleocharis acuta*
Common Swamp Wallaby-grass	*Amphibromus nervosus*
Common Wallaby-grass	*Austrodanthonia caespitosa*
Copperburr	*Sclerolaena sp.*
Cotton Fireweed	*Senecio quadridentatus*
Cumbungi	*Typha sp.*
Dense Crassula	*Crassula colorata*
Duckweed	*Spirodela oligorrhiza*
Eel Grass	*Vallisneria americana var. americana*
Feather Spear-grass	*Austrostipa elegantissima*
Fennel Pondweed	*Potamogeton pectinatus*
Ferny Small-flower Buttercup	*Ranunculus pumilio*
Filamentous algae	
Finger Rush	*Juncus subsecundus*
Floating Pondweed	*Potamogeton tricarinatus s.l.*
Grassland Wood-sorrel	*Oxalis perennans*
Groundsel	*Senecio sp.*
Hairy Carpet-weed	*Glinus lotoides*
Hollow Sedge	*Carex tereticaulis*
Jersey Cudweed	*Helichrysum luteoalbum*
Knob sedge	*Carex inversa*
Knobby Club-sedge	*Ficinia nodosa*
Lesser Joyweed	*Alternanthera denticulata*

Common Name	Scientific Name
Mallee Love-grass	*Eragrostis dielsii*
Narrow-leaf Cumbungi	*Typha domingensis*
Narrow-leaf Nardoo	*Marsilea costulifera*
New Holland Daisy	*Vittadinia sp.*
Nodding Saltbush	*Einardia nutans ssp. nutans*
Pacific Azolla	*Azolla filiculoides*
Pale Knotweed	*Persicaria lapathifolia*
Paper Sunray	*Rhodanthe corymbiflora*
Peppercress	*Lepidium pseudohyssopifolium*
Poison Pratia	*Lobelia concolor*
Prickly Saltwort	*Salsola tragus*
Red Water-milfoil	*Myriophyllum verrucosum*
Rigid Panic	*Homopholis proluta*
River Red Gum	*Eucalyptus camaldulensis*
Rough Spear-grass	*Austrostipa scabra ssp. falcata*
Ruby Saltbush	*Enchylaena tomentosa var. tomentosa*
Saltbush	*Atriplex sp.*
Short-leaf Bluebush	*Maireana brevifolia*
Slender Dock	*Rumex brownii*
Slender Knotweed	*Persicaria decipiens*
Slender-fruit Saltbush	*Atriplex leptocarpa*
Small Knotweed	*Polygonum plebeium*
Small Loosestrife	*Lythrum hyssopifolia*
Small Spike-sedge	*Eleocharis pusilla*
Spiny Flat-sedge	*Cyperus gymnocaulos*
Spiny Lignum	*Muehlenbeckia horrida subsp. Horrida*
Star Fruit	*Damasonium minus*
Swamp Buttercup	*Ranunculus undosus*
Swamp Starwort	*Stellaria angustifolia*
Tall Fireweed	*Senecio runcinifolius*
Tall Spike-sedge	*Eleocharis sphacelata*
Tangled Lignum	*Muehlenbeckia florulenta*
Unidentified Grass	*(#174)*
Unidentified Rush	*(#169) Juncus* sp.
Unidentified Rush	*(#172) Juncus* sp.
Upright Water-milfoil	*Myriophyllum crispatum*
Variable Sida	*Sida currugata*
Water Ribbons	*Triglochin procerum s.l.*
Willow-herb	*Epilobium sp.*
Windmill Grass	*Chloris truncata*
Yellow Rush	*Juncus flavidus*
Flora - exotic	
African Box-thorn	*Lycium ferocissimum*
Aster Weed	*Aster subulatus*
Barley Grass	*Hordeum sp.*
Bearded Oat	*Avena barbata*
Black Nightshade	*Solanum nigrum*
Blue Sow-thistle	*Sonchus asper ssp. glaucescens*
Burr Medic	*Medicago polymorpha*
Cat's Ear	*Hypochoeris radicata*
Celery Buttercup	*Ranunculus sceleratus subsp. sceleratus*

