Environmental Water Management Plan for the Murray River at the Lock 15 Weir Pool

mallee
catchment management authority

DOCUMENT CONTROL

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Executive Summary

Environmental Water Management Plans (EWMPs) have been developed for key sites in the Mallee region. The Mallee Waterway Strategy 2014-22 (Mallee CMA, 2014) identified 23 Waterway Management Units (WMU) from 216 targeted waterways in the Mallee. The interconnectedness and commonality of threats impacting on the waterways values were used to group them into planning units.

A regional context document provides further information on the region and has been created to complement the Mallee CMA's EWMPs and should be read in conjunction with this document (Sunraysia Environmental, 2014).

This EWMP has been developed to target the Murray River channel, wetlands and floodplain influenced by the Lock 15 (Euston) weir pool. This region includes areas in Victoria and New South Wales. Although EWMPs are a Victorian water management instrument, this document has been prepared cooperatively with both jurisdictions to provide a reference and guide to environmental water management for the entire reach.

Euston Weir is located at the townships of Robinvale (Victoria) and Euston (New South Wales) at 1,117 river km. The weir has significantly changed the hydrology of the area and impacted the ecological values and processes.

The floodplain features a range of hydrological environments (water areas) that contribute to the diversity of habitats and the species they support. The main hydrological environments are permanently inundated wetlands, permanent and temporary watercourses, intermittently flooded wetlands and River Red Gum (*Eucalyptus camaldulensis),* Lignum (*Muehlenbeckia florulenta)* shrubland and woodland and Black Box (*Eucalyptus largiflorens)* forests and woodlands.

The long term management goal of the Lock 15 EWMP is to protect and restore the key species, habitat components and functions of the ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities. To achieve this, ecological and hydrological objectives were developed to target the ecological values within the target area.

Specifically the target area of this EWMP includes:

- Shallow areas in backwaters on the Murray River including scroll bars near Ruel Lagoon, Bumbang Island, Knights Bend and Walshes Bend.
- Perimeter of permanently iunundated wetlands including Dry Lake, Lake Benanee and Margooya Lagoon.
- Low terraces on the Murray River including features at Bumbang Island, Euston Lakes floodplain, Knights Bend, Walshes Bend and Margooya Lagoon.
- Minor wetlands and watercourses in the floodplain between Washpen Creek and the Murray River.
- Lake Caringay (potentially).

Delivery of environmental water within the target area will be achieved by manipulation of Lock 15, within safe operating levels, to provide a more variable water regime with greater seasonal variation.

Acknowledgements

The EWMP was produced by the Mallee Catchment Management Authority, with funding from the Victorian Government. The valuable contributions of Parks Victoria, Jane Roberts, Terry Hillman, other agencies and community members are also acknowledged.

1 Introduction

This Environmental Watering Management Plan has been prepared for the Mallee CMA to establish the long-term management goals of the Murray River channel, wetlands and floodplain influenced by the Lock 15 (Euston) weir pool.

Environmental Water Management Plans (EWMP) is prepared by Catchment Management Authorities to present the water management intentions for a site over a five to ten year time-frame. The plans are used by the Department of Environment, Land, Water and Planning (DELWP) and the Victorian Environmental Water Holder (VEWH) for short-term and long-term environmental water planning.

The key purposes of the EWMP are to:

- identify the long-term objectives and water requirements for the wetlands, identified as a high priority by the CMA;
- provide a vehicle for community consultation, including for the long-term objectives and water requirements of the wetland;
- inform the development of seasonal watering proposals and seasonal watering plans;
- inform Long-term Watering Plans that will be developed under Basin Plan requirements.

The study area supports important conservation values that are subject to significant water-related threats. It supports important populations of native fish, birds, reptiles and extensive communities of floodplain vegetation. Many plant and animal species are rare or threatened and several birds are migratory species that are protected under international agreements. These values are threatened by river regulation, including the depletion of flood flows and the stabilisation of river levels by the Lock 15 weir.

In recent years a range of measures have been implemented to address these threats and to restore natural values. On-ground works have been completed to restore seasonally variable water levels to wetlands. Increased environmental water reserves have provided new opportunities to improve the river flow regime and to reduce threats associated with river operations. Further works and new water management opportunities are currently being investigated.

2 Site Overview

2.1 Site Location

The Mallee CMA region is situated in the north-west of Victoria. The area of responsibility is close to 39,000 km2 (3.9 million ha), with a regional population estimated to be 65,000. Population centres include Mildura, Birchip, Sea Lake, Ouyen, Robinvale, Red Cliffs and Merbein.

The boundaries of the Mallee CMA region cover almost one fifth of Victoria, making it the largest area managed by a CMA in the state.

Approximately 40% of the land area within the Mallee CMA boundary is public land, consisting mainly of national parks, reserves, wilderness, and large areas of riverine and dryland forests. The other 60% is predominantly dryland crops, but there is also a significant investment in irrigation of grapes, citrus, almonds, olives and vegetables along the Murray River corridor which contributes over 40% of the value of agricultural production for the region.

In 2006, the Mallee CMA engaged consultants (Ecological Associates) to investigate water management options for the Murray River floodplain from Robinvale to Wallpolla Island. One of the major outcomes of these investigations was the development of a system of Floodplain Management Units (FMUs). These divide the floodplain into management units which water regimes can be managed independently of another FMU, but which are relatively consistent in their ecological values and land uses. The Mallee CMA has based its environmental water management plans on these FMUs to achieve more effective management of hydrologically connected systems. In addition to this, the Mallee CMA has also used individual FMUs or groupings of FMUs to form Waterway Management Units (WMUs) for planning within its Mallee Waterway Strategy.

This EWMP has been prepared for the Murray River and its floodplain in the Lock 15 weir pool, hereafter referred to as Lock 15 floodplain in this document, shown in Figure 1.

This region includes areas in Victoria and New South Wales. Although EWMPs are a Victorian water management instrument, this document has been prepared cooperatively with both jurisdictions to provide a reference and guide to environmental water management for the entire reach.

A regional context document has been prepared to compliment the Mallee CMA EWMPs and should be read in conjunction with this document (Sunraysia Environmental, 2014).

2.2 Catchment Setting

In Victoria the study area is within the Murray Fans Bioregion which is located in the north central part of the state. The region is characterised by a flat to gently undulating landscape on recent unconsolidated sediments with evidence of former stream channels, braided old river meanders and palaeochannels and broad floodplain areas associated with major river systems and prior streams. The vegetation is a mosaic of Plains Grassy Woodland, Pine Box Woodland, Riverina Plains Grassy Woodland and Riverina Grassy Woodland ecosystems. The bioregion covers the margins of six separate drainage basins: Broken River, Campaspe River, Loddon River, Avoca River and the Mallee (DEPI 2015).

In New South Wales the study area is classified within the Murray Darling Depression. The bioregion includes the Murray, Murrumbidgee, Lachlan, Darling, Barwon, Yanda and Peacock catchments.

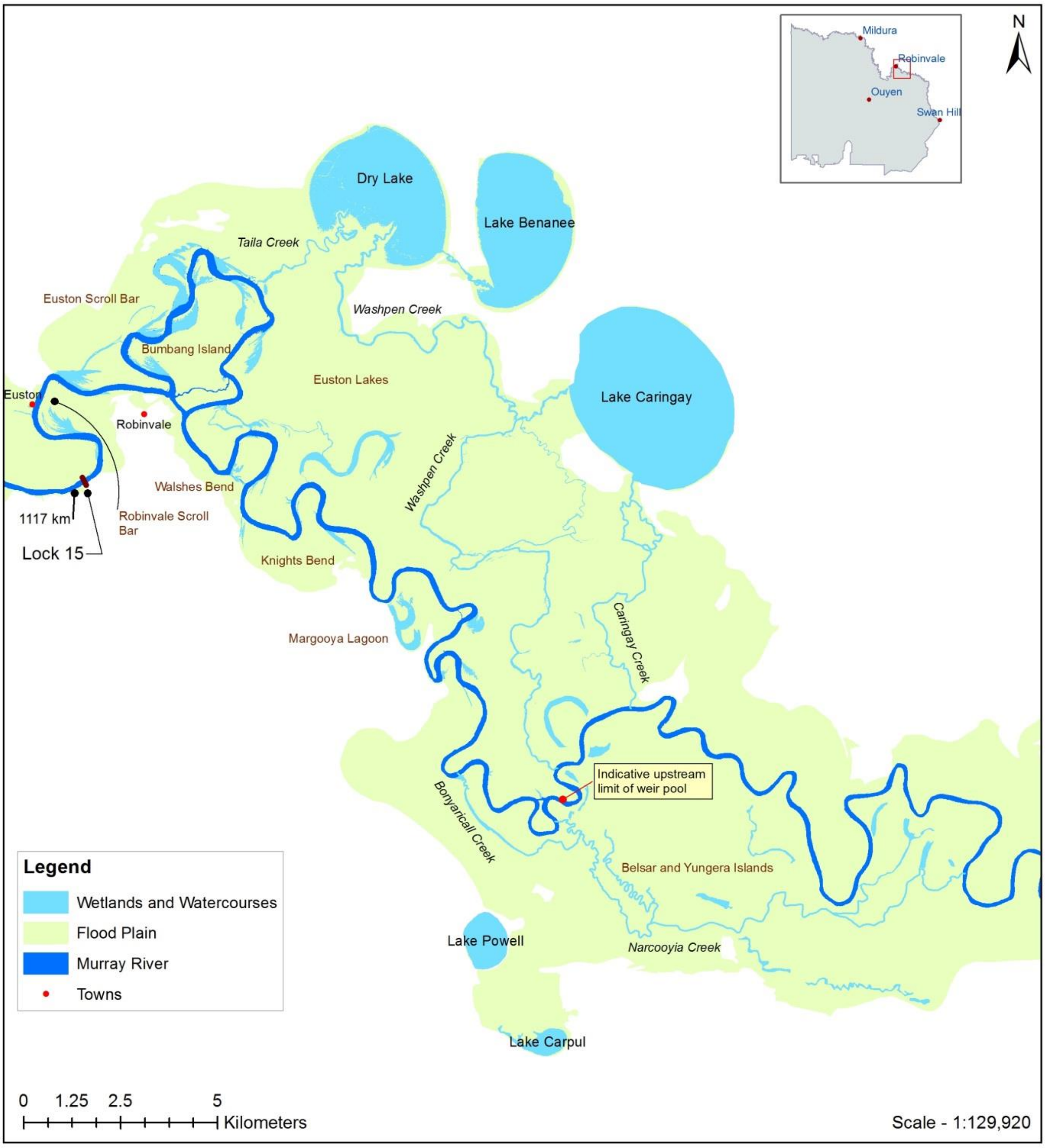


Figure 1. The Murray River upstream of Lock 15

The study area is in the Mallee tract of the Murray River which extends from Swan Hill to the Darling River junction. The river generally has a single channel and is inset within a large trench cut 10 to 20 m into an ancient lake and marine sediments (Thoms, et al. 2000).

The floodplain features a range of hydrological environments that contribute to the diversity of habitats and the species they support. The main hydrological environments are permanently inundated wetlands, permanent and temporary watercourses, intermittently flooded wetlands and River Red Gum and Black Box forests and woodlands. Each of these zones is associated with particular soil types, groundwater conditions and flooding histories.

2.3 Land Status and Management

The governance and water management of the study area is complex. The Murray River itself and the floodplain to the north lie in New South Wales. The floodplain to the south of the river lies in Victoria. The river is a shared resource, managed cooperatively by the states and the Commonwealth Government through the Murray-Darling Basin Authority. Environmental water in the reach may be supplied through the Commonwealth Environmental Water Holder, the New South Wales Office of Environment and Heritage, the Victorian Environmental Water Holder or private organisations.

The Victorian floodplain is mainly public land managed for conservation and recreation. The floodplain lies mainly in Murray River Reserve or Proposed Murray River Park including Belsar Island, Margooya Lagoon, Walshes Bend and Knights Bend. Bumbang Island is protected in the Bumbang Island Historic Reserve.

The majority of the New South Wales floodplain is privately owned and managed for agricultural production, recreation and, to some extent, for conservation.

2.4 Stakeholders for the Lock 15 EWMP

Stakeholders associated with or interested in environmental water management outcomes for the Lock 15 floodplain are listed in Table 1.

Table 1 – Lock 15 Floodplain Environmental Water Management Stakeholders

Group	Role
Parks Victoria	Land Manager
Mallee Catchment Management Authority (MCMA)	Regional waterway management
Department of Environment, Land, Water and Planning	State level environmental water management planning, land manager, threatened species manager
Victorian Environmental Water Holder	Manager of Victoria's environmental water entitlements
State Water (NSW) Lower Murray Water (Vic)	Water management Lock 15 operators Rural drainage provider
Aboriginal Communities	Indigenous Representation
Murray Darling Basin Authority (MDBA)	Murray River operations
Murray-Darling Freshwater Research Centre	Research operations
Landowners	Landowners
Recreational users	Land user
General community	Land user

2.5 Wetland Characteristics - Floodplain Morphology and Hydraulics

The key wetlands and floodplain features within the Lock 15 floodplain are shown in Figure 1 and described below.

2.5.1 Murray River

Euston Weir is located at the townships of Robinvale (Victoria) and Euston (New South Wales) at 1,117 river km. At the normal operating level the weir pool has a capacity of approximately 37 GL and extends upstream for approximately 50 river km to Belsar Island at low river flows.

2.5.2 Robinvale Scroll Bar

Robinvale Scroll Bar is located on the left bank (in Victoria) located immediately upstream of the weir (1,123 river km). Punts Lagoon is a shallow backwater located on the downstream side of the floodplain (Figure 2). As a key wetland in the Lock 15 floodplain (a Victorian wetland influenced by Lock 15), Punts Lagoon will be influenced by the Lock 15 weir pool manipulation proposed in this document. Punts Lagoon (7428 607711) has been classified as an open water wetland (Corrick and Norman 1994).

The floodplain area is inundated at high river flows, similar to the removal flow for Lock 15 (Ecological Associates 2006).This floodplain area was previously termed Euston Floodplain by Ecological Associates (2006) but has been renamed here to avoid confusion with areas north of the river in New South Wales.

Figure 2. Punts Lagoon

2.5.3 Euston Scroll Bar

Euston Weir is constructed between high ground on the left bank (Victoria) and a broad scroll bar on the right bank (New South Wales) which extends from the township of Euston. Smaller scroll bars are located upstream adjacent to Bumbang Island. The scroll bar systems feature permanently inundated backwaters at the downstream fringe, the largest of which is Ruel Lagoon located opposite Bumbang Island at 1,129 river km. Low terraces near the Murray River are vegetated by River Red Gum and higher terraces support Black Box woodland and Lignum shrubland.

2.5.4 Bumbang Island

Bumbang Island is located directly north of Robinvale between 1,137 and 1,125 river km. The main channel of the river circles Bumbang Island to the north and an excavated channel, The Cut, forms a shorter path for the river across the south side of the island. The Cut conveys a significant proportion of river flow at low discharges, so that flow in the main river channel is slow and the channel is subject to sedimentation. The Cut is shallow so that navigation becomes difficult if weir levels are lowered.

Bumbang Island contains four key wetlands in the Lock 15 floodplain: wetlands 7428638738, 7428652741, 7428631727, and an unidentified wetland (Figure 3). These wetlands are all categorised as Permanent Open Freshwater (Corrick and Norma 1994). Elevated weir levels inundate low-lying areas at the perimeter of the island including low floodplain terraces, wetlands and Bumbang Creek. Due to the proximity of the island to the weir, river flows only inundate these areas at discharges exceeding approximately 50,000 ML/d. The central part of the island comprises a high terrace vegetated by Black Box and is rarely inundated (Ecological Associates 2006).

Figure 3. Bumbang Island

2.5.5 Euston Lakes Floodplain

The Euston Lakes floodplain is an extensive complex of wetlands, lakes and watercourses on the right bank of the river extending upstream from Bumbang Island at 1,132 river km to Belsar Island at 1,173 river km. The floodplain is up to 10 km wide. Three lakes lie at the perimeter of the floodplain: Dry Lake (690 ha), Lake Benanee (748 ha) and Lake Caringay (1,922 ha). Between the lakes and the river is a floodplain complex of wetlands and watercourses.

At the normal operating level of Lock 15, the weir pool extends into the system along Taila Creek, which connects to the Murray River at the north of Bumbang Island. Taila Creek provides a pool level connection firstly to Dry Lake and then Lake Benanee. The lakes are inundated at the normal operating level of Euston Weir and have experienced a near-permanent inundation regime since the weir was constructed. Under natural conditions the lakes were inundated by peaks in river flow and would have dried out during periods of sustained low flow.

Washpen Creek provides a connection from Dry Lake to Lake Caringay. The creek is inundated by the Euston Weir pool as far as an old pump site and block bank, 12 km from Dry Lake. Leakage through the bank provides inundation along a further 1.1 km of the channel. An earthen bank with a disused regulator at the perimeter of Lake Caringay prevents water entering the lake. Under natural conditions

Washpen Creek would have provided a hydraulic connection between Dry Lake and Lake Caringay during periods of high flow.

Caringay Creek provides an upstream connection between the Murray River and Lake Caringay and has an estimated commence to flow of 50,000 ML/d. The creek is blocked by an earthen bank with a crest of 52.93 m AHD at the southern perimeter of the lake (Lake Caringay Rehabilitation Project Steering Committee 2008). Prior to the construction of Lock 15, Lake Caringay would fill and drain in sympathy with Murray River levels, retaining approximately 0.5 m of water on the flood recession. Following construction of the weir the lake was flooded to approximately 0.6 m. In the 1960s stop banks were constructed on the two channels connecting the lake to the river, to exclude the weir pool and flood water and to allow the lake bed to be developed for cropping.

Between the Taila and Washpen Creeks the floodplain comprises a complex of channels, wetlands and floodplain terraces of which the hydraulics are poorly understood.

The hydraulics of the Euston Lakes was observed during the 2010/11 flood event, Figure 4, when the river peaked at 79,000 ML/d at Boundary Bend. High river levels initially increased flow in Taila Creek to Dry Lake and Lake Benanee. As river discharge approached 50,000 ML/d water entered the upstream part of the system at Caringay Creek and created throughflow in Washpen Creek. Modelled peak flows in this event were 6,500 ML/d in Washpen Creek and 3,000 ML/d in Taila Creek (Clark 2012).

Figure 4. Flood inundation extent on 7/2/2011 (Clark 2012)

2.5.6 Knights Bend and Walshes Bend

Walshes Bend and Knights Bend are adjacent point bar systems located at 1,143 river km and 1,150 river km respectively. The floodplain is part of the Murray River Reserve. Knights Bend comprises one key wetland in the Lock 15 floodplain, wetland 7428679683 (Figure 5). This wetland is categorised as Permanent Open Freshwater.

Most of Walshes Bend is elevated and inundated at only high flows. Walshes Cut crosses the meander loop and is permanently inundated by the Euston Weir Pool. A low-lying wetland adjacent to the cut on the downstream is inundated by moderate peaks in river flow.