Common Name	Scientific Name
Common Peppercress	*Lepidium africanum*
Common Sow-thistle	*Sonchus oleraceus*
Couch	*Cynodon dactylon*
Curled Dock	*Rumex crispus*
Dock	*Rumex sp.*
Drain Flat-sedge	*Cyperus eragrostis*
Giant Mustard	*Rapistrum rugosum*
Great Brome	*Bromus diandrus*
Hairy Hawkbit	*Leontodon taraxacoides subsp. Taraxacoides*
Hogweed	*Polygonum aviculare*
Horehound	*Marrubium vulgare*
Kikuyu	*Pennisetum clandestinum*
Knotweed	*Persicaria sp.*
Little Medic	*Medicago minima*
London Rocket	*Sisymbrium irio*
Madrid Brome	*Bromus madritensis*
Oat	*Avena sp.*
Ox-tongue	*Helminthotheca echioides*
Pampas Grass	*Cortaderia sp.*
Paradoxical Canary-grass	*Phalaris paradoxa*
Paspalum	*Paspalum dilatatum*
Pepper Tree	*Schinus mollee*
Perennial Rye-grass	*Lolium perenne*
Poplar	*Populus sp.*
Poppy	*Papaver sp.*
Prickly Lettuce	*Lactuca serriola*
Prickly Sow-thistle	*Sonchus asper*
Rat's Tail Fescue	*Vulpia myuros*
Red Brome	*Bromus rubens*
Red Sand-spurrey	*Spergularia rubra*
Red-stem Goosefoot	*Chenopodium macrospermum*
Rye-grass	*Lolium sp.*
Sea Barley-grass	*Hordeum marinum*
Sharp Rush	*Juncus acutus ssp. acutus*
Small-flower Mallow	*Malva parviflora*
Soft Brome	*Bromus hordeaceus ssp. hordeaceus*
Spear Thistle	*Cirsium vulgare*
Strawberry Clover	*Trifolium fragiferum var. fragiferum*
Subterranean Clover	*Trifolium subulatus*
Tall Mallow	*Malva sylvestris var. sylvestris*
Tamarisk	*Tamarix ramosissima*
Toowoomba Canary-grass	*Phalaris aquatica*
Variegated Thistle	*Silybum marianum*
Vetch	*Vicia sp.*
Water Buttons	*Cotula coronopifolia*
Water Couch	*Paspalum distichum*
Weld	*Reseda luteola*
Wild Oat	*Avena fatua*
Willow-leaf Lettuce	*Lactuca saligna*
Wimmera Rye-grass	*Lolium rigidum*
Woolly Clover	*Trifolium tomentosum var. tomentosum*

Appendix F: Vegetation composition map

Vegetation composition mapping 2009



Appendix G: Hydrology (SWET OUTPUT)

set	Wetland Name	Lake Leaghur							
		Degrees	Degrees	Minutes					
set	Latitude	-35.98272	-35.00	58.9631					
set	Longitude	143.80077	143.00	48.0463					
		Metres (AHD)							
	Altitude	85.85						Runoff coefficient	
		ha	m^2	ML/ha/yr	ML/yr	Rainfal	Total (ML)	Mean	Max.
set	Local contributing catchment area	0.1	1000	0.2	0.020	355	0	0.056	0.2
		%area	Depth						
set	Initial loss to wetland bed parameters	0.25	300						
		Mean	Max						
set	Assumed average wetland bed runoff coeff	0.150	0.40						
		ML/d							
adjust	Notional artificial wetland filling inflow rate	60							
		mm/day							
adjust	Maximum artificial filling rate	20							

	Management parameters	Day	Month	Start day
adjust	Earliest start to fill	1	8	213
adjust	Latest start to fill	1	12	
adjust	Duration wet cycle - includes filling	244	8	
adjust	Duration dry cycle - includes drawdown	852	28	
				Years
set	Start condition	Dry		
set	Maximum wet-dry cycle length			5

To operate the model

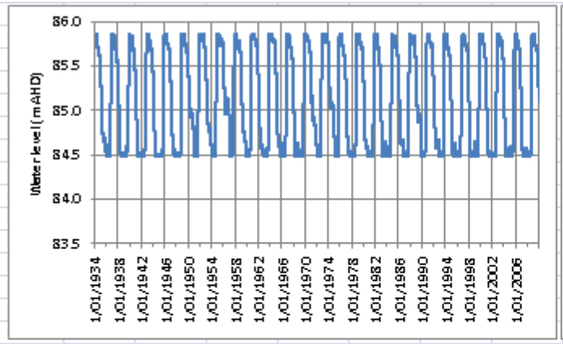
First fill in the required input data cells.
Calculation is set to Manual, so
when ready press Function9 (F9) key
It takes 20 seconds to re-calculate and plot