Knights Bend features low-lying areas near the river bank. A deep, broad depression connects to the Murray River at the downstream edge of the floodplain. In the past the wetland has been used to store irrigation drainage. A second wetland lies on the upstream edge of the floodplain.

Figure 5. Walshes and Knights Bend

2.5.7 Margooya Lagoon

Margooya Lagoon (7428695661) is a key wetland in the lock 15 floodplain (Figure 6). It is categorised as Open Water. Margooya Lagoon is located in the proposed Murray River Park located at 1,151 river km, approximately 7 km southeast of Robinvale. The lowest area of the floodplain is Margooya Lagoon, a 31 ha wetland permanently inundated by the Euston Weir pool. A regulator constructed in

2009 is operated to provide a variable environmental water regime by controlling flow on a narrow creek between the wetland and the river at the downstream end of the floodplain. The regulator allows water to be stored at up to 48.7 m AHD, increasing the area of inundation from 32 ha to 60 ha. An upstream channel introduces water to the wetland from the upstream part of the floodplain at elevated river flow (Ecological Associates 2006).

The wetland is fringed by Cumbungi (*Typha orientalis)* with River Red Gum (*Eucalyptus camaldulensis)* present on low floodplain terraces. Black Box (*Eucalyptus largiflorens)* woodland occurs on higher floodplain areas. Surveys of fish movement and recruitment have found the wetland supports juvenile Golden Perch (*Macquaria ambigua)* and Silver Perch *(Bidyanus bidyanus)* and may be an important nursery habitat. Three managed drying events since 2009 have controlled a previously large population of European Carp (*Cyprinus carpio)* (Ellis 2011).

Figure 6. Margooya Lagoon

2.5.8 Belsar and Yungera

The Belsar and Yungera floodplain system comprises Belsar, Yungera and Tonsing Islands, the adjacent floodplain and Lakes Powell and Carpul.

Narcooyia Creek defines the southern side of Belsar and Yungera Islands. Flowing over 17 km, it diverges from the river at 1195 river km, upstream of Yungera Island, and returns to the river at 1168 river km downstream of Belsar Island. Bonyaricall Creek branches from Narcooyia Creek near its downstream end. It is 6 km in length and joins the Murray River at 1163 river km to create Tonsing Island.

Euston Weir influences river levels in Bonyaricall Creek and the Murray River on the eastern part of Belsar Island.

Narcooyia Creek has been significantly modified to allow its use as a delivery channel for irrigation water. The channel is impounded between a bank where it branches from the Murray River and a weir just above Bonyaricall Creek. Water is pumped from the Murray River into the creek to meet irrigation demand. Water is extracted from the creek just above the downstream weir (GHD 2013). These operations maintain constant flooding in the creek and near-constant flow (Ecological Associates 2006).

Excess water flows over the weir in Narcooyia Creek and enters Bonyaricall Creek rather than the final reach of Narcooyia Creek. Both creeks are subject to siltation and encroachment by Cumbungi. (Ecological Associates 2006; GHD 2013). The velocity in Bonyaricall Creek is negligible due to the width and depth of the channel. Intensive irrigation diversions from Bonyaricall Creek may draw water into the creek from downstream, reversing the flow.

Lakes Powell and Carpul are large floodplain lakes to the south of Bonyaricall Creek. Lake Powell naturally fills at its northern end when high flows spill from Bonyaricall Creek along a narrow floodway. The channel passes under the Murray Valley Highway where the invert of the pipe culverts matches the maximum thalweg level (valley course) of the channel: 51.2 m AHD. The bed of Lake Powell is generally flat and has an invert of 49.75 m AHD, so that the lake stores water at a depth of 1.45 m after flood water recedes. Lake Powell has an approximate area of 115 ha and a volume of 1.5 GL (GHD 2012).

Lake Carpul fills primarily from overflows from Lake Powell when water levels exceed 52.3 m AHD. The lake has an approximate invert of 49.3 m AHD and retains water to a depth of up to 3 m. It has an area of 115 ha and a volume of 1.5 GL (GHD 2012).

Due to the effect of Euston Weir, rising river flows inundate upstream areas of the Belsar-Yungera floodplain before the downstream areas. Water first enters the floodplain at the downstream connection of Yungera Creek when river discharge exceeds 16,000 ML/d (Table 2). Pools and wetlands near the creek are more than 2 m deep. They are readily filled by small peaks in river flow and can retain water for up to a year. Significant inundation of the surrounding areas occurring at flows exceeding 20,000 ML/d. Higher flows activate upstream connections and create through-flow.

Low floodplain terraces on meander loops of the Murray River commence when river levels exceed 20,000 ML/d with significant inundation occurring at flows over 27,000 ML/d (Table 2). The Carp Hole is the largest wetland in the meander loops.

Table 2 - Inundation thresholds and hydrology under current conditions for key floodplain features (Gippel 2008) (Jacobs 2014) at Belsar and Yungera

Site	Generalised Flow Threshold (ML/d)
Yungera Creek and associated wetlands	20,000 - 30,000
Murray River meander loops	25,000 - 40,000
Lignum Shrubland	70,000 - 120,000
Black Box Woodland	70,000 - 120,000
Lake Powell	140,000
Lake Carpul	170,000

Lignum shrubland occupies a broad, shallow basin in central Belsar Island and is significantly inundated by flows exceeding 70,000 ML/d. Inundation is largely complete at flows of 120,000 ML/d (Table 2). Black Box woodland has a similar flooding pattern with flooding initiated at flows over 70,000 ML/d and mostly complete at flows of 120,000 ML/d (Table 2) (Jacobs 2014).

The flow threshold for significant flooding in Lake Powell is in the order of 140,000 ML/d and 170,000 for Lake Carpul (Table 2) (Jacobs 2014).

2.6 Management Scale

This EWMP has been prepared for the Murray River and its floodplain in the Lock 15 weir pool. Specifically the target area of this EWMP includes:

- Shallow areas in backwaters on the Murray River including scroll bars near Ruel Lagoon, Bumbang Island, Knights Bend and Walshes Bend.
- Perimeter of permanently iunundated wetlands including Dry Lake, Lake Benanee and Margooya Lagoon.
- Low terraces on the Murray River including features at Bumbang Island, Euston Lakes floodplain, Knights Bend, Walshes Bend and Margooya Lagoon.
- Minor wetlands and watercourses in the floodplain between Washpen Creek and the Murray River.
- Lake Caringay (potentially)

2.7 Environmental Water Sources

The Environmental Water Reserve (EWR) in Victoria is the legally recognised amount of water set aside to meet environmental needs. The EWR can include minimum river flows, unregulated flows and specific environmental entitlements. Environmental entitlements can be called out of storage when needed and delivered to wetlands or streams to protect their environmental values and health.

Environmental water for the target area may be sourced from the water entitlements and their agencies listed in the table below and further explained in the Regional Context Document (Sunraysia Environmental, 2014).

Table 3 - Summary of environmental water sources available to the Lock 15 target area (Victorian assets).

Water Entitlement*	Responsible Agency
Murray River Unregulated Flows (RMUF)	Murray Darling Basin Authority
Murray River Surplus Flows	
Victorian Murray River Flora and Fauna Bulk Entitlement	Victorian Environmental Water Holder
Commonwealth Water	Commonwealth Environmental Water Holder
Donated Water	Mallee CMA

*Other sources of water may become available through water trading or changes in water entitlements.

2.8 Related Agreements, Policy, Plans and Activities

The following policies, plans and activities are directly relevant to the environmental management of Lock 15:

Mallee Regional Waterway Strategy

The Mallee Regional Waterway Strategy (Mallee CMA, 2014) prioritises the development of EWMPs for key sites within the Lock 15 target area.

Scoping Study: Environmental Water Management Plans

In July 2014, Sunraysia Environmental completed a report for Mallee CMA to identify priorities for the development of environmental water management plans. The scoping study identified a number of sites within the Lock 15 target area for EWMP preparation.

Investigation of water management options for the Murray River – Nyah to Robinvale

In 2006, the Mallee CMA engaged consultants Ecological Associates to investigate water management options for the floodplain of the Murray River from Nyah to Robinvale (Ecological Associates, 2006). This investigation prioritised options to increase the frequency and duration of floodplain inundation for each FMU. The investigation also looked at the scope of manipulating river levels to benefit ecosystems through operation of the Euston Weir.

The Living Murray Initiative

The Lock 15 target area is located within a reach of the Murray River listed as a “Significant Ecological Asset” under the Living Murray Initiative (Ecological Associates, 2006).

Mallee CMA Frontage Action Plan for Nyah to Robinvale

The Lock 15 target area is within the area covered by the Mallee CMA Frontage Action Plan (FAP) for Nyah to Robinvale (Mallee CMA, 2003) and has the potential to attract future funding and works through that project.

Environmental Water Management Plans for Bumbang Island, Walshes Bend, Margooya Lagoon

Environmental water management plans for Bumbang Island, Walshes Bend and Margooya Lagoon have been developed and should be considered in conjunction with this EWMP.

Lock 15 Weir Manipulation Trials

Mallee CMA are working with stakeholders to undertake weir level manipulation in late 2015 in order to meet environmental objectives identified through EWMPs relating to the Lock 15 target area.

Other

The Lock 15 target area includes sections of the Victorian floodplain of the Murray River which is the subject of investigation in many guises. These include salinity management plans, flow studies and Land Conservation Council reviews.

3 Hydrology and System Operations

3.1 Hydrology of the Murray River

The hydrology of the Murray River at Euston under natural and current conditions was analysed by (Fluvial Systems 2014) (Figure 7).

For flows greater than 20,000 ML/d, event frequency has reduced significantly under regulated conditions. Current event frequency is in the order of 50% to 70% less than pre-regulation frequency, even for flows exceeding 170,000 ML/d.

The duration of spells is also lower for intermediate events: spells are approximately 50% shorter for events 20,000 to 60,000 ML/d. However for high flows, greater than 90,000 ML/d, the duration of spells under natural and benchmark scenarios is similar.

The river is in a low-flow state for a greater proportion of time under current conditions as it is managed to deliver water to downstream consumers efficiently. The river fluctuates frequently over the 10,000 ML/d flow threshold. Under natural conditions these events were less frequent, 93 events per 100 years, but longer due to the higher and more sustained flow peaks.

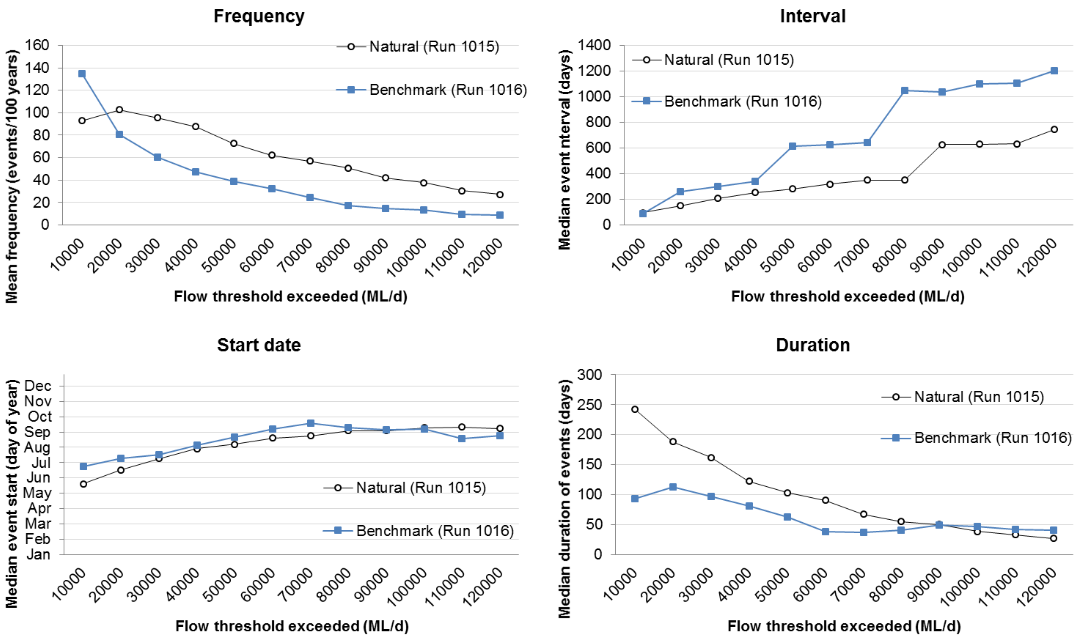


Figure 7. Comparison of characteristics of spells at Euston DS for Natural and Benchmark series over a 114 year modelled period (Fluvial Systems 2014).

3.2 Groundwater

The study area lies in the Murray Geological Basin, which is a shallow sedimentary basin with a sequence of sediments of Tertiary to Recent age. The three main sedimentary sequences underlying the project area are the Renmark Group, the Murray Group Limestone and the Parilla Sands. Geological units outcropping in the surrounding landscape include:

- the Parilla Sands, which form broad parallel dunes underlying the more recent landscape
- the Blanchetown Clay and
- Aeolian dune deposits of the Woorinen Sands formation.

The hydrogeology of the study area is largely related to the regional Parilla Sand Aquifer. The aquifer is a closed system where regional groundwater flows to the central-west of the basin, near the South Australian border (Figure 8). The regional groundwater gradient at Euston is from east to west. The salinity of the regional aquifer is consistently saline and higher than 35,000 EC (Ecological Associates 2006).

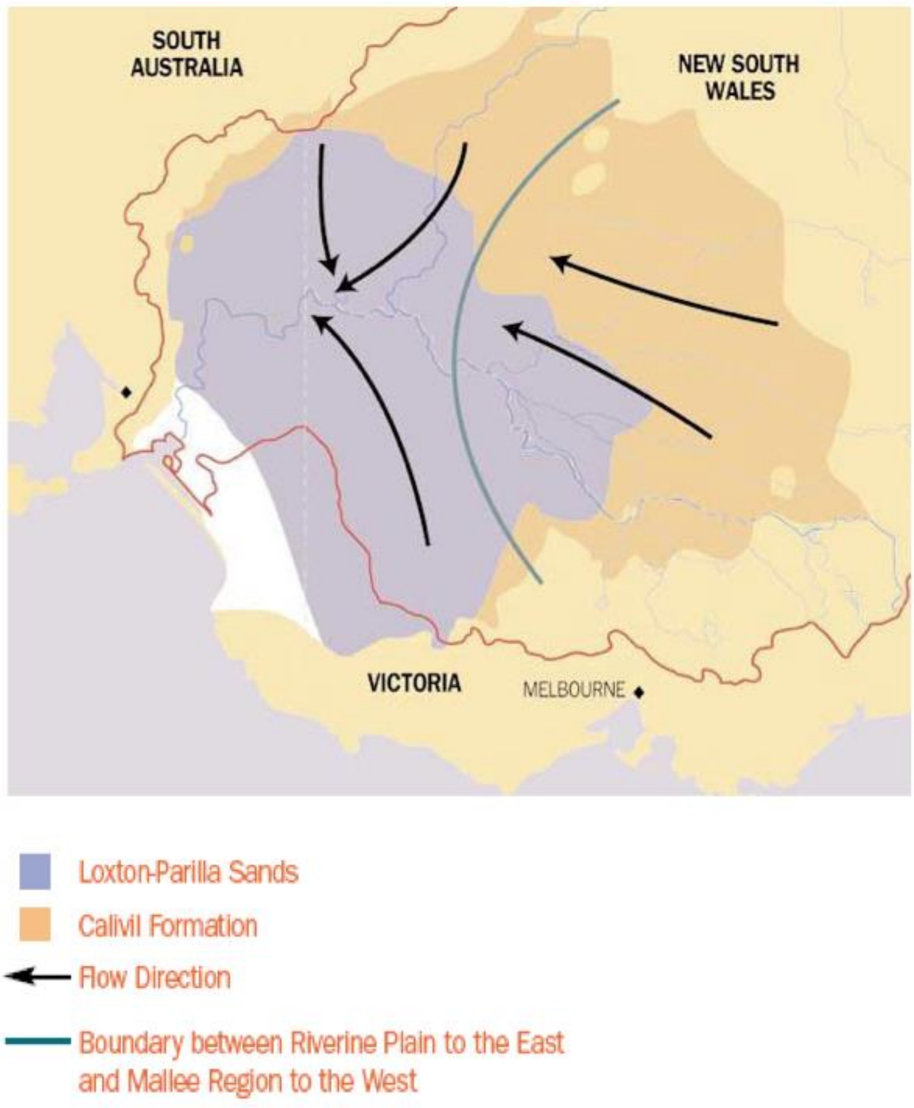


Figure 8. Flow directions in the Parilla Sand aquifer (MDBC 1999 Murray Darling Basin Groundwater - a resource for the future).

Euston Weir affects local groundwater levels and salinities. The weir has elevated the river by up to 3 m, to a level above the regional water table, so that the local groundwater gradient is directed away from the river, with river water recharging the Parilla Sands aquifer (Figure 9). Groundwater salinity near the Euston weir pool is consistently fresher than the surrounding dryland landscape and often less than 5,000 EC (Ecological Associates 2006).

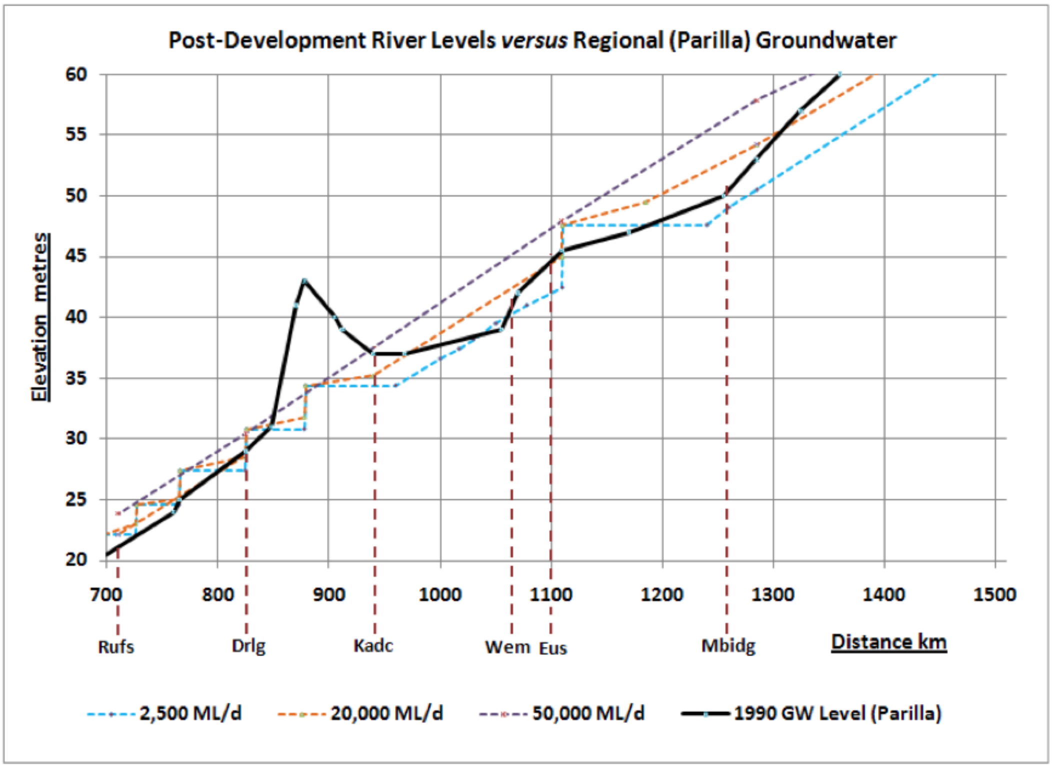


Figure 9. Murray River level at three river flows compared with the 1990 regional groundwater level in the Parilla Sand. Distance is from the river mouth (river km). Locations are Rufus River, Darling River, Karadoc, Wemen, Euston, and Murrumbidgee River. From (Evans 2012)

Groundwater monitoring at Lake Benanee indicates a strong hydraulic connection between surface water bodies and the water table aquifer (Figure 10). Water levels in the lake and a nearby bore (87108) show a close correspondence as the lake was dried out in 2008. In contrast, bores more distant from the lake (near Lake Caringay) have a lower level and do not respond to the drying event. The low salinity of bore 87108 is indicative of fresh water seepage from the lake and contrasts with the higher salinity of the other monitoring bores. This groundwater recharge effect will be strongest near the weir and will weaken upstream to the limit of the weir pool.

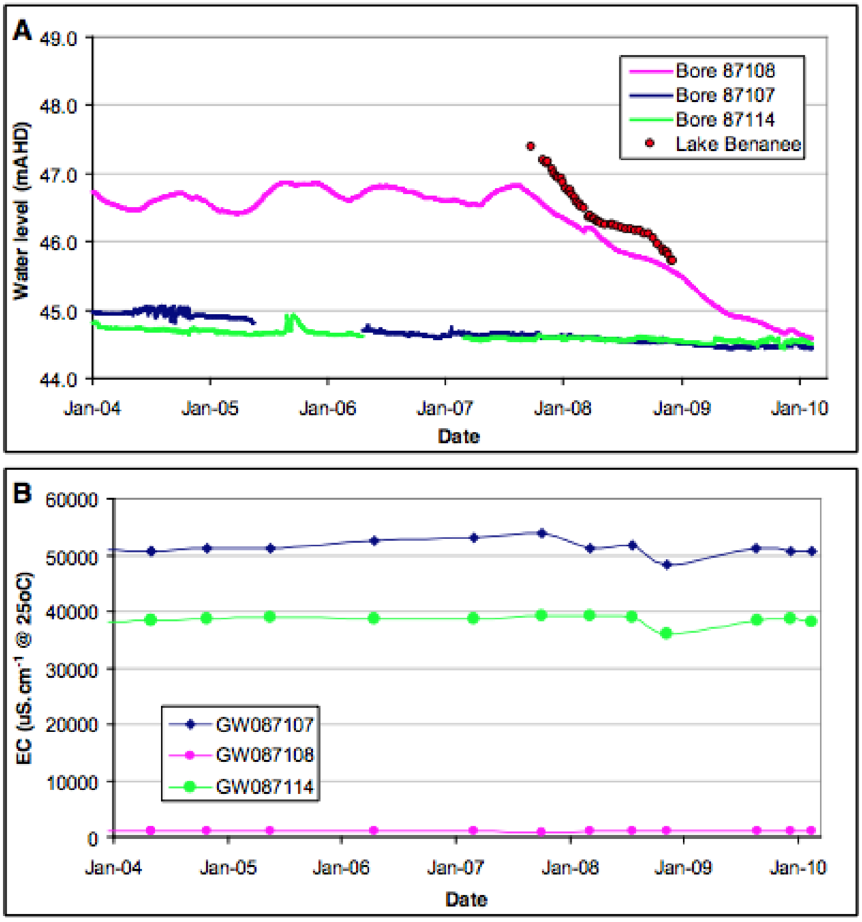


Figure 10. Groundwater and lake surface water levels (A) and electrical conductivity (B) at three bores located 0.25 km (87107), 3.5 km (87108) and 5.3 km (87114) southeast of Lake Benanee (McCarthy, Chapman, et al. 2010).

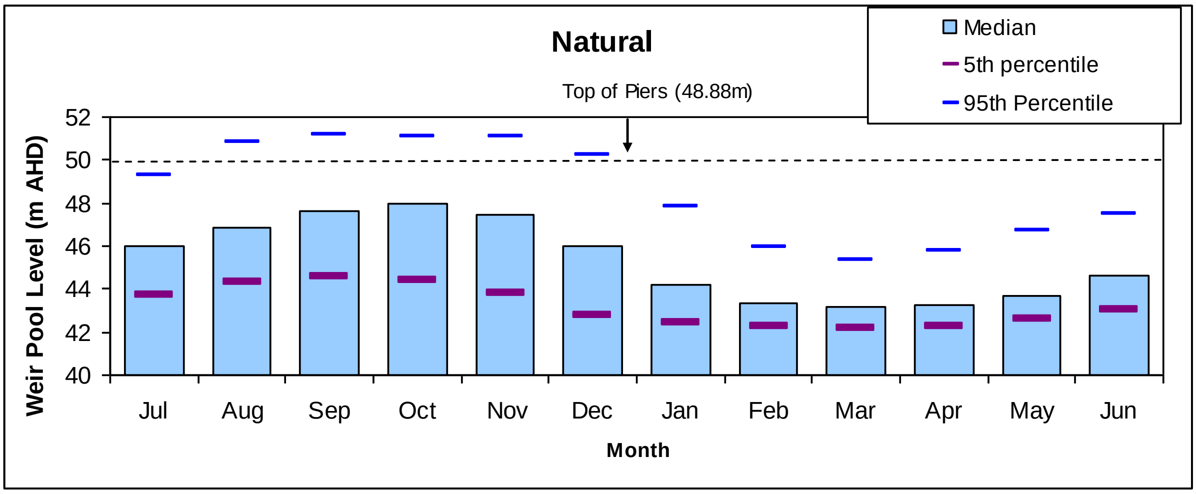
3.3 Hydrological Impacts of the Weir

3.3.1 Water Level Variability

Lock 15 is normally operated to create a stable level upstream, close to the capacity of the river channel. The weir is opened and closed as flow varies, so that a stable river level can be maintained. The weir is effective until discharge at the weir exceeds the capacity of the structure. At this point the river levels below and above the weir equalise. When the weir cannot be opened any further, it is removed and rising discharge results in rising river levels.

The influence of the Euston Weir is strongest in the river immediately upstream. Upstream of Belsar Island the river is free-flowing with the gradient in the river determined by discharge and the morphology of the channel. Free-flowing conditions extend closer to the weir as discharge increases, which correspond to a shrinking of the weir pool.

The natural variation of river levels has been greatly reduced by the operation of the weirs and the depletion of flows through storage and diversion. An analysis of natural and current (baseline) weir levels at Lock 15 is provided in Figure 11.



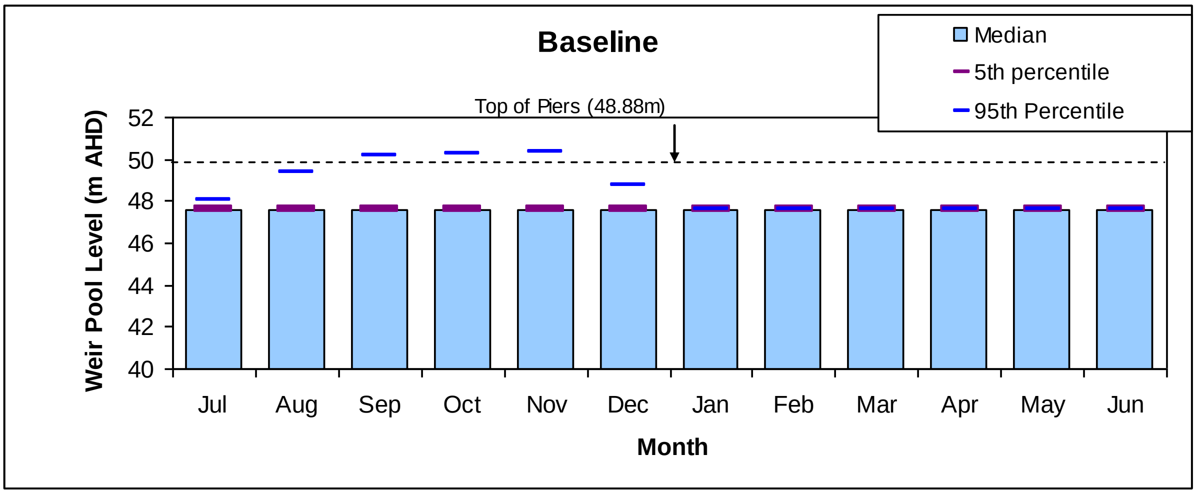


Figure 11. Distribution of monthly water levels downstream of Lock 15 under Natural and Current (Baseline) scenarios. Pre-weir and pre-regulation water levels have been modelled using data that relates river level and discharge.

Under natural conditions the river levels exhibited a strong seasonal cycle in water levels with the median autumn level four metres lower than the median level in spring. The river levels showed high inter-annual variability with the 5th and 95th percentiles in spring ranging over 8 m.

Under current development and operating practices the weir has raised the river to 47.6 m AHD. This equates to the median annual peak under natural conditions of approximately 50,000 ML/d, which typically occurred in spring. Variation in river levels has been largely eliminated from the low-flow seasons of summer and autumn. In winter and spring median river levels are maintained close to the target pool level, but rare, high flows continue to provide elevated water levels.

3.3.2 Velocity

Lock 15 reduces the velocity of water in the main channel of the Murray River upstream of the weir. The weir increases the depth and cross-sectional area of the channel so that water velocities are ecologically insignificant. Fast-flowing water is an important habitat requirement for native fish and is associated with the diversity, abundance and recruitment success of Murray Cod *(Muccullochella peelii peelii*) and other native fish and with healthy populations of Murray crayfish *(Euastacus armatus)* (McCarthy 2005).

The upstream extent of the weir pool is reduced as river flow increases, and natural channel velocities are completely restored at high flows when the weir is removed.

3.3.3 Weir Re-instatement

Weir boards are removed during high flows then re-instated when river levels fall.

Weir re-instatement is timed to restore the weir pool while flood water is present in the river and levels are still above normal operating level. This ensures that the weir pools can be restored quickly and with unregulated flood water. If weirs were re-instated after the river fell below the normal operating level, the weir pools could not be restored until water flowing down the river re-filled the weir storage. This could involve the use of relatively costly regulated water and would involve an undesirable period of low water levels. Capturing water in the weir pool would also reduce flow downstream of the weir which would reduce the supply of water downstream and delay the re-filling of other weirs.

The effect of weir reinstatement on downstream water levels is illustrated Figure 12 which shows upstream and downstream water levels and rates of change at Lock 15 at the tail of a flood peak in March 2011. Initially, the upstream and downstream water levels are similar and about 1.5 m above the normal pool level of 47.6 m AHD. The weir is reinstated when the river level reaches the normal pool level. The rate of fall in tail water level increases marginally during weir reinstatement and achieves a stable level within a few days.

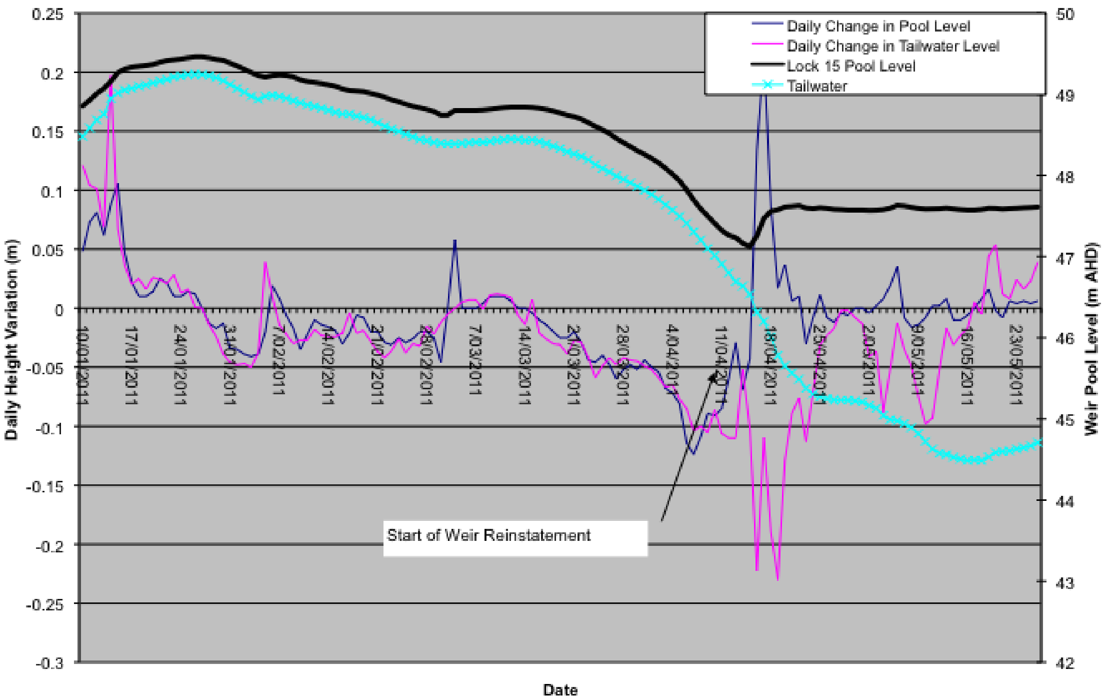


Figure 12. Lock 8 water level dynamics during weir reinstatement at the tail of a flood peak in September 1995 showing upstream and downstream water levels and rates of water level change.

Recent improvements in flow forecasting and weir operability have greatly reduced the impact of weir reinstatement on the rates of fall in tail water levels. In the past rapid rates of fall were identified as a threat to bank stability (Thoms and Walker 1992). Rapidly falling water levels also have the potential to strand fish in isolated floodplain water bodies, with potentially significant impacts to fish recruitment success and adult survival.

Rapidly falling water levels continues to be a consideration in weir re-instatement. River banks and trees downstream of the weir are prone to slumping and collapse if water levels fall quickly after sustained high flow events. To avoid rapid decreases in downstream water levels, operators at Lock 15 aim to fill the weir pool at a rate of no more than 1,000 ML/d (Phil Cocks NSW Office of Water 19 Nov 2014).

3.4 Environmental Watering

The water regime of Margooya Lagoon has managed since 2009 when a regulator was installed, allowing the wetland to be disconnected from the weir pool and dried out and surcharged up to a level 1.1 m above the weir pool.

The wetland has been dried three times and refilled by pumping, by reconnecting the wetland to the weir pool or by the overbank associated with high river levels in the summer of 2010/2011.

The Euston Lakes Floodplain has also been subject to drying and reflooding in recent years. In 2007 the lakes were selected for temporary disconnection from the Murray River to achieve water savings as part of drought contingency planning. The planned disconnection of the Euston Lakes was preceded by lowering the Euston weir pool to 46.9 m AHD from August 2007 to January 2008, which lowered water levels in the lakes. A temporary regulator was constructed on Taila Creek in December 2007 to disconnect Dry Lake, Lake Benanee and a section of Taila Creek from the Murray River. Washpen Creek received pumped water from Taila Creek via a flood runner to maintain habitat for freshwater catfish.

Refilling of the lakes commenced in November 2009. Following this, a high river flow peaking at 74,000 ML/d in early 2011 inundated the floodplain and filled the lakes nearly 2 m above normal weir pool levels, resulting in inundation of riparian areas fringing the wetlands.

Between 22 July and 29 August 2014, the NSW Office of Water undertook a weir manipulation trial, raising the weir gradually to 47.9m AHD (P. Cocks pers. comm., September 2014). The trial was not specifically aimed at environmental watering but had the potential to provide ecological outcomes. The purpose of the trial was to test recent upgrade works and to assist with works downstream of Lock 15 by holding back some water (P. Cocks pers. comm., September 2014).

The operation of Lock 15 during the millennium drought saw it drawn down 700mm, with some impacts to irrigators (S. Jaensch pers. comm. March 2015).

4 Water Dependent Values

4.1 Listed Flora

The flora of the system is diverse, with over 630 native plant species known to occur near the site and 124 of these having conservation significance. The high diversity of plants is related to the close proximity of contrasting Mallee and floodplain vegetation. A recent survey of Belsar Island in November 2013 recorded 207 native species. Of these 57 are floodplain species that are rare or threatened under the Advisory List of Rare or Threatened Plants in Victoria (Table 4).

Plant communities are strongly influenced by the Lock 15 weir pool. Stable water levels have promoted dense stands of Cumbungi in backwaters, wetlands and creeks including Ruel Lagoon, Margooya Lagoon, Taila Creek and Dry Lake. Sheltered backwaters also support a variety of aquatic species: Floating Pondweed (*Potamogeton sulcatus),* Water Milfoil (*Myriophyllum papillosum)* and Eel Grass (*Vallisneria spiralis)* are present in Washpen Creek (Lake Caringay Rehabilitation Project Steering Committee 2008). Amphibious species growing at the fringes of wetlands include Common Rush (*Juncus usitatus),* Water Primrose *(Ludwigia peploides)* and Marsh Club-rush (*Bolboschoenus caldwellii)*. Wetlands and watercourses are lined by River Red Gum, Black Box and River Cooba (*Acacia stenophylla)*, often with shrubby understorey of Nitre Goosefoot (*Chenopodium nitrariaceum*) and Lignum (*Muehlenbeckia florulenta*).

Low floodplain terraces, adjacent to the Murray River support River Red Gum forest while higher terraces support River Red Gum forest and woodland. Lignum shrublands and woodlands are present at intermediate flood levels, often in shallow floodplain depressions.

A notable stand of the NSW Vulnerable Swamp Sheoak (*Casuarina obesa)* is present at Lake Benanee (McCarthy, et al., 2010).

The Euston Lakes Floodplain system is subject to grazing and vegetation has been substantially cleared from Lake Caringay (Lake Caringay Rehabilitation Project Steering Committee 2008).

The pest plant Dense Waterweed (*Egeria densa*) has been abundant in Taila Creek in the past. However, this species was removed by high flood flows in 2010/2011 and has not yet re-established.