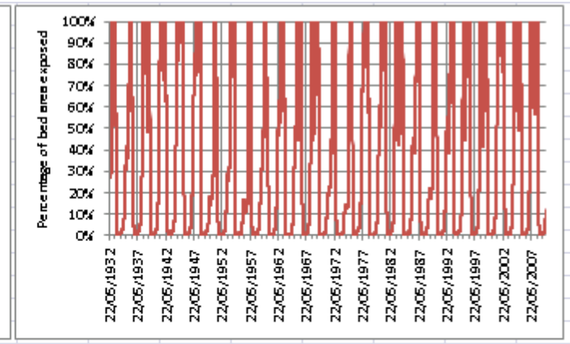
		Day	Month
adjust	Irrigation year start	1	8

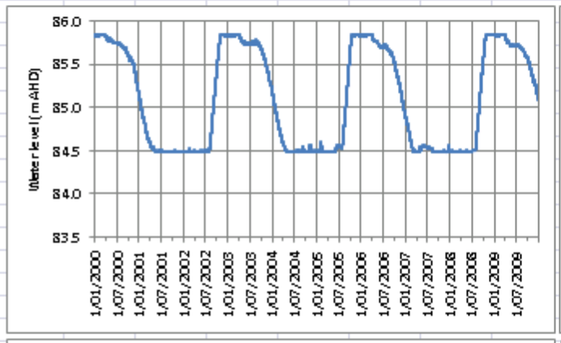
		Elevation	Volume	Area
adjust	Target level	85.85	664240	589250
		Elevation	Volume	Area
set	Wetland spill level	85.85	664240	589250
		Elevation	Tolerance for drying (m)	
adjust	Lowest wetland level	84.49	0.1	
			1 = Pan; 2 = Modelled	
choose	Factored Pan evaporation or modelled ET method?		2	

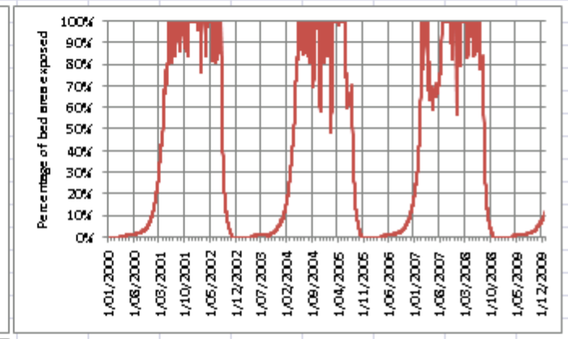
RESULT	ML/year	P95 (ML/yr)	Years with no inflow
Mean long-term annual artificial water inflows	447	1,377	78 in 118 years
	ML	No. Periods	Record length (years)
Average water inflows for filling periods	1,319	40	118
Drawdowns over record (number of)	40		
Drawdowns not fully dried out (number of)	0		
Drawdowns not fully dried out (percentage)	0%		
95th percentile duration of full period (months)	5.5	Target is 3 to 6 months	
50th percentile duration of full period (months)	4.9	Target is 3 to 6 months	

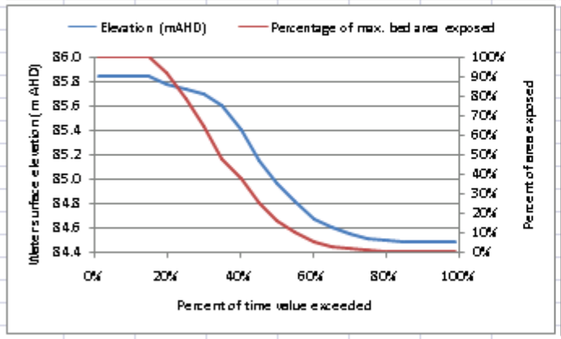
Fill cycle length (yr)	No. cycles
1	
2	
3	40
4	
5	
6	
7	
8	
9	
10	

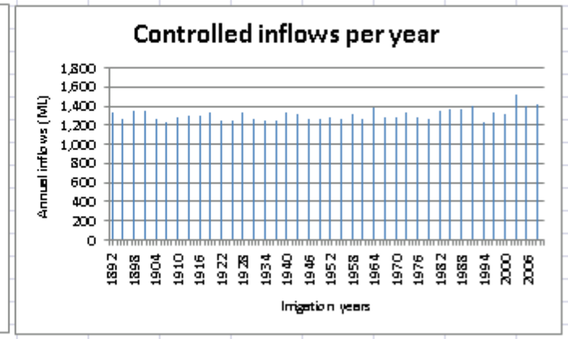












Appendix H: Preliminary leakage and seepage loss contribution calculations

Wetland	Wetland within 200 m of main supply channel (Yes/no)	Length of channel (m) <200 m	Channel width (m)	Irrigation channel	Seepage Calculation Figures					Seepage Range (min - max)	
					Channel width category	5 mm/day (ML/yr)	10 mm/day (ML/yr)	15 mm/day (ML/yr)	20 mm/day (ML/yr)	ML/yr (@ 5 mm/day)	ML/yr (@20 mm/day)
Lake Leaghur	Yes	270	7 to 9	channel 2/2	10 m	7	14	20	27	1.89	7.29