Table 4. Plant species of conservation significance reported from the study area (Australian Ecosystems 2009)

Scientific Name	Common Name	Conservation Status		
		EPBC	FFG	Advisory List
Alternanthera nodiflora	Common Joyweed			k
Alternanthera sp. 1 (Plains)	Plains Joyweed			k
Asperula gemella	Twin-leaf Bedstraw			r
Asperula wimmerana	Wimmera Woodruff			r
Atriplex paludosa subsp. paludosa	Marsh Saltbush			r
Atriplex papillata	Coral Saltbush			r
Atriplex rhagodioides	Silver Saltbush		L	v
Atriplex spinibractea	Spiny-fruit Saltbush			e
Bergia ammannioides	Jerry Water-fire			v
Cardamine moirensis	Riverina Bitter-cress			r
Centipeda crateriformis subsp. compacta	Compact Sneezeweed			r
Centipeda nidiformis	Cotton Sneezeweed			r
Centipeda thespidioides s.l.	Desert Sneezeweed			r
Centipeda thespidioides s.s.	Desert Sneezeweed			r
Ceratophyllum demersum	Hornwort			k
Craspedia haplorrhiza	Plains Billy-buttons			k
Cullen cinereum	Hoary Scurf-pea		L	e
Cynodon dactylon var. pulchellus	Native Couch			k
Cyperus nervulosus	Annual Flat-sedge		L	e
Cyperus rigidellus	Curly Flat-sedge		L	e
Dianella porracea	Riverine Flax-lily			v

Scientific Name	Common Name	Conservation Status		
		EPBC	FFG	Advisory List
Eleocharis pallens	Pale Spike-sedge			k
Eragrostis lacunaria	Purple Love-grass			v
Eragrostis setifolia	Bristly Love-grass			v
Eremophila divaricata subsp. divaricata	Spreading Emu-bush			r
Eremophila maculata subsp. maculata	Spotted Emu-bush			r
Eryngium paludosum	Long Eryngium			v
Frankenia crispa	Hoary Sea-heath			r
Frankenia foliosa	Leafy Sea-heath			r
Frankenia serpyllifolia	Bristly Sea-heath			r
Heliotropium asperrimum	Rough Heliotrope			v
Isolepis australiensis	Inland Club-sedge			k
Isolepis congrua	Slender Club-sedge		L	v
Lepidium papillosum	Warty Peppercress			k
Lepidium phlebopetalum	Veined Peppercress			e
Lepidium pseudohyssopifolium	Native Peppercress			k
Lepidosperma canescens	Hoary Rapier-sedge			r
Lipocarpha microcephala	Button Rush			v
Lotus australis var. australis	Austral Trefoil			k
Malacocera tricornis	Goat Head			r
Minuria integerrima	Smooth Minuria			r
Muehlenbeckia horrida subsp. horrida	Spiny Lignum			r
Ophioglossum polyphyllum	Upright Adder's-tongue			v

Scientific Name	Common Name	Conservation Status		
		EPBC	FFG	Advisory List
Rorippa eustylis	Dwarf Bitter-cress			r
Sarcozona praecox	Sarcozona			r
Sclerolaena muricata var. muricata	Black Roly-poly			k
Sclerolaena patenticuspis	Spear-fruit Copperburr			v
Senecio campylocarpus	Floodplain Fireweed			r
Sida ammophila	Sand Sida			v
Stemodia glabella s.s.	Smooth Blue-rod			k
Templetonia egena	Round Templetonia			v
Tetragonia moorei	Annual Spinach			k
Teucrium albicaule	Scurfy Germander			k
Trigonella suavissima	Sweet Fenugreek			r
Vittadinia australasica var. oricola	Sticky New Holland Daisy			k
Vittadinia condyloides	Club-hair New Holland Daisy			r

FFG Act status: Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing
DELWP Advisory List Status: x Presumed extinct, e Endangered in Victoria, v Vulnerable in Victoria, r Rare in Victoria, k Poorly Known in Victoria

4.2 Vegetation Communities

In Victoria vegetation mapping units are known as Ecological Vegetation Classes (EVCs) and are assigned conservation ratings within each bioregion (

Table 5). Of the twelve EVCs present in the study area, one is considered endangered and six are considered vulnerable in the Murray Fans Bioregion. Appendix 1 provides a full description of each EVC.

Table 5. Bioregional conservation status of Ecological Vegetation Classes in the study area.

Ecological Vegetation Class	Bioregional Conservation Status
103 Riverine Chenopod Woodland	Endangered
104 Lignum Swamp	Vulnerable
106 Grassy Riverine Forest	Depleted
107 Lake Bed Herbland	Vulnerable
200 Shallow Freshwater Marsh	Vulnerable
295 Riverine Grassy Woodland	Vulnerable
808 Lignum Shrubland	Least Concern
810 Floodway Pond Herbland	Depleted
811 Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted
813 Intermittent Swampy Woodland	Depleted
818 Shrubby Riverine Woodland	Least Concern
819 Spike Sedge Wetland	Rare
821 Tall Marsh	Depleted
823 Lignum Swampy Woodland	Vulnerable

4.3 Listed Fauna

4.3.1 Fish

The study area has a diverse fish fauna with eight native species present. The river reach in which Euston Weir lies supports healthy populations of Murray Cod and Golden Perch. Murray Cod are present in Narcooyia Creek (SKM 2006; GHD 2009). Golden Perch and Silver Perch have been recorded in the Euston Lakes Floodplain system including Washpen Creek, Dry Lake and Taila Creek (Bogenhuber, et al. 2011).

Washpen Creek supports a regionally significant population of Freshwater Catfish (*Tandanus tandanus)* (McCarthy, et al., 2010). Over 160 individuals were sampled in November 2007, including larvae, indicating the species breeds at this site. This species has experienced a significant decline in abundance and distribution throughout its southern range and is threatened in Victoria. Freshwater Catfish requires still or slow flowing water and habitat with aquatic vegetation. Other species present in Washpen Creek include Carp Gudgeon (*Hypseleotris spp.)*, Flathead Gudgeon (*Philypnodon grandiceps*), Australian Smelt (*Retropinna semoni*), Dwarf Flathead Gudgeon (*Philypnodon macrostomus*) and Flyspecked hardyhead (*Melanotaenia fluviatilis)* (McCarthy, McGuffie and Ho 2007).

Bonyaricall Creek provides slow-flowing, shallow water with fringing reed beds which supports a number of small fish species (Ho, et al. 2004). Narcooyia Creek is permanently flooded and provides complex habitat including deep holes and woody debris over a length of 17 km. The creek supports populations of Murray Cod and Golden Perch.

Oriental Weatherloach (*Misgurnus anguillicaudatus*) was reported in Euston Lakes in February 2009. Other exotic species present include Common Carp (*Cyprinus carpio*), Gambusia (*Gambusia holbrooki*), Goldfish (*Carassius auratus*) and Redfin Perch (*Perca fluviatilis*) (Bogenhuber, et al. 2011).

Table 6. Native fish fauna of Belsar Yungera (Ho, et al. 2004) (SKM 2006), (GHD 2009) (McCarthy, McGuffie and Ho 2007).

Scientific Name	Common Name	Conservation Status		
		Advisory List	FFG	EPBC
Maccullochella peelii	Murray Cod	v	L	V
Macquaria ambigua	Golden Perch	v		
Melanotaenia fluviatilis	Murray-Darling Rainbowfish		L	
Nematalosa erebi	Bony Bream			
Melanotaenia fluviatilis	Fly-specked Hardyhead			
Hypseleotris spp.	Carp Gudgeon			
Retropinna semoni	Australian Smelt			
Craterocephalus stercusmescarum fulvus	Freshwater Hardyhead		L	

DELWP Advisory List Status: x Presumed extinct, e Endangered in Victoria, v Vulnerable in Victoria, r Rare in Victoria, k Poorly Known in Victoria

FFG Act status: Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing

EPBC Act status: EXtinct, CRitically endangered, ENdangered, Vulnerable, Conservation Dependent, Not Listed

4.3.2 Birds

The diversity of the bird fauna is promoted by the close proximity of the contrasting floodplain and Mallee environments, with 118 species of bush birds and waterbirds recorded in the area. A recent survey in November 2013 reported 87 species of which 22 have conservation significance at the state or national level (Table 7). Three species are protected under international migratory bird agreements.

Birds of conservation significance known from Euston Lakes include Caspian Tern (*Hydroprogne caspia*) (CAMBA), Great Egret (*Ardea alba*) (CAMBA) and White-bellied Sea-eagle (*Haliaeetus leucogaster*) (McCarthy, et al., 2010). White-bellied Sea-eagles are frequently present at Bumbang Island.

Dry Lake has historically provided a rookery for colonial nesting waterbirds including Great Cormorant (*Phalacrocorax carbo*) and Pied Cormorant (*Phalacrocorax varius*). The rookery was regularly used until the mid-1970s (McCarthy, et al., 2010). During the flood flows in 2011 the rookery was used again; 140 great cormorant nests and 220 nestlings were observed (Bogenhuber, et al. 2011).

The region supports important breeding colonies for Regent Parrot (*Polytelis anthopeplus monarchoides)* with birds nesting in River Red Gum trees near the Murray River at Gearbox Loop on Belsar Island (GHD 2009).

Grey-crowned Babbler (*Pomatostomus temporalis*) has been reported from Belsar Yungera. These birds are insectivores that build stick nests in saplings, shrubs and the lower canopy of trees. Their favoured habitat is Black Box and River Red Gum woodland where they forage partly on the ground and partly on the trunks and branches of trees and shrubs.

The large lakes of Lakes Powell and Carpul can support large numbers of breeding waterbirds when flooded including birds of conservation significance such as Blue-billed Duck (*Oxyura australis*) and Freckled Duck (*Stictonetta naevosa*) (VEAC 2008). The smaller, semi-permanent wetlands of Yungera Creek and the Carp Hole provide reliable breeding sites for waterfowl.

Terrestrial species of conservation significance known from Euston Lakes are Regent Parrot, Hooded Robin (*Melanodryas cucullata*) and White-fronted Chat (*Epthianura albifrons*) (McCarthy, Chapman, et al. 2010).

4.3.3 Reptiles and Amphibians

Wetland, forest and woodlands provide habitat for a range of reptiles and frogs. Fifteen reptile species are present including three species of conservation significance (Table 8). Tessellated Gecko has not been reported from the site but would be expected to occur in wetland beds which provide shelter in cracking clays. Carpet Python (*Morelia spilota metcalfei)* and Lace Monitor (*Varanus varius)* both depend on high levels of floodplain productivity to provide a supply of vertebrate prey within dense understorey vegetation, tree hollows and hollow logs to provide shelter.

Six frog species have been reported from the study area. The nationally vulnerable Growling Grass Frog (*Litoria raniformis)* has been recently observed at Belsar and Yungera (GHD 2014). Other frog species present are Eastern Sign-bearing Froglet (*Crinia parinsignifera)*, Barking Marsh Frog (*Limnodynastes fletcheri*), Spotted Marsh Frog (*Limnodynastes tasmaniensis*), Eastern Banjo Frog (*Limnodynastes dumerilii dumerilii*)and Perons Tree Frog (*Litoria peronii*)(McCarthy, et al., 2010).

4.3.4 Mammals

The bat fauna of study area is diverse. A recent survey at Belsar Yungera recoded eight taxa (Table 9). The bats are almost entirely insectivorous. Flooding maintains the high levels of canopy and understorey productivity required to provide insect prey, while trees provide roosting habitat in bark, crevices and hollows.

A number of woodland mammal species are present including Western Grey Kangaroo (*Macropus fuliginosus*), Short-beaked Echidna (*Tachyglossus aculeatus*), Sugar Glider (*Petaurus breviceps*) and Common Brushtail Possum (*Trichosurus vulpecula*). The recent observations of Sugar Glider in

November 2014 are a range extension that represents the most-downstream population of this species (GHD 2014).

Water Rat (*Hydromys chrysogaster*) has been detected in Washpen Creek and is known to occur in Margooya Lagoon.

Table 7. Birds of conservation significance expected to occur at Belsar Yungera (GHD 2014; Australian Ecosystems 2014)

Scientific Name	Common Name	Conservation Status			Migratory Bird Agreements		2013 Surveys	Data-bases
		EPBC	FFG	Advisory List	Bonn	CAMBA JAMBA ROKAMBA		
Anas rhynchotis	Australasian Shoveler			v			x	x
Ardea intermedia	Intermediate Egret		L	e				x
Ardea modesta	Eastern Great Egret		L	v		C J		x
Ardeotis australis	Australian Bustard		L	ce				x
Aythya australis	Hardhead			v				x
Biziura lobata	Musk Duck			v				x
Calidris ferruginea	Curlew Sandpiper			e	A2H	C J R		x
Chlidonias hybridus javanicus	Whiskered tern			nt			x	
Climacteris picumnus	Brown Treecreeper			nt			x	
Dromaius novaehollandiae	Emu			nt			x	x
Gelochelidon nilotica macrotarsa	Gull-billed Tern		L	e				x
Haliaeetus leucogaster	White-bellied Sea-eagle		L	v		C	x	x
Lophocroa leadbeateri	Major Mitchells Cockatoo		L	v				x
Lophoictinia isura	Square-tailed Kite		L	v			x	
Nycticorax caledonicus hillii	Nankeen Night Heron			nt				x
Oxyura australis	Blue-billed Duck		L	e				x
Phalacrocorax varius	Pied Cormorant			nt				x

Scientific Name	Common Name	Conservation Status			Migratory Bird Agreements				2013 Surveys	Data-bases
		EPBC	FFG	Advisory List	Bonn	CAMBA	JAMBA	ROKAMBA		
Platalea regia	Royal Spoonbill			nt					x	x
Polytelis anthopeplus monarchoides	Regent Parrot	V	L	v					x	x
Pomatostomus temporalis temporalis	Grey-crowned Babbler		L	e						x
Stictonetta naevosa	Freckled Duck		L	e						x
Struthidea cinerea	Apostlebird		L							x

DELWP Advisory List Status: x Presumed extinct, e Endangered in Victoria, v Vulnerable in Victoria, r Rare in Victoria, k Poorly Known in Victoria

FFG Act status: Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing

EPBC Act status: EXtinct, CRitically endangered, ENdangered, Vulnerable, Conservation Dependent, Not Listed

Table 8. Reptiles and amphibians of conservation significance reported from Belsar Yungera (GHD 2014)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	Advisory List		
Morelia spilota metcalfei	Carpet Python		L	e		x
Lampropholis delicata	Delicate Skink			dd	x	
Varanus varius	Lace Monitor			e		x
Litoria raniformis	Growling Grass Frog	V	L	e		x

DELWP Advisory List Status: x Presumed extinct, e Endangered in Victoria, v Vulnerable in Victoria, r Rare in Victoria, k Poorly Known in Victoria

FFG Act status: Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing

EPBC Act status: EXtinct, CRitically endangered, ENdangered, Vulnerable, Conservation Dependent, Not Listed

Table 9. Native mammal species (GHD 2014)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Chalinolobus gouldii	Gould's Wattled Bat				x	
Chalinolobus morio	Chocolate Wattled Bat				x	
Macropus fuliginosus	Western Grey Kangaroo				x	x
Macropus rufus	Red Kangaroo					x
Mormopterus ridei (species 2)	Southern Freetail Bat				x	
Nyctophilus corbeni	South-eastern Long-eared Bat				x	
Petaurus breviceps	Sugar Glider				x	
Scotorepens balstoni	Inland Broad-nosed Bat				x	
Tachyglossus aculeatus	Short-beaked Echidna				x	
Tadarida australis	White-striped Freetail Bat				x	
Trichosurus vulpecula	Common Brushtail Possum				x	x
Vespadelus regulus	Southern Forest Bat				?	
Vespadelus vulturnus	Little Forest Bat				?	

4.3.5 Invertebrates

River Snail (*Notopala sublineata hanleyi*) has been reported from Euston Lakes, Taila Creek and Dry Lake. This species is endangered under the NSW Threatened Species Conservation Act and the Fisheries Management Act. This species has undergone major declines in recent years and is considered very rare. River Snails filter feed on bacteria suspended in the water column and graze on the early successional biofilm communities that occur on hard surfaces in free-flowing waters. Water level variation is important to promote bacteria-dominated biofilms and prevent the dominance of benthic algae.

Murray Crayfish occur upstream and downstream of Euston Weir but are absent from the weir pool where water velocity is too low (McCarthy 2005).

4.4 Social Values

4.4.1 Cultural Value

The Mallee has been occupied for thousands of generations by Indigenous people with human activity dated as far back as 23,400 years ago. The region's rich and diverse Indigenous heritage has been formed through the historical and spiritual significance of sites associated with this habitation; together with the strong connection Traditional Owners continue to have with the Mallee's natural landscapes.

Given the semi-arid climate of the region, ready access to more permanent water has been a major determinant of human habitation, and as such the highest density of identified Indigenous Cultural Heritage sites are located around or close to areas of freshwater sources.

Within the Mallee CMA region, the Murray River and its associated waterways were important habitation areas for multiple Aboriginal groups, containing many places of spiritual significance. The high number of Indigenous Cultural Heritage sites throughout the Murray floodplain is unique in Victoria, for both concentration and diversity. They include large numbers of burial, middens and hunting sites.

In the south of the region, waterways were focal points for the region's Traditional Owners, with many lakes being the site for large gatherings of several social clan groups that afforded trade and cultural exchanges.

Waterways also play a large role in the region's more recent non-Indigenous heritage due to the historical infrastructure (e.g. buildings, irrigation and river navigation structures) they often contain. These places provide links to early industries and settlements and play a key part in the region's identity.

4.4.2 Cultural Heritage

Robinvale is of significant cultural value to Indigenous and non-indigenous people, with the area popular for fishing, camping, hunting and as a meeting place. Some cultural sites have been documented through various archaeological investigations, but the true extent of the number and types of sites present is still unknown.

Long before Europeans settled the Robinvale area it is known that the land was inhabited by the Latje Latje Aboriginal tribe. Reminders of their occupancy remains today on the Bumbang Island Reserve, just north-east of the township of Robinvale, where evidence of burial and camping grounds and canoe trees can still be found.

Surveyed sites include middens, earth features scarred trees, Aboriginal mounds and surface scatters. Surface scatters in this area may consist of worked stone artefacts, animal bones, shell, charcoal, hearth stones, clay balls, ochre, burial sites and historical sites. A search of the DELWP Geo Vic Database shows that most areas in the area around the Murray River and the wetlands are areas of Cultural Heritage Sensitivity. A contingency plan (Appendix 2) is in place should any further evidence of cultural heritage sites be discovered during site visits of works.

The recorded cultural sites show the area was an important meeting place for Aboriginal people, with water and food sources making it possible to survive in this landscape.

Aboriginal people continue to have a connection to this country. There is no Registered Aboriginal party (RAP) that covers this area. The land council, and other Aboriginal community members, continue to value this country through traditional laws and customs.

European heritage reflects the pioneering history of the area. The town of Robinvale, along with nearby Euston, soon after WWII developed rapidly with the surrounding acquired and parcelled up as part of the soldier settlement scheme, principally used to grow grapes and citrus.

Migration saw many European nationalities, but mainly Italian migrants, move into the area. These new residents diversified the local produce to include vegetables, olives and almonds. The small town of Robinvale still remains a culturally diverse community today.

4.4.3 Recreation

This large expanse boasts one of the widest stretches of the Murray River for many kilometres, which makes the area popular for all sorts of water front activities such as fishing, water skiing, swimming, camping, bike riding, bird watching and bush walking.

4.4.4 Economic Values

Historically Robinvale was used for wheat during the late 1800s through the creation of channels and dams that brought permanent water away from the river onto small holdings of land. The town was initially built during the 1920s as a business centre for a wheat farming district. Not until after World War 2 was pumped irrigation commonplace giving rise to a wide range of horticultural and agricultural diversity including citrus and grapes.

5 Ecological condition and threats

5.1 Current Condition

The rapid assessment technique used to assess wetland condition in Victoria is called the Index of Wetland/Stream Condition (IWC). The IWC defines wetland condition as the state of the biological, physical, and chemical components of the wetland ecosystem and their interactions. Such an assessment has been undertaken on one of the three key wetlands within the Lock 15 floodplain whilst the other two are general field observations as discussed below.

Two separate on site condition assessments described below have been undertaken on Bumbang Island, and Walshes & Knights Bend over the past year by the Mallee CMA and is based upon brief field observations and limited existing literature. It should be considered high priority to undertake a more up to date condition assessment, including studies on values, benchmark condition and investigating water quality impacts associated with irrigation drainage, which will be included as a knowledge gap in this report.

Bumbang Island is in good condition due to its isolation, its protection in a historic reserve and lack of access. It is free of major invasive pest species such as foxes and cats and therefore provides significant habitat value for native species subject to high predation levels at other sites. Despite this generally good condition, impacts from the changed water regime associated with the Euston Weir are evident, as seen in figures 13 and 14 (Riverness, 2014).

Figure 13. Drowned trees in a backwater at Bumbang Island (Riverness, 2014)

Figure 14. Lack of understorey diversity in River Red Gum woodlands (Riverness, 2014)

Across Walshes Bend the vegetation appears relatively healthy, with very little evidence of any die back of mature trees and shrubs. There is plentiful leaf litter and structural habitat. Wetland #7428679683 is shown in figure 15. All wetlands within the target area at Walshes Bend were dry at the time of the field inspections (February, 2015) and had no connection to the Murray River.

Figure 15. Wetland #7428679683 Grassy Riverine Forest/Floodway Pond Herbland Complex (Riverness, 2015)

Knights Creek is a channel that cuts off the meander loop which is Knights Bend. Prior to the construction of Lock 15 the creek would have occasionally flowed during high river levels, but it is now permanently inundated by the weir pool. Knight Creek contains extensive structural habitat, including submerged macrophytes and large wood. However, bank vegetation is absent for much of the creek length. There would also be a lack of biofilm diversity on the structural habitat due to the stable water levels. Knights Creek in shown in Figure 16.

Figure 16. Knights Creek (Riverness, 2015)

Wetland #7428653680 was historically used for irrigation drainage disposal, including permanent inundation of 18 hectares. This practice has ceased due to increased irrigation efficiency; although an excavated drainage channel is likely to consistently leak irrigation drainage water into the wetland. The Intermittent Swampy Woodland and Lignum Swamp Woodland (Figure 17) would benefit from a drying period. Evidence of poor water quality (high nutrients) from the drainage channel, including excessive algal growth was seen during field inspections (Figure 18). High nutrient levels may impact vegetation condition within the wetland.

Figure 17. Wetland #7428653680 Lignum Swampy Woodland and Intermittent Swampy Woodland (Riverness, 2015)

Figure 18. The irrigation drainage channel is contains significant amounts of algae and has been cleared of reeds and other fringing vegetation (Riverness, 2015)

Shallow fresh groundwater, associated with the backwater effect of the Euston Weir has promoted dense growth by Red Gum woodland (Figure 19) and forest vegetation associations (Ecological Associates, 2006). Higher terraces support Black Box and Lignum woodland and shrublands. Most wetlands within Walshes Bend live above the normal operating level of the Euston Weir pool and are rarely inundated. (Riverness, 2015)

Figure 19 - Dense growth of River Red Gum woodland (Riverness, 2015)

The condition of Margooya Lagoon was assessed in December 2009, which was prior to the construction of regulators and provision of a variable water regime. Condition was assessed using the IWC method which uses five sub-indices based on the catchment of the wetland and its fundamental characteristics: physical form, hydrology, water properties, soils and biota. Each sub-index is given a score between 0 and 20 based on the assessment of a number of measures. The overall IWC score is not a simple summation of the sub-index scores. A formula is used that weights each sub-index according to the contribution it makes to the overall condition of the wetland. The wetland hydrology sub-index for example contributes more to the overall score than the soils sub-index.

Table 10. Margooya Lagoon IWC sub-index and overall score (Stacey, 2012)

IWC sub-index	Score /20	Category
Wetland catchment	16	Good
Physical form	20	Excellent
Hydrology	0	Very poor
Water properties	17	Excellent
Soils	14.5	Good
Biota	8.52	Poor
Overall IWC score	**5 / 10**	**Moderate**

The overall IWC score of Margooya Lagoon was 5 out of 10, which is considered to be moderate. The hydrology and biota sub-indices were considered to be in very poor and poor condition respectively. Hydrology was considered to be very poor due to the significant disruption the permanent inundation due to Euston weir pool has had on the natural wetting and drying cycle of Margooya Lagoon.

The altered water regime is considered the major threat for the target area of the Margooya Lagoon target area (Stacey, 2012).

5.2 Condition Trajectory

Condition of wetlands within the target area will continue to decline without regular and well planned environmental watering targeting appropriate objectives. Regular weir manipulation, both drawdown and surcharge phases, will provide a more natural drying and wetting cycle; providing greater opportunities for flora and fauna species influenced by the raising and lowering of Lock 15.

The reduced flooding duration and frequency will continue to impact the ecology of the wetlands through:

- Reduced organic matter recruitment;
- Reduced breeding sites/habitat for fish;
- Reduced connectivity for movement of organic matter, fish and transport of salt;
- Reduced suitable nesting and roosting sites for waterbird species who rely on flooded shrub land and forest; and
- Limited food sources for all waterbird types, fish, reptiles and amphibians through reduced recruitment of terrestrial and aquatic invertebrates and reduced extent of emergent and sub-emergent macrophytes.

5.3 Water Related Threats

Threats to the ecological water-dependent values are the result of factors such as human intervention and climate, and include:

- Changed water regime;
- Loss or reduction of wetland connectivity;
- Water quality; and
- Introduction/increase of exotic flora and fauna.

6 Ecological Objectives and Hydrological Requirements

6.1 Management Goal

The overall goal of water management in the target area is:

"to protect and restore the key species, habitat components and functions of the ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities".

6.2 Ecological Objectives

The goal will be achieved by addressing the following ecological objectives:

- Maintain aquatic habitat and provide refuge for a range of aquatic fauna species.
- Improve the productivity of connected riparian zones and wetlands.
- Maintain resident populations of frogs and small fish in wetlands.
- Provide reliable breeding habitat for waterbirds, including colonial nesting species.
- Frequently provide feeding habitat for thousands of waterbirds.
- Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and insectivorous bats.
- Contribute to the carbon requirements of the Murray River channel ecosystem.

Ecological objectives will be achieved by providing ecosystem water requirements in key water areas of the target area. The following describes their ecology and water requirements.

6.3 Watercourses

Watercourses are the principal aquatic environments in the study area, providing a network of permanent and intermittent habitat in the river and through the floodplain.

Watercourses provide mainly open water habitat where moderate levels of primary productivity are provided by planktonic algae. Macrophyte vegetation occurs in riparian zones, backwaters and in low connected wetlands. Shallow water, where there is some protection from turbulence, supports semi-emergent macrophytes including Floating Pondweed, Water Milfoil and Eel Grass (D'Santos, 2007). Persistently flooded banks can support dense stands of Phragmites (*Phragmites australis)*, and Cumbungi. Intermittently inundated channel fringes will support seasonal aquatic macrophytes such as Salt Club-sedge (*Bolboschoenus caldwellii)* or drought tolerant species such as Spiny Flat Sedge (*Cyperus gymnocaulos).* A large proportion of the organic carbon and mineral nutrients on which watercourse productivity depends originates from catchment runoff and the inundation of wetlands and floodplain.

The river channel, Bonyaricall Creek and other permanent watercourses are the principal habitat and refuge for large-bodied native fish species. Murray Cod, Golden Perch and Silver Perch are largely predators, consuming small fish, various larvae and macro-invertebrates. Bony Herring eat algae and micro-crustaceans and are a significant prey for the large Murray Cod and Golden Perch. Habitat complexity is provided by access to deep open water, snaggy banks and riparian vegetation. Fast-flowing water has been largely eliminated from the weir pool but is an important habitat requirement for Murray Cod. Stream complexes that include fast and slow flowing water are associated with large, viable populations of Murray Cod (Saddlier, O'Mahony and Ramsey 2008) and significant populations of Golden Perch and Silver Perch (Conallin and Meredith 2006). Vegetated riparian zones are important habitat components for small fish such as Murray-Darling Rainbowfish and Gudgeon spp. while backwaters, slow flowing creeks, including Washpen Creek, are important habitat for Freshwater

Catfish. In the study area watercourses support tortoises and a variety of macroinvertebrates. Larger species such as Freshwater Prawn (*Macrobrachium spp.)* and Native Shrimp (*Paratya spp.)* are an important food source for fish and waterbirds while zooplankton contributes to the food requirements of larval fish.

Biofilms are communities of bacteria, algae and fungi that grow on submerged surfaces such as wood, rocks, plants and sediments. They are an important food source for a number of grazing invertebrates including snails (Sheldon and Walker 1997) and decapods (Burns and Walker 2000) which in turn are important food sources for fish and waterbirds. The composition of biofilms and their nutritional value has been related to water regimes. Bacteria are the primary colonisers when degradable substrates are first flooded and will dominate the biofilm community, consuming the nutrients made available by the preceding dry conditions. Over time autotrophic algae increase in abundance and become dominant. Permanent inundation of wetlands, backwaters and benches by weirs has promoted algae in biofilms while bacterial biofilms have declined (Sheldon and Walker 1993). Disturbance such as exposure and drying for periods exceeding 40 days (Burns and Walker 2000) and scouring flows (Burns and Ryder 2001) can re-establish bacteria as the dominant component of biofilms.

The composition of biofilms is important to aquatic fauna because the carbon to nitrogen ratio in bacterial biofilms is much lower than in algae, making them more nutritious to grazers. It has been suggested that macroinvertebrate productivity of the Murray River has decreased as a result and been specifically linked with the decline of the River Snail (Sheldon and Walker 1997).

For many native fish species movements over long distances are an important part of their life cycle. Golden and Silver Perch travel over thousands of kilometres, often swimming upstream in response to spawning cues. Other species including Bony Herring and Murray Cod, move long distances to access food or to colonise new areas. Even small native fish species, such as Carp Gudgeon, Murray-Darling Rainbowfish and Unspecked hardyhead are understood to make upstream migrations (Barret 2008). Adult Murray Cod generally move in a small home range (5 km) in summer, autumn and winter. In spring adult fish may remain in their home range or move actively up to 25 km between main-stem and anabranch habitats.

Barriers to fish passage also fragment habitat. Isolated habitats may not be recolonised after disturbance, so that overall populations decline. Barriers also isolate breeding populations. Inbreeding occurs, reducing the genetic diversity of fish populations and reducing their long-term viability (Schiller and Harris 2001).

6.3.1 Water Requirements

Lock 15 has largely eliminated fast flowing habitat from the main channel. Significant velocities now only occur at high flows, when the weir has been removed. This has made conditions less favourable for species that depend on fast flowing water, such as Murray Cod and Murray Crayfish. The weir has reduced scouring and promoted sedimentation upstream of the weir, which has reduced habitat diversity.

The watercourses in the Euston Lakes Floodplain are subject to sedimentation and dense vegetation growth as a result of shallow stable water levels. While Washpen Creek provides important habitat for Freshwater Catfish and a diverse frog population, the habitat has the potential to deteriorate without periodic scouring flows. High river discharges, exceeding 50,000 ML/d, are required to create through-flow in floodplain watercourses including Caringay Creek and Washpen Creek.

Weir manipulation provides opportunities to improve watercourse habitat. Raising and lowering water levels on a seasonal basis would create a more diverse and broader riparian vegetation community, would help suppress emergent plant growth in deeper channel areas and would promote diversity in biofilm communities.

Lowering Lock 15 while river discharge is elevated has been proposed to improve riverine habitat (see Section 7.4). Lowering the weir would reduce the extent of the weir pool and would temporarily increase channel velocities and sediment mobilisation. The ecological benefits and risks of this measure need to be explored before a recommendation can be made. It is unlikely that a temporary increase in velocity is sufficient to sustain local populations of Murray Crayfish but it may contribute to the habitat requirements of Murray Cod.

Table 10. Water management objectives for watercourses

Objectives Addressed	Maintain aquatic habitat and provide refuge for a range of aquatic fauna species Improve the productivity of connected riparian zones and wetlands
Strategy	Raise and lower weir on a seasonal basis Activate floodplain watercourses by high river flows
Hydrological Objectives	Maintain permanent aquatic habitat in weir pools Provide scouring flows in floodplain Washpen Creek 1 year in 5

6.4 Semi-permanent Wetlands

6.4.1 Ecological Objectives

Semi-permanent wetlands occur close to the river channels and at the fringes of floodplain watercourses. Under natural conditions water was almost always present in these wetlands due to low flow thresholds, frequent peaks in river flow, and the capacity of wetlands to retain water for long periods. Many wetlands would only dry out during rare, prolonged periods of low flow. Within the wetlands water levels would vary seasonally with deep flooding in winter and spring and receding water over summer and autumn. Lock 15 provides these conditions in a number of wetlands connected to the weir pool Margooya Lagoon and Ruel Lagoon.

Persistent, deep flooding excludes emergent macrophytes from the central wetland bed, which instead either provides open water or supports semi-emergent plant species such as Floating Pondweed, Water Milfoil and Eel Grass. Seasonal inundation of the wetland fringe provides habitat for emergent macrophytes such as Phragmites, Marsh Club-sedge and Spiny Flat-sedge. Vegetation at the perimeter grades into the grass and sedge-rich understorey of the surrounding River Red Gum forest and woodland (Reid, Durant and Nielsen 2009; Ecological Associates 2007).

The productivity of semi-permanent wetlands can be low, with an accumulation of unavailable organic matter in anoxic sediments in persistently flooded areas. Productivity is maintained by the growth of macrophytes at the wetland fringe and mineralisation of plant debris through annual water level variation (Young 2001). Overhanging vegetation can also provide significant organic matter inputs.

Extensive and complex riparian vegetation benefits a range of fauna species including turtles, avian herbivores, cryptic waterbirds such as crake and bittern, frogs that lay eggs on flooded vegetation and shelter from predators in reeds, and small fish such as Murray-Darling Rainbowfish and *Gudgeon spp*. which occur predominantly in aquatic vegetation. Reed beds provide nesting materials for Black Swan (*Cygnus atratus*) and grebes and nesting sites for a wide range of bird species. Inundated littoral vegetation is an important source of organic matter in the aquatic food web. Semi-permanent wetlands are the principal habitat for growling grass frog which depends on perennial flooding and dense reedy plant growth. A number of insectivorous birds and bats obtain food and nesting habitat in and near wetlands, which can be important for maintaining local populations between flood events.

Dabbling ducks such as Freckled Duck, Australasian Shoveler and Pink-eared Duck (*Malacorhynchus membranaceus*) feed on soft-leaved aquatic plants and aquatic macro-invertebrates. Semi-permanent wetlands provide reliable breeding habitat for bird species which build nests using reeds on, scrapes in and around fringing vegetation and require water to be present for at least three months in winter and spring. Reeds provide frogs with a source of food, a substrate for eggs and shelter from predators. Grazing waterfowl including Black Swan, Australian Shelduck (*Tadorna tadornoides*) and Wood Duck (*Chenonetta jubata*) will also be favoured by semi-emergent vegetation and will regularly breed.

Frequent connection and isolation to riverine aquatic habitats is important to the ecological role of these wetlands. Isolated wetlands can support local aquatic fauna populations that would otherwise be vulnerable to large predators including Murray Cod. A mosaic of semi-permanent wetlands across the landscape provides some protection from local disturbance and contributes significantly to overall plant and animal diversity. Reconnection permits aquatic fauna to disperse and interbreed, maintaining genetic diversity. A large number of wetlands with a semi-permanent water regime is required to maintain viable populations across the region.

6.4.2 Water Requirements

Semi-permanent wetlands are threatened by permanent inundation. Lock 15 has raised and stabilised water levels to permanently flood wetlands such as Margooya Lagoon and Ruel Lagoon. Stable water levels have reduced floodplain productivity, created a simple and narrow riparian plant community and reduced habitat linkages to watercourse and floodplain habitats. A regulator on Margooya Lagoon mitigates these impacts by allowing wetland water levels to be varied independently of the weir pool.

Manipulation of the Lock 15 weir pool provides scope to address these threats. A cycle where the weir was raised in winter and spring, then lowered in summer and autumn, would promote a broader, more complex riparian plant community and increase wetland productivity.

Table 11. Water management objectives for semi-permanent wetlands

Objectives Addressed	Improve the productivity of connected riparian zones and wetlands Maintain resident populations of frogs and small fish in wetlands Provide reliable breeding habitat for waterbirds, including colonial nesting species
Strategy	Raise and lower weir on a seasonal basis Regulate individual wetlands
Hydrological Objectives	Inundation of more than 50% of the wetland bed in 90% of years Seasonal fluctuation in water level in the upper 50% of the wetland bed in 90% of years Intermittent connection and isolation of wetlands from other aquatic habitat

6.5 Seasonal Wetlands

Ecology

Seasonal wetlands are distributed throughout the floodplain. They represent a variety of flooding frequencies, durations and depths but are characterised by an intermittent, broadly seasonal flooding regime. Sites that could be managed with this water regime include Walshes Bend Wetland, Lake Benanee, Lake Caringay and Dry Lake.

Seasonal wetlands alternate between flooded and dry states. They tend to be filled by freshes in river flow in winter and spring after which they gradually dry out. Flooding may persist over several years if the wetlands receive summer inflows, but will dry out to some degree between inflow events. The wetlands may remain dry over several years if river levels fail to reach the wetland sill.

When flooded, beds of soft-leaved semi-emergent plants will develop in the deeper parts of the lake bed including *Myriophyllum* sp. and *Potamogeton* sp. Open water may be present in the central part of the wetlands where water is too deep to support these species. Emergent macrophytes such as Spiny Flat Sedge and Common Spikerush (*Eleocharis acuta)* will occupy the narrow seasonally inundated zone at the fringe of the wetland. Lignum and Nitre Goosefoot may also extend into the bed of less-frequently flooded wetlands.

The drying wetland bed will support a range of wetland herbs such as Old Man Weed (*Centipeda cunninghamii),* Pale Knotweed (*Persicaria lapathifolia), Alternanthera* spp. *Glossostigma elatinoides* and *Heliotropum* spp. Between flood events the wetland bed will develop a community of lake bed herbs and grasses such as Native Liquorice (*Glycyrrhiza acanthocarpa)* and Pale Knotweed. These plants, together with colonising River Red Gum, will die during subsequent sustained flood events.