Taken from WCMF Draft 19 March 2010 (*Table 14 Estimated volumes of seepage per year from 1000 m of channel for different channel widths and seepage rates*)

Chanel width (m)	Chanel half-width (m)	Seepage Rate in mm/day			
		5 mm/day (ML/yr)	10 mm/day (ML/yr)	15 mm/day (ML/yr)	20 mm/day (ML/yr)
10	5	7	14	20	27
20	10	14	27	41	54
40	20	27	54	81	108

Assumptions/Notes
Preliminary calculations were only completed for wetlands within 200 m of a main supply channel as recommended by the WCMF (19 March 2009)
Seepage rates are based on 1,000 m of channel. Where less than 1000 m is within 200 m of the wetland, seepage rates have been reduced proportionally
Seepage rates are site specific, depending on local conditions. Therefore, a range of seepage volumes for each wetland was determined using the minimum and maximum seepage rates specified in the WCMF 19 March 2010
Channel lengths, channel widths and channel distance from wetlands were measured using ArcGIS

Appendix I: Additional risks and limiting factors

The following risks are to be managed by the relevant organisations and agencies as stipulated through their current roles and as is legislated.

Risks/limiting factors	Impacts	Mitigation measures
Delivery of Water		
Limited water availability	Failure to achieve identified objectives and goal	Ensure sufficient information is collected for prioritisation of Lake Leaghur in environmental allocation processes. Regularly review rainfall and climate data to utilise natural inflows where possible. Re-model volumes required in light of changing climatic conditions and wetland phase.
Climatic variability	Variability in water availability (e.g. wet seasons during a planned dry phase)	Adaptive management of water regime and delivery options as above. Re-model volumes required in light of changing climatic conditions and wetland phase.
Poor water quality (i.e. temperature fluctuations, blackwater events, high turbidity, salinity and nutrient levels)	Reduced primary production (turbid water), limiting food resources for aquatic invertebrates and waterbirds. Encroachment of nutrient tolerant vegetation *Typha* sp. and *Phragmites* sp. Excessive algal growth	Monitoring of groundwater levels, salinity and nutrient inputs in conjunction with a monthly water quality monitoring program (Section 8 and Appendix J). Adaptively manage water regime and delivery. Re-model volumes required in light of changing climatic conditions and wetland phase.
Groundwater intrusion or discharge to low-lying surrounding areas resulting from elevated groundwater levels[13]	Poor vegetation health Limited regeneration and dominance of salt tolerant species Unsuitable habitat for waterbirds and food sources	Monitoring of groundwater levels and salinity within wetland and surrounding area (Section 8 and Appendix J). Adaptive management of water regime.
Flooding of adjacent landholders	Community angst Liability	Regularly monitor rainfall and climate data and adapt water delivery to account for potential flood events. Re-model volumes required in light of changing climatic conditions and wetland phase.
Ecological Response		
Fluctuating groundwater height and salinity levels	Saline groundwater intrusion or discharge onto low-lying surrounding land[8]	Groundwater monitoring and adaptive management of recommended water regime (Section 8 and Appendix J).
Unreliable supply of food/nesting sites	Limited occurrences of waterbirds	Seasonal water delivery, regular monitoring (e.g. IWC and waterbirds) and adaptive management of water regime (Section 8 and Appendix J).

[13] Under current conditions of low groundwater levels, this is unlikely. However, if conditions were to change and groundwater levels rose there would be a risk of saline groundwater intrusion into the wetland or onto low-lying adjacent land (Bartley Consulting 2009).

Risks/limiting factors	Impacts	Mitigation measures
Lag time between wetland watering and bird breeding	No successful breeding events	Seasonal water delivery, monitoring and adaptive management of water regime (Section 8 and Appendix J). Top-ups may be required to prolong inundation to complete bird breeding events.
Proliferation of pest plants and animals[14]	Reduced habitat and resource availability	Regular monitoring, active management (weed and pest control), carp screen installation.
	Predation of native fauna	
	Limited establishment of native vegetation	
Lack of seedbank viability	Emergence of unexpected native or exotic species	Regular monitoring (e.g. Index of Wetland Condition) and adaptive management (Section 8 and Appendix J). Fluctuation of water levels will be required to support Red Gum germination.
	Restricted regeneration (e.g. Cane Grass)	
	Limited regeneration and dominance of salt tolerant species	
High soil salinity[8]	Poor vegetation health	Monitoring and adaptive management of recommended water regime to reduce potential groundwater intrusion or discharge to low-lying surrounding areas (Section 8 and Appendix J).
	Limited regeneration and dominance of salt tolerant species	
Other		
Recreational pressures e.g. hunting increases in response to watering event	Loss of non-game species	Monitoring of waterbird numbers and diversity (Section 8 and Appendix G). Reporting of information to relevant bodies including Field and Game Association and DSE (particularly the occurrence of listed species prior to opening of the hunting season).