Flooded wetlands will be colonised by the larvae of flying insects and by invertebrates released from resting stages on the lake bed. Over several weeks the wetlands will provide productive food sources for small fish, waterbirds, frogs and turtles. Large numbers of juvenile Golden Perch, Silver Perch and Bony Bream were found following drying and re-flooding in Dry Lake, Lake Benanee and Margooya Lagoon suggests temporary wetlands provide important nursery habitat (Bogenhuber, et al. 2011) (Ellis 2011).

Some of the temporary wetlands in the study area are large and have the potential to support thousands of waterbirds. After years of persistent flooding substantial populations of fish can develop, including large-bodied native species such as Golden Perch.

In sustained dry periods the wetland water levels will fall below the red zone to expose a muddy herbland on the lake bed. Small wading birds such as Ruddy Turnstone (*Arenaria interpres*) and Red-necked Stint (*Calidris ruficollis*) will feed on macro-invertebrates in shallow water and mud. Fish-eating birds and carrion feeders, including White-bellied Sea-eagle, will feed on stranded fish.

Water Requirements

Seasonal wetlands are threatened by reduced variation in water levels. Wetlands at Bumbang Island and Margooya Bend are permanently inundated while higher floodplain wetlands at Knights Bend and Walshes Bend are rarely inundated. Dry Lake and Lake Benanee are permanently inundated by the Lock 15 weir pool while Lake Caringay is permanently isolated from the river by stop banks.

Seasonal wetlands should be intermittently inundated and exposed on a broadly seasonal cycle. This water regime will create productive aquatic habitats with diverse aquatic plant and animal communities. The type and extent of remnant vegetation at the lakes suggests that under a natural flow regime the lakes would have been flooded every three in four years (D'Santos 2007). The existence of a Great Cormorant rookery at Lake Benanee prior to the mid-1970s indicates a water regime that provided reliable spring flooding and high food availability.

The peak in wetland level is required sometime between September and December to match the growth requirements of emergent macrophytes and the breeding requirements of waterbirds, small native fish and frogs. Drying of 80% of the wetland bed is required in more than 50% of years to promote the growth of wetland macrophytes and herbs on the wetland bed and to mineralise organic matter.

Table 12. Water management objectives for seasonal wetlands

Ecological Objectives	Improve the productivity of connected riparian zones and wetlands Provide reliable breeding habitat for waterbirds, including colonial nesting species Frequently provide feeding habitat for thousands of waterbirds
Strategy	Raise and lower weir on a seasonal basis Increase the frequency of flow events between 25,000 and 40,000 ML/d
Hydrological Objectives	Completely fill wetlands between 25% and 90% of years Peak water level between September and December Dry 80% of the wetland bed in more than 50% of years

6.6 River Red Gum Forest and Woodland

Ecology

River Red Gum forest and woodland occurs on freely-draining, frequently flooded floodplain areas. Forest vegetation structures occur on low terraces and scroll bars fringing the river. Woodland structures occur on higher terraces that are flooded less frequently.

Inundation occurs mostly in winter and spring. The plant community comprises species that benefit from seasonal flooding but tolerate dry conditions over summer and occasional years without any flooding. During floods aquatic plants develop from propagules including Common Nardoo (*Marsilea drummondii),* Common Spike-rush (*Eleocharis acuta)* and *Triglochin multifructum*. The drier areas are dominated by grasses and sedges including Spiny Flat-sedge and Rat's-tail Couch (*Sporobolus* *mitchellii)* and may include Lignum. Species that colonise the drying forest floor include Common Blown-grass (*Lachnagrostis filiformis),* Native Liquorice and Old man Weed.

Inundation of River Red Gum woodland provides temporary habitat for aquatic fauna, particularly vegetation-dependent fish such as Gudgeon *spp*. and Murray-Darling Rainbowfish. The habitat for terrestrial frogs, which is normally limited to the reeds fringing wetlands, will expand to the River Red Gum understorey. Burrowing frogs, which aestivate in the floodplain soil, will become active. Other wetland species that will extend into the flooded woodland will include yabby, tortoises and water rat.

During longer flooding events River Red Gum woodland will support waterbird breeding. The trees provide nesting sites for waterbirds that breed over water such as Nankeen Night Heron, Cormorant and Australasian Darter (*Anhinga novaehollandiae)*. A range of other waterbird guilds will breed including waterfowl, large waders and small waders.

River Red Gum trees and their understorey have an important role in providing structural habitat for floodplain fauna, particularly hollows for Carpet Python, bats and Brush-tailed Possum. River Red Gum growing close to water provide nesting habitat for some birds which feed in adjacent Mallee including Regent Parrot and Major Mitchell Cockatoo. The tree growth triggered by flooding will provide much of the leafy and woody material on which the floodplain ecosystem depends and will also increase flowering which supports nectar-eating insects and birds and insectivorous birds.

Water Requirements

Flows of 25,000 to 40,000 ML/d inundate River Red Gum forest and woodland. Under natural conditions these events occurred almost annually and lasted for four to five months. Under current conditions the duration and frequency of flow peaks above 40,000 ML/d have both declined by approximately 50%. In many areas the health, extent and species diversity of floodplain vegetation is poor due to insufficient flooding (Australian Ecosystems 2009).

Flooding in spring and early summer for two to three months will meet the seasonal requirements of understorey plants and maintain vegetation structure and diversity. Flooding at this time of year will also address the seasonal breeding requirements of native fish, frogs and waterbirds.

Long flooding events, lasting over six months, are required to support breeding by colonial nesting waterbirds. These events will influence the structure of the vegetation, limiting reducing the cover of *Duma florulenta* and River Red Gum and promoting wetland understorey species.

Flooding frequencies of 6 years in 10 are recommended for lower-lying areas and 5 years in 10 for high floodplain areas.

Table 13. Water management objectives for River Red Gum forest and woodland

Ecological Objectives	Provide reliable breeding habitat for waterbirds, including colonial nesting species Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and insectivorous bats Contribute to the carbon requirements of the Murray River channel ecosystem
Strategy	Raise and lower weir on a seasonal basis Increase the frequency of flow events between 25,000 and 40,000 ML/d
Hydrological Objectives	Inundation events should commence between September and December Provide flood events 8 years in 10 to a level equivalent to flows of 40,000 ML/d • four of these events to be 3 months long • four of these events to be 4 months long

6.7 Lignum Shrubland and Woodland

Ecology

Lignum shrubland and woodland occurs on intermediate floodplain terraces and shallow floodplain depressions that are intermittently waterlogged or flooded by rainfall or high river levels. Lignum is the dominant species and, when flooded frequently, can form extensive, dense thickets. Other large shrubby species Nitre Goosefoot and Swamp Canegrass (*Eragrostis australasica)* can co-occur with Lignum. River Red Gum*,* Black Box and Shoestring Acacia (*Acacia stenophylla)* can form a sparse overstorey.

Lignum shrublands experience intermittent flooding separated by potentially long dry periods. When flooded the ground layer supports a range of wetland herbs including Common Nardoo, Common Spike-rush*,* Spiny Flat Sedge and *Rumex spp*. When flooding is less frequent the shrubs are smaller and more widely spaced allowing the ground layer vegetation to become more dense and diverse, supporting shrubs, grasses and herbs including Round-leaved Pigface (*Dysphyma crassifolium)*, Slender-fruited Saltbush (*Atriplex leptocarpa*)*,* Lindley's Saltbush *(A. lindleyi),* Giant Red Burr (*Sclerolaena tricuspis)* and *Austrodanthonia spp*.

Inundation of Lignum shrubland represents an extension of the habitat for aquatic floodplain fauna such as fish, reptiles and frogs. Their bushy structure and debris provides a productive substrate for epiphytes that supports high macroinvertebrate productivity and also provides shelter from predators. Flooded Lignum is also used as a platform by nesting waterbirds including ibis and spoonbill. Floodwater draining from Lignum will carry dissolved and particulate carbon as well as algae and invertebrates which will contribute to the food web of the river channel.

Between flood events, Lignum is an important habitat for terrestrial vertebrate fauna including lizards and small mammals.

Water Requirements

Flows from 45,000 ML/d to 70,000 ML/d inundate Lignum shrubland and woodland. Under natural conditions river flow exceeded 50,000 ML/d in approximately 80% of years, with half these events exceeding 3 months duration.

A range of flooding frequencies is required to achieve the ecological objectives. Lower-lying shrublands, equivalent to 50,000 ML/d flow threshold, should be flooded in 80% of years. Events of 2 months duration will maintain ecosystem structure and productivity and will provide seasonal habitat for aquatic fauna. Longer floods, of 4 months duration, should be provided in 4 of these years to support waterbird breeding.

Higher areas, equivalent to 70,000 ML/d flow threshold, should be flooded in 7 years in 10. Four of the events should be of 3 weeks duration to maintain vegetation structure. Three of the events should be 9 weeks duration to support breeding by fish, frogs and waterbirds.

Table 14. Water management objectives for Lignum shrubland and woodland

Objectives Addressed	Provide reliable breeding habitat for waterbirds, including colonial nesting species Frequently provide habitat for thousands of waterbirds Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and insectivorous bats Contribute to the carbon requirements of the Murray River channel ecosystem
Strategy	Increase the frequency of flow events between 50,000 and 70,000 ML/d. Weir pool manipulation should reach some lignum communities in areas such as Dry Lake.
Hydrological Objectives	For areas above an inundation threshold equivalent to 50,000 ML/d • provide flooding 8 times in 10 years • four of these events to be 2 months long • four of these events to be 4 months long • For areas above an inundation threshold equivalent to 70,000 ML/d • provide flooding 7 times in 10 years • four of these events to be 3 weeks long • three of these events to be 9 weeks long

6.8 Black Box Woodland

Ecology

Black Box woodland occurs mostly on high, infrequently flooded floodplain terraces. The canopy is open and the community has a diverse, shrubby understorey that includes Lignum, Nitre Goosefoot, Hedge Saltbush (*Rhagodia spinescens),* Ruby Saltbush (*Enchylaena tomentose)* and Shoestring Acacia (*Acacia stenophylla)*. The ground layer comprises low shrubs, herbs and a range of terrestrial grasses. Aquatic plants that appear during or shortly after flooding would include Common Nardoo, Common Spikerush and Rat's-tail Couch.

Tree recruitment and the productivity of the vegetation are strongly linked to flooding (Roberts and Marston 2011). Flooding maintains a diverse age structure and a complex understorey plant community that is required by Carpet Python and other vertebrate fauna. The diversity of birds is particularly high because Black Box woodland contributes to the habitat requirements of both riverine and dryland species (Carpenter 1990). Black Box woodland supports a high proportion of ground foragers and hollow-nesting species. Black Box woodlands are important for canopy feeding bush birds such as Superb Fairy-wren (*Malurus cyaneus)*, Little Friarbird (*Philemon citreogularis)* and Blue-faced Honeyeater (*Entomyzon cyanotis).* Black Box woodland also supports seasonal migrants normally associated with higher rainfall areas such as Grey Fantail (*Rhipidura albiscapa*) and White-bellied Cuckoo-shrike (*Coracina papuensis)*. Black Box is an important habitat component for insectivorous bats.

Flood events that inundate Black Box woodland contribute to the carbon requirements of the Murray River ecosystem. Receding flood water conveys organic debris to the river channel where it promotes macro-invertebrate productivity and maintains the riverine food web.

Water Requirements

Flows from 60,000 to more than 100,000 ML/d inundate Black Box woodland. Under natural conditions these events occurred in approximately 6 times in 10 years with duration of 1 to two months. In the more frequently flooded part of this range the woodland supports an understorey of Lignum while chenopods and other shrubs dominate in less frequently flooded habitat.

While the duration of flood events is similar under the current flow regime, the frequency of events has declined to less than 3 in 10 of years.

The overall structure of Black Box woodland has been maintained, but tree recruitment and productivity has declined, threatening the long-term viability of vertebrate fauna populations. Resilience to prolonged drought events, where understorey vegetation becomes sparse and food resources diminish is poor.

Black Box woodland productivity can be restored by increasing the frequency of floods equivalent to 60,000 ML/d to 6 years in 10 for with events lasting 2 months and floods equivalent to 100,000 to 5 years in 10 with events lasting 1 month.

Table 15. Water management objectives for Black Box woodland

Objectives Addressed	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and insectivorous bats Contribute to the carbon requirements of the Murray River channel ecosystem
Strategy	Increase the frequency of flow events between 60,000 and 100,00 ML/d
Hydrological Objectives	Provide flood events 6 years in 10 for a duration of 2 months to a level equivalent to flows of 60,000 ML/d Provide flood events 5 years in 10 for a duration of 1 month to a level equivalent to 100,000 ML/d

7 Hydrological Objectives

7.1 Summary of hydrological objectives

As discussed in the ecological objectives section, hydrological objectives have been identified for each of the water areas within the target area. The hydrological objectives are summarised below in Table 16.

Table 16. Summary of hydrological objectives

Water Area	Hydrological Objective
Watercourses	Maintain permanent aquatic habitat in weir pools Provide scouring flows in floodplain Washpen Creek 1 year in 5
Semi-permanent wetlands	Inundation of more than 50% of the wetland bed in 90% of years Inundation of more than 50% of the wetland bed in 90% of years Seasonal fluctuation in water level in the upper 50% of the wetland bed in 90% of years Intermittent connection and isolation of wetlands from other aquatic habitat
Seasonal wetlands	Completely fill wetlands between 25% and 90% of years Peak water level between September and December Dry 80% of the wetland bed in more than 50% of years
River Red Gum forest	Inundation events should commence between September and December Provide flood events 8 years in 10 to a level equivalent to flows of 40,000 ML/d • four of these events to be 3 months long • four of these events to be 4 months long
Lignum Shrubland and woodland	For areas above an inundation threshold equivalent to 50,000 ML/d • provide flooding 8 times in 10 years • four of these events to be 2 months long • four of these events to be 4 months long • For areas above an inundation threshold equivalent to 70,000 ML/d • provide flooding 7 times in 10 years • four of these events to be 3 weeks long • three of these events to be 9 weeks long
Black Box woodland	Provide flood events 6 years in 10 for a duration of 2 months to a level equivalent to flows of 60,000 ML/d Provide flood events 5 years in 10 for a duration of 1 month to a level equivalent to 100,000 ML/d

7.2 Weir Manipulation

7.2.1 Ecological Outcomes

A program to raise and lower the weir at Lock 15 has the potential to partially address environmental water requirements in the weir pool. In particular an annual cycle of weir level adjustments would:

- promote a broader zone of aquatic macrophyte vegetation at the perimeter of wetlands, increasing primary productivity and habitat quality for native fish, frogs and waterbirds
- increase mineralisation of organic matter, biofilm diversity and secondary productivity, supporting increased abundances and diversity of macro-invertebrates, fish and waterbirds
- allow flooding of floodplain vegetation, promoting the health of River Red Gum and providing habitat opportunities for waterbirds, fish, frogs and other aquatic fauna
- increase the productivity of floodplain vegetation and the quality of habitat for terrestrial species including regent parrot and carpet python.

7.2.2 Proposed Weir Level Program

A water pool adjustment regime is proposed to address environmental water requirements within the existing limitations of the weir. A possible seasonal cycle is presented in Table 17. The regime is designed to replicate aspects of the natural flow regime of the Murray River by providing inundation of low-lying areas in spring and gradual exposure of inundated areas over summer and autumn.

Table 17. A possible seasonal weir pool regime for Lock 15

Month	Variation from Normal Operating Level (m)	Level (m AHD)
Jan	0	47.6
Feb	0	47.6
March	0	47.6
April	-0.2	47.2
May	-0.3	47.3
June	0	47.6
July	0	47.6
August	+0.4	48.0
September	+0.5	48.1
October	+0.5	48.1
November	+0.6	48.2
December	+0.3	47.9

The range of river levels proposed in this regime is much smaller than the variation that occurred in the Murray River prior to development, which frequently varied over 4 m (see Section 3.3.1). However the proposed regime affects important environmental features and will contribute significant to habitat diversity and quality in the weir pool (Table 18).

Table 18. Key features affected by weir level variation

Threshold	Affected Features
-0.3 m	Expose shallow areas in backwaters on the Murray River including scroll bars near Ruel Lagoon, Bumbang Island, Knights Bend and Walshes Bend. Expose the perimeter of permanently inundated wetlands including Dry Lake, Lake Benanee and Margooya Lagoon
+0.6 m	Inundate low terraces on the Murray River including features at Bumbang Island, Euston Lakes floodplain, Knights Bend, Walshes Bend and Margooya Lagoon. Inundate the perimeter of Dry Lake, Lake Benanee and Margooya Lagoon. Introduce water to minor wetlands and watercourses in the floodplain between Washpen Creek and the Murray River. Potentially introduce water to Lake Caringay.

The cycle holds water levels at gradual increments for long periods. Drought refilling in 2009/10 found that the movement of water in Taila Creek and Washpen Creek is restricted by vegetation and channel capacity that and long cycles are required to fill and drain the lakes (S. Jaensch pers. comm. March 2015).

7.2.3 Water Use and Savings

Raising the weir will increase the flooded area subject to evaporation and seepage losses, while lowering the weir will reduce losses. Any savings will not be credited, as accounting is based on incremental loss and seepage.

A water balance model is required to calculate changes in water losses in the weir pool under different levels and seasonal conditions. Linking this model to the MSM BigMod long term river flow model would allow water use and savings to be calculated over the long term for a range of river flow scenarios.

A hydraulic model has been developed by the MDBA for the Euston weir pool and can be used to predict the extent of inundated areas, as required in a water balance model (Figure 20,

Figure21).

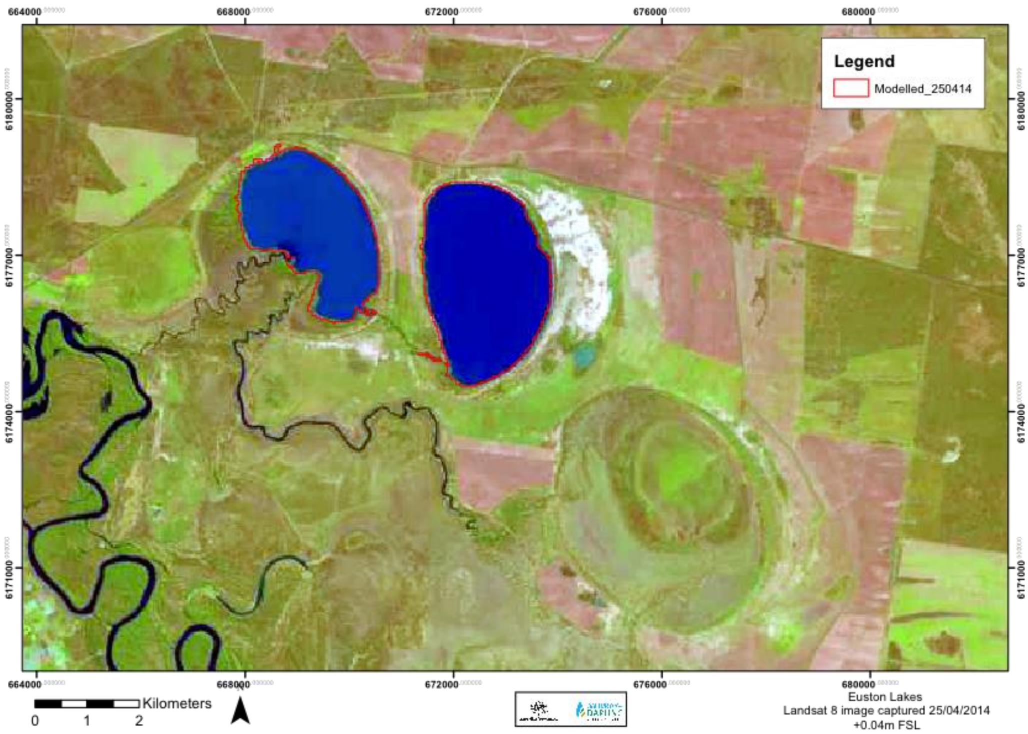


Figure 20. Landsat imagery showing the extent of inundation in the Euston Lakes on 25/4/2014 at a weir level of +0.04 (47.64 m AHD). Hydraulic modelling predictions of the inundation extent are indicated by the red outline.