[14] May result from reductions in pest plant and animal management on adjoining land to changed management practices (e.g. absentee landholders).

Appendix J: Monitoring program recommendations

It is not a requirement of GMW Connections Project to provide long-term condition or intervention monitoring nor does this document represent a comprehensive management plan for Lake Leaghur. However, recommendations are made below for variables to be monitored in order to assess the response to the provision of the desired water regime and inform its adaptive management.

It is recommended that an environmental monitoring plan is developed for the wetland, to ensure planned analysis and reporting of the impacts of the adopted water regime.

1. Long Term condition monitoring

Long term condition monitoring is recommended in order to evaluate any changes to wetland values (particularly vegetation and groundwater) over time. It should be noted that condition monitoring is recommended to be conducted in conjunction with intervention monitoring to comprehensively evaluate any changes to Lake Leaghur.

Vegetation Condition and Distribution

A number of photo points and objectives for long term vegetation monitoring need to be established for Lake Leaghur to enable the assessment of changes in wetland condition over time. It is recommended that photos are taken from these points, facing the same direction, on a yearly basis to capture vegetation condition and distribution. It is recommended that a database be compiled in order to store details of the monitoring photos captured.

It is also recommended that the condition and distribution of vegetation communities, including exotic species, throughout Lake Leaghur, are assessed every five years. The IWC not only provides useful information on the condition and distribution of vegetation but also highlights indicators of altered processes (threatening processes). It is recommended that an IWC assessment be completed for Lake Leaghur every 5 years. However, this may need to be undertaken sooner depending on the rate of response to water (DSE 2005b) and should be adaptively managed.

In addition, information on vegetation communities gathered on aerial photography during this project has been digitised and is available in a GIS format to enable comparison in distribution over time (distribution mapping) (Baldwin *et al*. 2005).

Groundwater Monitoring

Long term monitoring of groundwater within the immediate vicinity of Lake Leaghur is currently conducted by DEDJTR (Section 4.3). It is recommended that this monitoring continue in order to identify potential risks associated with the delivery of the recommended water regime and for consideration in adaptive management.

It is recommended that the environmental monitoring plan to be prepared for the wetland includes a groundwater monitoring component setting out the monitoring objectives, the linkages with other monitoring programs, the monitoring approach, and the reporting and review process.

Table J1 identifies additional recommendations to improve long-term groundwater monitoring, as well as the quality and breadth of data collected (Bartley Consulting 2009).

Table J1: Additional groundwater monitoring recommendations (Bartley Consulting 2009)

Target	Recommendation
Long-term groundwater monitoring	A review of the groundwater-related aspects of the site, including a re-assessment of environmental risks, is undertaken at least every seven years and sooner if the water regime is changed or regional groundwater levels rise.
	The impact of change to the water regime is reviewed and assessed in accordance with the requirements of the environmental monitoring plan, and subject to the availability of suitable data should include an appraisal of the movement of the wetting front and salt, impacts on

Target	Recommendation
	surrounding groundwater levels and neighbouring land, and a water budget that includes estimates of accessions to groundwater.
Data quality	Installing data loggers in selected groundwater bores, to provide data before watering and throughout the wetting and drying cycle at the site.
	Installing data loggers to record surface water level and salinity at the inlet, in the wetland, and at the outlet if there is overflow.
	Confirming the water level gauge elevation, and use volume rating tables to assist recording level and volume, to verify surface water data logger readings.
	Recording the inflow and outflow volumes during the watering event.
Breadth of data	Regular liaison with neighbouring landholders to understand their water use and irrigation practices, and how these change over time.
	Monitoring neighbouring areas that are considered susceptible to salinisation or waterlogging.
	Installation of shallow and deep groundwater monitoring bores, at two locations, at the northern end of the site.
	Assessing the watertable depth and soil and salinity profile beneath the site floor.

It is important that the monthly monitoring results are provided by DPI to the North Central CMA and the land manager to facilitate data analysis and inform adaptive management.

2. Intervention Monitoring

Monitoring the response of key environmental values to the provision of water is imperative in informing the adaptive management of the recommended water regime. Monitoring will also assess the success of implementation, the achievement of ecological objectives and the progress towards achieving the goal outlined in Section 5.

It is essential that analysis of monitoring results is regularly undertaken in order to develop an understanding of changes occurring at the wetland.

Vegetation

Following the provision of water it is important that the response of vegetation is monitored. A number of previous surveys and records are available to provide baseline data in order to evaluate any response. Monthly monitoring is recommended and snapshot assessments should incorporate the components outlined in Table J2. A database of any previous flora records has been compiled for Lake Leaghur and should be updated following regular monitoring.

Table J2: Components of vegetation intervention monitoring

Component	Target	Method	Objective
Vegetation distribution	River Red Gum, emergent aquatic plant community, aquatic and amphibious plant communities, Cane Grass	• Distribution mapping • Photo points	Habitat objectives, species/community objectives
Vegetation condition	River Red Gum, emergent aquatic plant community, aquatic and amphibious plant communities, Cane Grass	• Photo points	Habitat objectives, species, 2.1
Species diversity	Additional species with a focus on aquatic and amphibious species	• Species list comparison	1.3, 2.1

Waterbirds

The diversity and abundance of waterbirds at Lake Leaghur needs to be monitored following watering for the duration of the inundation period in order to assess the success of implementation and achievement of objectives. It is essential that commentary on abundance and breeding events informs the adaptive management of the delivered water regime.

Waterbird monitoring is currently undertaken by DELWP under a contract with North Central CMA. Monthly monitoring as water levels fluctuate will ensure changes in bird communities are captured (Baldwin *et al*. 2005). Numerous previous surveys and records are available to provide baseline data in order to evaluate the response of waterbirds to the provision of water. A database has been compiled of all recordings made at Lake Leaghur and should be updated regularly following monitoring. Table J3 outlines the recommended components of waterbird monitoring.

Table J3: Components of intervention monitoring of waterbirds

Component	Target	Method	Objective
Species diversity	All species including those of conservation significance	• Area searches (Baldwin *et al*. 2005)	Habitat objectives, 2.2
Waterbird abundance			Habitat objectives, 2.2
Habitat availability	Open water (including aquatic and amphibious species), mudflats, tall marsh vegetation, River Red Gum	• Undertaken in conjunction with vegetation monitoring	Habitat objectives, 2.2 , 2.3
Breeding populations	Little Pied Cormorants, Ducks, Great Egret	• Spring surveys • Nest surveys (Baldwin *et al*. 2005)	Habitat objectives, 2.2

Fish and Macroinvertebrates

It is recommended that the response of fish and macroinvertebrates is monitored following watering as they provide important food sources for several waterbirds. Numerous surveys and records exist to provide baseline data to enable evaluation of the response to watering. A database has also been compiled of all recordings made at Lake Leaghur and should be updated regularly following monitoring. Table J4 details the components to be incorporated in monitoring fish and macroinvertebrates. Incidental observations of reptiles and amphibians should also be recorded.

The results of the monitoring should also be used to inform the assessment of habitat availability for waterbirds as they provide a significant food source for a number of species.

Table J4: Components of intervention monitoring for fish and macroinvertebrates

Component	Target	Method	Objective
Species diversity	All species including those of conservation significance	• Electrofishing, bait trapping, seine and fyke netting (Baldwin *et al*. 2005) • Sweep netting/AusRivas • Call playback, funnel trapping, drift fences and pit traps (Baldwin *et al*. 2005)	2.2, 2.3
Species abundance			

Water Quality

A monthly water quality monitoring program should be developed prior to watering Lake Leaghur. The program will assess water quality in association with water level fluctuations. Table J5 identifies elements to be considered as part of the water quality monitoring program

Table J5: Components of intervention monitoring for water quality

Component	Target	Method		Objective
Water quality	Electrical conductivity	Conductivity metre	Water quality meter	Habitat objectives, 2.2, 2.3
	pH	pH metre		
	Turbidity	Turbidity metre		
	Dissolved oxygen	Oxygen metre		
	Nutrients	Laboratory analysis		

Appendix K: Contour and vegetation map

Lake Leaghur
Contours and Vegetation

Legend

Parcel

Lake Leaghur Contours

ELEVATION

- 1.0m
- 0.5m
- 0.1m

Watercourse

- River
- Stream
- Channel
- Connector

Roads

- Freeway
- Highway
- Major Road
- Arterial Road
- Road
- Residential Street
- Track