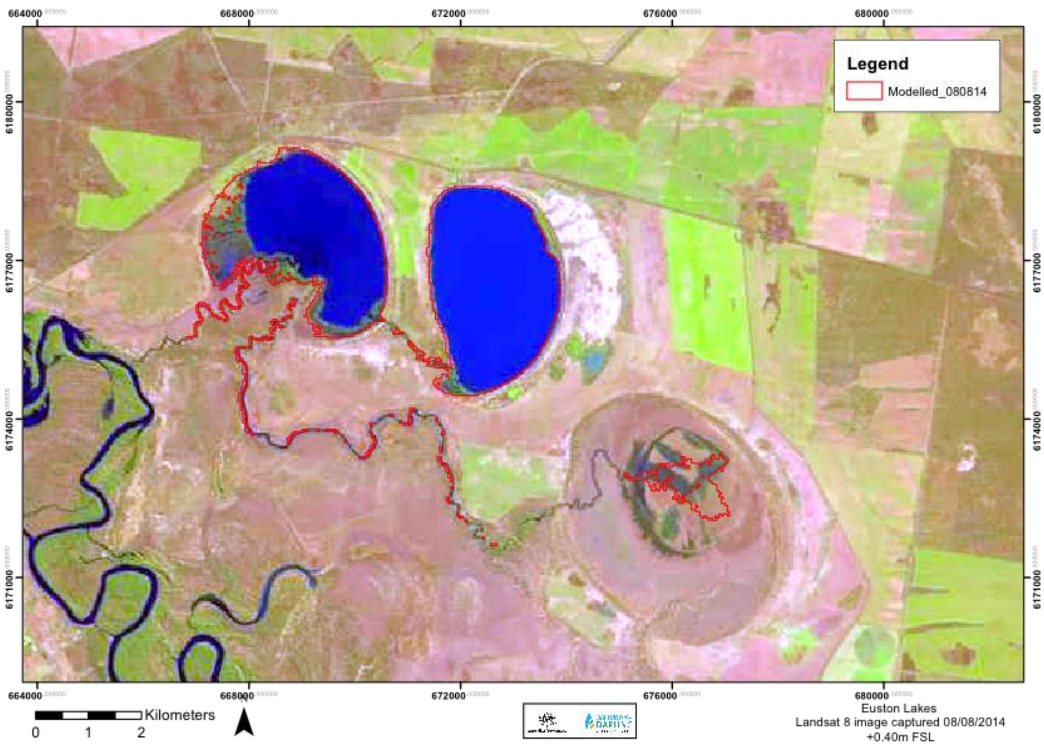


Figure 21. Landsat imagery showing the extent of inundation in the Euston Lakes on 8/8/2014 at a weir level of +0.40 (48.0 m AHD). Hydraulic modelling predictions of the inundation extent are indicated by the red outline.

7.2.4 Complementary Actions

Water may be pumped water to Lakes Powell and Carpul to achieve environmental objectives. Raising Lock 15 reduces the amount that pumps must lift water and substantially reduces pumping costs.

Providing flooding in these lakes while the weir is raised may increase the environmental outcomes of weir manipulation. Flooding these large lakes while Lake Benanee, Dry Lake and Lake Caringay are also flooded may help attract birds to the region and improve waterbird habitat use and breeding.

7.3 Enhanced River Flows

Enhanced river flows have some potential to improve ecosystem health in the Euston weir pool. Key flow thresholds in the study area include:

- 25,000 to 40,000 ML/d to inundate wetlands and River Red Gum forest and woodland on low floodplain terraces
- 50,000 to 70,000 ML/d to inundate Lignum shrubland and woodland
- 60,000 to 100,000 ML/d to inundate Black Box woodland

The required timing, frequency and duration of these flows are provided in Section 5.

The provision of flows in this range is severely constrained by the capacity of headworks, the risks of flooding impacts on river users and the available volumes of environmental water. There is some scope to augment flows less than 40,000 ML/d by changing river operations, particularly through the management of unregulated flow events. This may involve operating Lake Hume more transparently to allow large flow peaks to pass, resulting in more frequent flow peaks in the river downstream.

7.4 Promotion of Fast-flowing Habitat

There may be scope to promote fast-flowing habitat in the Lock 15 weir pool by lowering the weir at elevated river flows. The ecological objectives of promoting fast-flowing habitat would be to:

- increase hydraulic diversity in the river channel and the quality of habitat for Murray cod
- reduce sedimentation and scour deep holes that are important for large-bodied channel-specialist fish species
- reduce the encroachment of emergent macrophytes, particularly *Typha orientalis*, on channel habitats.

These objectives may be promoted in the river channel north of Bumbang Island by lowering the weir to the extent that flow in The Cut is significantly restricted. These objectives may also be promoted in the upper end of the weir pool, near Belsar Island by lowering the weir pool and increasing the extent of the free-flowing river channel further downstream.

Further investigation is required to explore this proposal. Hydraulic modelling is required to assess the degree to which fast-flowing conditions can be achieved and if they would be effective in addressing ecological objectives. The degree of drawdown in the weir for this measure to be effective may not be feasible if it severely disrupts pumping or other river uses.

8 Environmental Water Delivery Infrastructure

8.1 River System Management - Storages

8.1.1 *Murray River System Water Management*

The principle sources of water for the study area are from the:

- Regulated releases from Hume Dam and Dartmouth Dams (3,005 GL and 3,856 GL) on the Murray River.
- NSW and Victorian tributary unregulated inflows to the Murray River.

The resources of the Murray River system are managed under the Murray Darling Basin Agreement by the Murray-Darling Basin Authority in coordination with the NSW, Victorian and South Australian governments. The agreement aims to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water and other natural resources of the Murray-Darling Basin.

Under the agreement, within the Murray River system, NSW and Victoria each receive 50% of the inflows to Hume, Dartmouth and from the Kiewa unregulated tributary, and 50 % of inflows to Menindee Lakes. South Australia owns all of the water in the Murray River within South Australia.

Other inflows to the Murray River are credited to the state from which they originate (e.g. flow in the Goulburn River at McCoys Bridge is credited to Victoria and the Murrumbidgee River at Balranald is credited to NSW).

8.1.2 Hume Dam

Hume Reservoir is the main operating storage of the Murray River System. Releases from the reservoir, in conjunction with downstream tributary flows, supply water along the Murray to New South Wales, Victoria and South Australia for irrigation, stock and domestic, urban as well as environmental purposes. The storage also re-regulates releases from the Snowy Mountains Scheme to better match downstream demand.

Releases from Hume Reservoir also supplement water supplies to South Australia from Lake Victoria and Menindee Lakes. In many years, when storage in Lake Victoria and Menindee Lakes is low, additional releases are made specifically for South Australian requirements, although deliveries are subject to the constraints of the Barmah Choke.

The travel time for flows from Hume Dam to Lock 15 is approximately 18 days.

8.1.3 Constraints on water delivery to the study area

There are a number of potential constraints to environmental water deliver in the target area (Table 19). These constraints potentially limit the opportunities to augment unregulated events with regulated releases to achieve floodplain inundation within the target area. Releases from Hume Dam are constrained by operational flooding constraints and delivery constraints associated with the Barmah Choke. Under regulated conditions, there is currently only have broad support to release 15,000 ML/day downstream of Yarrawonga for a Barmah-Millewa forest watering (although there are discussions underway to increase this) (A. McLean pers. comm. April 2015). A release of 15,000 ML/day equates to around 11,000ML/day at Barmah gauge (A. McLean pers. comm. April 2015).

Table 19. Physical and operational constraints on water delivery to the study area

Constraint	Constraint Type	Reason for Constraint
Hume to Yarrawonga		
Flow downstream of Hume Dam (Doctors Point) are typically limited to 25,000 ML/d under regulated flow conditions	Channel	River operational delivery constraint
River channel has a capacity of 62,000 ML/d downstream of Yarrawonga Weir.	Channel	River operational delivery constraint
Barmah-Millewa		
The Barmah Choke channel capacity of approximately 8,500 ML/d	Channel	River operational delivery constraint

8.2 Weir Operations

8.2.1 *Weir Description and Operation*

Lock & Weir 15 (Figure 22) at Euston is an asset of the MDBA, for which NSW State Water Corporation has responsibility for operation and maintenance (Table 20). The lock and weir is situated 1,117 km upstream of the Murray mouth and downstream of all the major tributaries of the Murray River with the exception of the Darling River. The weir raises the water in the river to a level that permanently inundates Euston Lakes (Dry Lake and Lake Benanee). Lake Caringay would also be inundated if it were not for levee banks isolating it (MDBA 2010).

During times of high flow or flooding, components of the weir are removed to protect the structure and minimise impacts on flow (MDBA 2010). This involves the complete removal of the weir structure except for the concrete columns. The current operating rules require that the movable components are reinstated as soon as flows allow to minimise the risk that the weir pool will fall below the normal operating level and to minimise the rate of drawdown on the river downstream. The approximate flows of weir removal and reinstatement are shown Table 21.

Figure 22. Lock & Weir 15 showing the lock on the South (Left) bank. The fishway is on the North (Right) bank located between the lock chamber and the weir section.

Table 20. Lock 15 specifications (MDBA 2010)

Year of Completion	1937
Construction	• Fixed weir and navigable pass consisting of concrete piers and stop logs. • Lock Chamber • Fish lock located in the first bay adjacent to the lock chamber and Denil fishway on the NSW bank
Distance from mouth	1110 km
Length of weir pool	Approximately 60 km"1
Weir pool storage at normal operating level	Approximately 76GL"1
Normal operating level (Full Supply Level)	47.6 m AHD
Maximum upstream pool level	48.36 m AHD
Flow at which upstream and downstream pools equalise	Approximately 53,000 ML/d"1

#1 Pers Com G. Hind Water NSW (2014)

Table 21. Lock 15 Weir Removal and Reinstatement Flows (MDBA 2010)

Weir Status	Lowest Flow (ML/d)	Highest Flow (ML/d)
Removal	40,000	50,000
Reinstatement	30,000	56,000

8.2.2 Fishway design

Euston Weir was constructed with a fishway, designed to the American salmon model. The steep concrete chute was originally fitted with submerged orifice baffles which only large native fish could negotiate. The existing chute was modified in 1996 and 2000 by fitting fibreglass Denil inserts to allow the successful upstream movement of small fish species. The fishway is operable for flows in the range of 3,500ML/d to 35,000ML/d. At 35,000 ML/d the flow through the weir is sufficient for it to be used for fish passage (pers com G. Hind 2014). The Denil fishway remains functional if the weir is raised up to the maximum operating level (Mallen-Cooper and Stuart 2007).

A fish lock has also been constructed, and is particularly important for smelt.

There is passive integrated transponder tag (PIT) reader systems reader at Euston Weir to automatically track the movement of tagged fish moving through the weir.

8.2.3 Routine Variation on Weir Levels

Currently, the water level in Euston Weir can be partially lowered by 0.2 to 0.3 m during the irrigation season (depending on irrigation demand and river flows) to boost the downstream flow and help meet peak demands downstream, while still meeting demand for water from the weir pool itself and not significantly impact access to irrigation water from Bonyaricall Creek. The water level in Euston Weir can be partially lowered (by 0.3 m) during the irrigation season to boost the downstream flow and help meet peak demands downstream, while still meeting demand for water from the weir pool itself. In recent years, the rate of lowering during the irrigation season has been restricted to about 20–30 mm/day to minimise impacts on diverters. Also, from time to time, the weir pool is fully lowered for short periods, for maintenance or construction requirements. When a cool period (and associated reduction in demand for irrigation water) or a rain rejection occurs, the weir pool can be raised back to the normal operating level (MDBA 2010).

9 Managing Risks to Achieving Objectives

9.1 Risks and Constraints associated with Weir Manipulation

9.1.1 Weir Stability

Weir level variation has the potential to destabilise weirs by increasing sliding or overturning forces. The weirs present an obstacle to the movement of water and are therefore subject to a downstream sliding force. Sliding instability increases as the head difference across the weirs increases.

The mass, and therefore the weight, of the weir contribute to its stability. Submersion of the weirs by raising the upper and lower pool levels increases the buoyancy of the structures and reduces the downward force of their weight. A weir is at an increased risk of overturning when the upper and lower weir pool levels are both elevated and the head difference across the weir provides a turning moment.

The weir is designed to tolerate sliding and overturning forces. Safe limits of operation can be expressed in terms of upper pool and tailwater levels. The weir may only be operated when the factor of safety is considered to be in a range that is acceptable. This can be above or below the safety level associated with normal upper pool and tailwater levels. The variation in safety levels for normal weir pool levels, different flows, and corresponding tailwater levels is presented for Weir and Lock 15 in the following section.

The variation in lock and weir sliding and overturning safety levels for a normal weir pool level of 47.64 m AHD and the maximum level of 48.36 m are presented in Table 22 and Table 23. Safety levels have been colour coded, with the value in the colour coded cells equalling the lock and weir 15 tailwater level. Purple corresponds to safety levels that are approximately equal to those experienced for normal operation for Lock and Weir 15. Normal operation occurs at a weir pool level of 47.64 m AHD and a tailwater level of 43.00 m AHD. The green colour code corresponds to improved safety levels beyond that experienced under normal lock and weir operation. The blue colour code corresponds to reduced safety levels below that experienced with normal weir operation. Importantly these levels are still judged to be acceptable. Orange colour coding indicates unacceptable safety levels, and black cells indicate flows and levels outside the range of weir regulation. As can be seen from **Error! eference source not found.**, Lock and Weir 15 is considered to have no unacceptable sliding or overturing safety issues for either normal or maximum weir pool levels of 48.36 m (+0.76 m) for flows up to 55,000 ML/d (URS 2014).

There is no structural constraint on removing the weir at any flow (P. Cox NSW Water NSW 19/11/2014). Risk associated with weir manipulation is the responsibility of the asset owner and operator.

Table 22 - Lock and Weir 15 Sliding Safety Level Variation with Tailwater for Normal (47.64m) . Maximum (48.36m), Top of Piers (48.88m) Lock and Weir 15 Pool Levels (URS 2014).

Flow Over Lock 15 Weir (ML/d)	**Tailwater Level**		
	Normal (47.6m) Lock 15 Weir Pool Level	Maximum 48.36m Lock 15 Weir Pool Level	Top of Piers (48.88m) Lock 15 Weir Pool Level
0	42.4	42.4	42.4
10000	43.77	43.77	43.77
15000	44.5	44.5	44.5
20000	45.1	45.1	45.1
30000	46.3	46.3	46.3
40000		47.3	47.3
50000		47.8	47.8
55000		48.1	48.1
60000			48.5

	Improved Safety of Above that for Normal
	Approximately Equal to Safety Level for Normal Pool (47.64m) and Normal Tailwater Level (43.00m)
	Acceptable Reduced Safety Level Below Normal
	Unacceptable Safety Level

Table 23 - Lock & Weir 15 Overturning Safety Level Variation with Tailwater for Normal (47.64m). Maximum (48.36m), Top of Piers (48.88m) Lock and Weir 15 Pool Levels (URS 2014).

Flow Over Lock 15 Weir (ML/d)	Tailwater Level		
	Normal (47.6m) Lock 15 Weir Pool Level	Maximum 48.36m Lock 15 Weir Pool Level	Top of Piers (48.88m) Lock 15 Weir Pool Level
0	42.4	42.4	42.4
10000	43.77	43.77	43.77
15000	44.5	44.5	44.5
20000	45.1	45.1	45.1
30000	46.3	46.3	46.3
40000		47.3	47.3
50000		47.8	47.8
55000		48.1	48.1
60000			48.5

	Improved Safety of Above that for Normal
	Approximately Equal to Safety Level for Normal Pool (47.64m) and Normal Tailwater Level (43.00m)
	Acceptable Reduced Safety Level Below Normal
	Unacceptable Safety Level

9.1.2 Safe Operating Level

Until further operational trials have been undertaken, the weir operators consider 48.2 m AHD (+0.6 m) the highest safe level for operation of the weir. A lower maximum level of 48.1 m (+0.5 m) provides a safety margin to respond to variation in flow in the river (Phil Cox Water NSW 19/11/2014).

The manipulation of stop logs becomes increasingly dangerous as the weir is raised and when the velocity of water over the weir increases. Stop logs are manipulated by a crane on an excavator. High, turbulent flows make the manipulation of logs difficult and can destabilise the excavator. The highest discharge for safe manipulation of stop logs is 30,000 ML/d (Phil Cox Water NSW pers. comm. February 2015). The safety of stop log movements should be evaluated and documented throughout weir manipulation to confirm and define safe operating conditions.

9.1.3 Fishway Function

Following modification, the fishway functions effectively at elevated weir pools of +0.72 m (Phil Cox Water NSW 19/11/14). The fishway remains effective if the weir pool is lowered (Phil Cox Water NSW 19/11/14).

9.1.4 Escape from Weir Pool

At levels up to 48.2 m AHD (+0.6 m) water is not diverted through the floodplain around Lock 15. At higher levels there is potential for water to reach the road to the Euston Cemetery and to pass through the road culvert. This possibility can be managed by temporarily blocking the culvert while weir levels are elevated.

9.1.5 Approvals and Impacts on River Volumes

Changes to the weir pool level alter the profile of water losses from the river to evaporation and seepage and must be accounted for by the MDBA. Following completion of upgrade works in 2013, the pool level can be raised 0.2 m above normal operating level without approval from the MDBA Executive Director River Management (EDRM). Raising the pool level more than 0.2 m requires approval from the EDRM.

In July 2014, precedent was set when EDRM approved raising the water level at Euston Weir to 0.4 m above normal operating level for operational reasons. On this occasion the raising and lowering of the weir pool back to pool level occurred during unregulated flows and so the associated incremental loss did not require accounting.