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Exotic

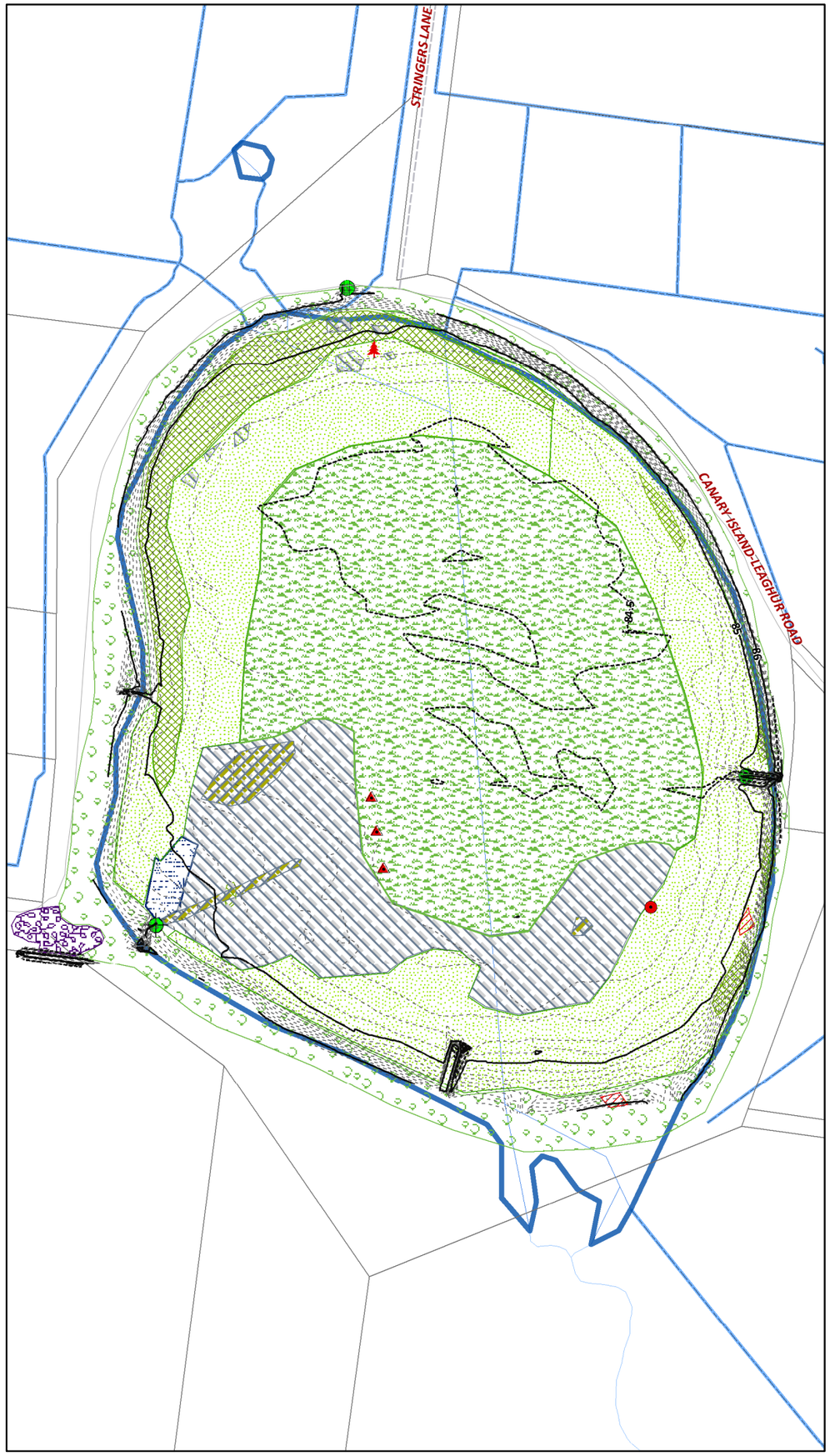
- Poppies
- Pampas Grass
- Tamarisk
- Prickly Lettuce
- Annual grass and Thistle
- African Boxthorn

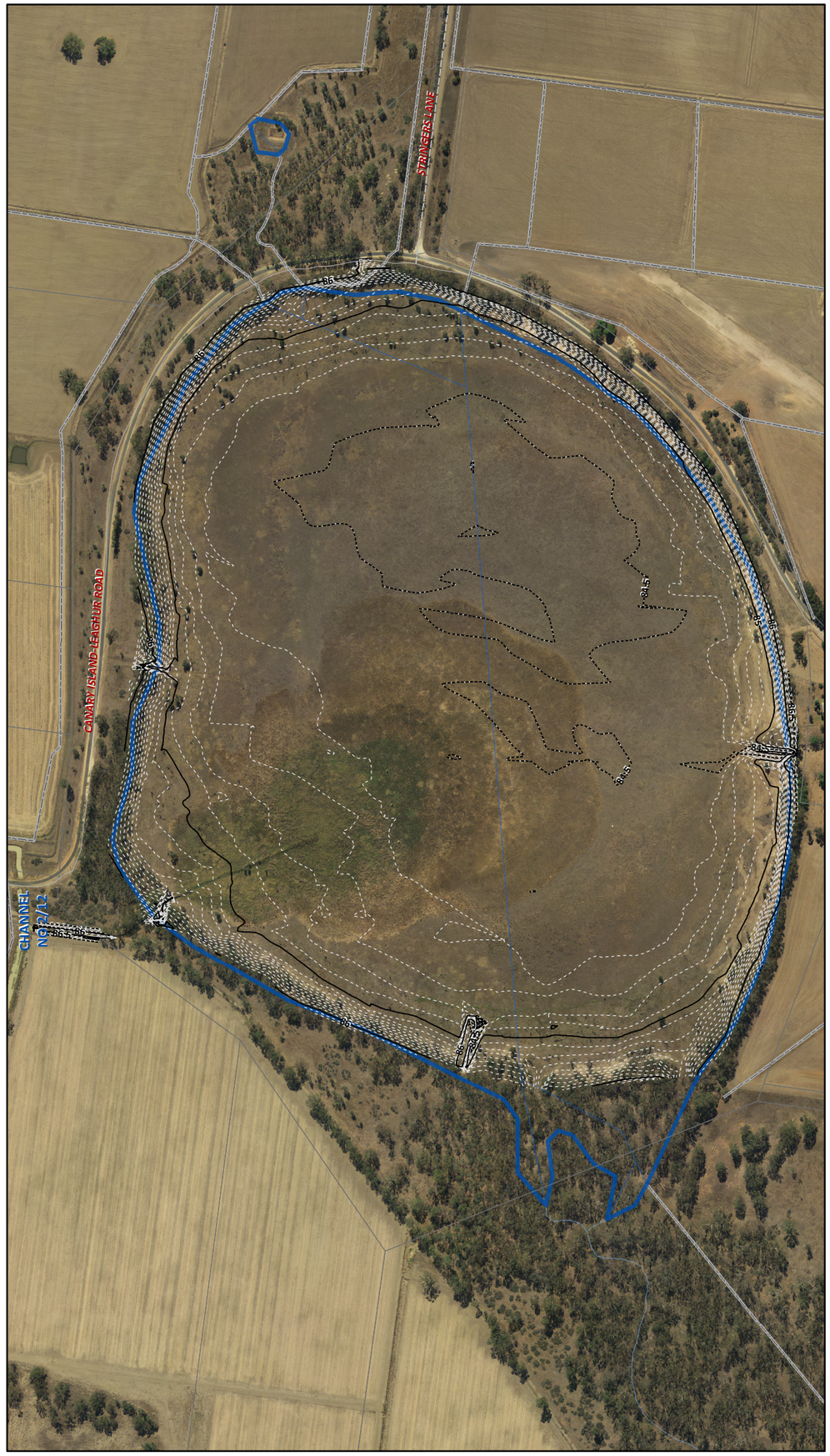
Native

- Scattered Lignum
- Dead Cumbungi
- Alive Cumbungi (part of Tall Marsh EVC 821)
- Spike Sedge and Rushes (EVC 819 Spike Sedge Wetland)
- Salt Club-sedge (EVC 308 Aquatic Sedgeland)
- Red Gum Swamp (EVC 292)
- River Red Gum regeneration

Infrastructure

- Channel outfall
- Outlet and Offtake points





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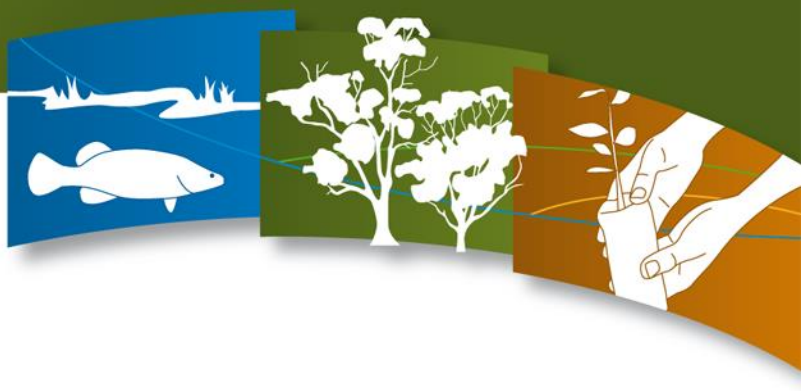

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