MDBA has advised that the incremental loss associated with raising the pool level (>0.2 m) above 47.8 mAHD will need to be accounted for and debited from a licence. Weir raising during an unregulated event may also require losses to be accounted. The incremental losses associated with a pool raising at Locks 8 and 9 is accounted for and debited from a licence (including during unregulated flow events).

9.1.6 Water Supply

Lowering weir pool levels may isolate pumps from water and interrupt water supply to irrigators and stock and domestic water users.

However water supply to diverters is not guaranteed. There is no obligation to provide river level heights for diversion, water quality nor water quantity. The supply of water is maintained with the best reasonable efforts of the water resource managers. Government cannot be held liable for water supply quantity, river level height nor water quantity.

Nevertheless, changes to weir pool levels are planned with consideration of impacts to river users including pump operation. Weir adjustments of up to -0.3 m (47.3 m AHD) generally allow continued operation of irrigation pumps subject to the following considerations:

- Pumps in Ruel Lagoon begin to be impacted at levels below -0.3 m. The lagoon is isolated from the weir pool at 1.0 m, leaving approximately 100 ML stored in the lagoon.
- Lake Benanee is isolated at levels below -0.5 m. However the lake holds significant volumes below this level and continues to supply water to pumps for several months.
- Water supply to Dry Lake is can be maintained at weir levels above -0.3 m.
- Drawdown is most sensitive in hot weather when irrigation water use is high.
- The Robinvale Irrigation Pump Station (Victoria) operates at adjustments to -1.0 m.
- Euston town pumps (NSW) has a theoretical tolerance of weir levels to -1.4 m.
- Lower Murray Water, Robinvale town pumps tolerate adjustments to -2 m.

Pumps in Bonyaricall Creek should not affected by weir manipulations within the proposed range depending on flow rate and demand. In the near future a large pump, that is vulnerable to weir adjustments as small as -0.15 m, will be relocated to the main river channel where it will access deeper water.

9.1.7 Navigation in the River Channel

Lowering weir pool levels may increase the exposure of river traffic to reefs and other navigation hazards. There is no obligation for the NSW government or the MDBA to maintain river levels to enable navigation in the river channel.

Riverboats in The Cut can be stranded by lower weir pools. River boats were stranded when the weir pool was lowered by 20cm, March 2015. It is necessary to notify boat operators before the weir is lowered.

The Robinvale / Euston Ski Race Classic is an important community event held on the Labour Day weekend in March each year. Low weir levels are not compatible with this event. The race is a significant constraint on implementing an appropriate water regime as it requires the normal pool level to be provided in March and delays drawdown later in the year than is desirable.

9.1.8 Navigation at the Lock

The Murray-Darling Basin Agreement is a schedule of the Water Act 2007 (Cwth). Clause 68 1(b) of the agreement requires that locks must be operated so that the depth of water immediately downstream of the lock is sufficient for navigation of vessels drawing 1.4 m of water or any such depth determined by the MDBA under clause 124 except when the lock is closed for maintenance or when there is an emergency. Importantly this clause does not apply to the Lock and Weir at Euston.

The minimum tailwater level to provide the required draft for navigation at Lock 15 is 43.95 m AHD. This corresponds to a flow over the weir of approximately 2,900ML/d (pers. com. G. Hind 2014).

9.1.9 Infrastructure and Access

Raising the weir to the theoretical limit of +0.7 m has the potential to flood the road bridge to Belsar Island.

By increasing water levels in Washpen Creek, weir raising can reduce floodplain access and make it difficult to move stock. Raising weir levels more than 400 mm may also cut access to mooring sites at the causeway at Ruel Lagoon.

9.2 Summary of weir operating constraints

A number of interacting and variable factors determine the levels at which the weirs may be operated, but some key parameters are presented in Table 24 as a summary guide. Operating within these constraints mitigates the risks associated with weir manipulation.

Table 24. Summary of the scope to raise and lower weir and Lock 15

Adjustment (m)	Basis of Limit
+1.28	Top of piers
+0.76	Maximum upstream pool level and the level before interference with deck structure occurs.
+0.6	Interim maximum for safe operation of the weir, to provide a margin of flexibility to respond to changes in river discharge. Flexibility would be higher at a maximum level of +0.5 m. Ongoing trials of weir manipulation will refine these limits.
+0.2	Maximum level before special approval is required from MDBA Executive Director River Management.
-0.15	Potential to affect supply to pumps in Bonyaricall Creek during periods of high irrigation demand
-0.3	Generally acceptable limit to weir lowering, below which, special approval is required from MDBA Executive Director River Management.

9.3 Acid Sulfate Soils

Depending on their chemistry, soils that have been saturated for long periods can become acidic when re-exposed to the air. Reduced sulfur mineral species can be oxidised on exposure to form sulfuric acid. Acidified soils can create toxic conditions in soil and water that result in the death of vegetation and aquatic fauna. The exposure of saturated soils is a hazard of lowering weirs and regulating wetlands.

Investigations at Margooya Lagoon indicate a low potential for the development of acidic conditions through the exposure of saturated soils (Baldwin 2007). The wetland has been dried on three occasions since 2009 and acidic conditions have not developed (Jane White pers. comm. Mallee CMA Feb 2015).

Acid sulfate soils potentially occur at other sites where soils are exposed after sustained waterlogging, including backwaters on the Murray River and Bonyaricall Creek.

The potential for acid sulfate soil development has been investigated in the Euston Lakes. Dry Lake does not contain sulfidic sediments and not represent a significant risk of acidification (Hall, et al. 2006). Lake Benanee contains sulfidic sediments however the high buffering capacity of the lake reduces the risk of acidification. High levels of reduced sulfur and high acidities have been reported from Washpen Creek (McCarthy, et al., 2010).

10 Consultation

Communication with river users, diverters and other stakeholders will accompany any program of weir manipulation. Consultation will inform stakeholders of the purpose, timing and scale of weir level adjustments. Communication is required to allow users to accommodate weir level change in their activities and to maintain confidence and trust between river users and river operators.

The MDBA will be the public face of the program and all consultation materials will refer to MDBA.

It is expected that few landholders will be affected. They will be contacted directly by NSW Office of Water and Mallee CMA via existing networks such as Water Authority databases.

A simple information sheet will be prepared for distribution to the wider community. The content will be based in an 'operational' context.

For many river users, Water NSW (L15 Lock Master) is the first point of enquiry. Water NSW staff will provide some advice to the community, but will refer specific enquiries to the MDBA.

Water NSW (L15 Lock Master) staff will also be provided with the information sheet to distribute.

Diverters will be advised through normal customer circulars from Lower Murray Water and Water NSW (Customer Liaison).

Early notification (press releases, direct contact and advice in circulars) will commence in early March 2015 for the first watering event.

Table 25. Consultation and Communications

Target Group	Consultation	Responsible Agency
Water Liaison Working Group	Advise WLWG of weir manipulation progress	MDBA
Broader Community	Reporting weir levels in Murray River Weekly Report. Make available flow advices (or media release) on website and via distribution lists Forecast expected downstream salinity loading to allow timely notification of any anticipated salinity issues.	MDBA
Boat, Fishing and General River Use Community	Press release prior to manipulation. Distribute information sheet. Provide information page on website.	Water NSW NSW/ NSW Office of Water and Mallee CMA
Boat, Fishing and General River Use Community	Provide one-on-one advice. Provide information page on website Refer enquiries to MDBA for further information	Water NSW (L15 Lock Master) / NSW Office of Water/ MCMA
NSW Landholders	Advise of weir manipulation program prior to implementation. Mail/Email out information sheet	NSW Office of Water
Victorian Landholders	Advise of weir manipulation program prior to implementation. Mail/Email out information sheet.	Mallee CMA/ Lower Murray Water
NSW Diverters	Advise through normal customer communication channels of weir manipulation program prior to and during implementation. Distribute information sheet through networks.	Water NSW
Victorian Diverters	Advise through normal customer communication channels of weir manipulation program prior to and during implementation Distribute information sheet through networks.	Lower Murray Water

11 Demonstrating Outcomes

11.1 Monitoring

Ecological monitoring is required to demonstrate the effectiveness of weir pool manipulation in achieving ecological objectives, to help manage environmental risks and to identify opportunities to improve the efficiency and effectiveness of the program. Important risks of weir manipulation include the recruitment of carp during wetland inundation and the exposure of acid sulfate soils when weir levels are lowered.

A comprehensive assessment of water quality, hydraulic and ecological characteristics has been undertaken of weir pools in the Mallee CMA (McCarthy, Gawne, et al. 2004). The study provides a baseline of environmental conditions against which the effects of future weir manipulations can be assessed. The study design established Lock 15, Lock 11 and Lock 10 as experimental 'treatments' and free-flowing sites as controls.

An ecological monitoring program has been developed for Margooya Lagoon where an environmental regulator is used to control wetland water levels. This program could also be extended to monitor the effects of weir manipulation.

An ecological monitoring program was also developed to assess environmental responses to drying and flooding Euston Lakes Floodplain during the Millennium Drought and subsequent 2011 flood event. This program monitors environmental variables including water levels, water quality and ecological responses including native and pest fish abundances, waterbird visitation and breeding and vegetation health. Elements of this program could be continued in the Euston Lakes to evaluate a weir manipulation program and could be extended to additional sites within the weir pool.

11.2 Recent Monitoring Results

The water regime of Margooya Lagoon has managed since 2009 when a regulator was installed, allowing the wetland to be disconnected from the weir pool and dried out and surcharged up to a level 1.1 m above the weir pool. A comprehensive monitoring program has been established and indicates the environmental responses that can be expected from a wider weir manipulation program.

The wetland has been dried three times and refilled by pumping, by reconnecting the wetland to the weir pool or by the overbank associated with high river levels in the summer of 2010/2011. The initial reflooding event resulted in an increased abundance of vegetation, zooplankton, tadpoles and macroinvertebrates (Ellis, Chapman and Pyke 2009). The wetland has become a productive habitat for small-bodied native fish. The juveniles of the large-bodied fish species Golden Perch and Silver Perch also made use of the re-flooded wetland, suggesting that the food resources in off-channel habitats supports the development of these channel-specialist species (Ellis and Pyke 2010).

The Euston Lakes Floodplain has also been subject to drying and reflooding in recent years. Ecological monitoring at this site also indicates the environmental responses that can be expected from a weir manipulation regime.

In 2007 the lakes were selected for temporary disconnection from the Murray River to achieve water savings as part of drought contingency planning. The planned disconnection of the Euston Lakes was preceded by lowering the Euston weir pool to 46.9 m AHD from August 2007 to January 2008, which lowered water levels in the lakes. A temporary regulator was constructed on Taila Creek in December 2007 to disconnect Dry Lake, Lake Benanee and a section of Taila Creek from the Murray River.

Washpen Creek received pumped water from Taila Creek via a flood runner to maintain habitat for freshwater catfish.

Refilling of the lakes commenced in November 2009. Following this, a high river flow peaking at 74,000 ML/d in early 2011 inundated the floodplain and filled the lakes nearly 2 m above normal weir pool levels, resulting in inundation of riparian areas fringing the wetlands.

No negative environmental responses were found. Environmental conditions including blue-green algae, surface water salinity, dissolved oxygen, pH and turbidity were all maintained at acceptable levels. The population of Swamp Sheoak at Lake Benanee remained in good condition.

Positive ecological responses included:

- An improvement in River Red Gum tree health.
- Disturbance and re-establishment of littoral and riparian plant communities, including the death of cumbungi from existing stands, the appearance of new lake bed species and wetland plant germination along wetland strandlines.
- A significant increase in the abundance of bony bream and golden perch in Washpen Creek following flooding. The abundance of common carp also increased.
- A significant increase in young-of-year freshwater catfish in Washpen Creek.
- High abundances of wading birds and piscivores visiting the drying lake beds.
- High abundances of wading birds and piscivores visiting the lake after reflooding.
- Re-use of the great Cormorant rookery at Dry Lake for the first time since the 1970s with 140 nests and 220 nestlings observed after the lake refilled.

Some of these responses will be related to high river flows. However, the drying of the lake and reflooding also would have contributed significantly to these outcomes (McCarthy, et al., 2010).

12 Knowledge Gaps and Recommendations

The following recommendations are made for environmental water management in the Lock 15 weir pool.

- Implement an annual program of weir level variation to meet ecological objectives in the Euston weir pool.
- Evaluate and document the management of stop logs throughout weir manipulation trials to define safe operating conditions.
- Adapt existing monitoring programs from the weir pool, Euston Lakes and Margooya Lagoon to evaluate the environmental risks, effectiveness in meeting ecological objectives and the scope for improvement of the environmental weir manipulation program.
- Promote the relocation or modification of pumps that constrain the lowering of the weir pool. The highest priority area is Bonyaricall Creek.
- Conduct further investigations to describe the hydraulics and environmental values of the Euston Lakes Floodplain between Washpen Creek / Caringay Creek and the Murray River. These investigations should identify flow paths and flow thresholds, opportunities for environmental water management and priorities for watering based on ecological characteristics and conservation values.
- Remove blockages to flow in the Euston Lakes Floodplain including obstructions to the movement of water between Lake Caringay and the Euston weir pool.
- Investigate the environmental benefits and feasibility of lowering weir pools to promote fast flowing habitat.
- Investigate the feasibility of lowering the weir pool below 300mm.

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Appendix 1 - Ecological Vegetation Classes (EVCs)

Appendix 1 provides a description of each EVC at Spence's Bend.

EVC no.	EVC name	Bioregional Conservation Status Robinvale Plains Fans	Description
810	Floodway Pond Herbland	Depleted	Low herbland to <0.3m tall with occasional emergent life forms, usually with a high content of ephemeral species. Floors of ponds associated with floodway systems. Typically heavy deeply cracking clay soils. Characteristically smaller wetlands with a more regular flooding and drying cycle in comparison to sites supporting Lake Bed Herbland.
106	Grassy Riverine Forest	Depleted	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are infrequent, on deposited silts and sands, forming fertile alluvial soils. River Red Gum Forest to 25m tall with a groundlayer dominated by tussock-forming graminoids. Occasional tall shrubs present.
811	Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted	Eucalypt forest or woodland of flood-prone areas, where herbaceous species characteristic of drying mud within wetlands (Floodway Pond Herbland or in part Lake Bed Herbland) are conspicuous in association or fine-scale mosaic with *Paspalidium jubiflorum* and other species characteristic of Grassy Riverine Forest. Restricted extent, Murray River system mainly in far north-west, but upstream at least as far as Barmah Forest.
813	Intermittent Swampy Woodland	Depleted	Eucalypt woodland to 15 m tall with a variously shrubby and rhizomatous sedgy – turf grass understorey, at best development dominated by flood stimulated species in association with flora tolerant of inundation. Flooding is unreliable but extensive when it happens. Occupies low elevation areas on river terraces (mostly at the rear point-bar deposits or adjacent to major floodways) and lacustrine verges (where sometimes localised to narrow transitional bands). Soils often have a shallow sand layer over heavy and frequently slightly brackish soils.

107	Lake Bed Herbland	Depleted	Herbland or shrubland to 0.5m tall dominated by species adapted to drying mud within lake beds. Some evade periods of prolonged inundation as seed, others as dormant tuber-like rootstock. Occupies drying deep-cracking mud of lakes on floodplains, Floods are intermittent but water may be retained for several seasons leading to active growth at the 'drying mud stage'.
808	Lignum Shrubland	Least Concern	Relatively open shrubland of species of divaricate growth form. The ground-layer is typically herbaceous or a turf grassland, rich in annual/ephemeral herbs and small chenopods. Characterised the open and even distribution of relatively small Lignum shrubs. Occupies heavy soil plains along Murray River, low-lying areas on higher-level (but still potentially flood-prone) terraces.
104	Lignum Swamp	Vulnerable	Typically treeless shrubland to 4m tall, with robust (but sometimes patchy) growth of lignum. Widespread wetland vegetation type in low rainfall area on heavy soils, subject to infrequent inundation resulting from overbank flows from rivers or local runoff.
823	Lignum Swampy Woodland	Depleted	Understorey dominated by Lignum, typically of robust character and relatively dense (at least in patches), in association with a low Eucalypt and/or Acacia woodland to 15 m tall. The ground layer includes a component of obligate wetland flora that is able to persist even if dormant over dry periods.
103	Riverine Chenopod Woodland	Depleted	Eucalypt woodland to 15m tall with a diverse shrubby and grassy understorey occurring on most elevated riverine terraces. Confined to heavy clay soils on higher level terraces within or on the margins of riverine floodplains (or former floodplains), naturally subject to only extremely infrequent incidental shallow flooding from major events if at all flooded.
295	Riverine Grassy Woodland	Depleted	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are rare, on deposited silts and sands, forming fertile alluvial soils. River Red Gum woodland to 20m tall with a groundlayer dominated by graminoids and sometimes lightly shrubby or with chenopod shrubs.
200	Shallow Freshwater Marsh	Vulnerable	Generally, shallow freshwater marshes are no more than half a metre deep and usually dry out in summer. They are usually formed in volcanic flow beds. Large stands of River Red Gum or Lignum are often found around shallow freshwater marshes, with reeds, rushes and Cane Grass, or low-growing herbs and sedges, dominating the vegetation.

818	Shrubby Riverine Woodland	Least Concern	Eucalypt woodland to open forest to 15 m tall of less flood-prone (riverine) watercourse fringes, principally on levees and higher sections of point-bar deposits. The understorey includes a range of species shared with drier floodplain habitats with a sparse shrub component, ground-layer patchily dominated by various life-forms. A range of large dicot herbs (mostly herbaceousperennial, several with a growth-form approaching that of small shrub) are often conspicuous.
819	Spike-sedge Wetland	Vulnerable	Low sedgy vegetation of species-poor seasonal or intermittent wetlands, dominated by spike-sedges. Typically treeless, but sometimes thickets of saplings or scattered more mature specimens of Eucalyptus camaldulensis. Mostly confined to a narrow ring around the upper margins of floodway ponds. Soils are typically heavy clays (eg mottled yellow-grey clay, grey loamy clay), occasionally silty near the surface. In some riverine sites, annual inundation is not reliable and the rhizomic rootstocks of Eleocharis acuta appear capable of surviving at least occasional periods of longer dormancy.
821	Tall Marsh	Depleted	Wetland dominated by tall emergent graminoids (rushes, sedges, reeds), typically in thick species-poor swards. Competitive exclusion in core wetland habitat - of optimum growing conditions for species tolerant of sustained shallow inundation. Occupies wetlands usually associated with anabranch creeks. Soils are almost permanently moist. Dominant species are tolerant of relatively deep and sustained inundation, but not total immersion for any sustained period.

Appendix 2 - Cultural Heritage Contingency Plan

CONTINGENCY PLANS

In the event that Aboriginal cultural heritage is found during the conduct of the activity, contingency measures are set out below. The contingency measures set out the sponsor's requirements in the event that Aboriginal cultural heritage is identified during the conduct of the activity.

Management of Aboriginal Cultural Heritage found during the Activity

In the event that new Aboriginal cultural heritage is found during the conduct of the activity, then the following must occur:

- The person who discovers Aboriginal cultural heritage during the activity will immediately notify the person in charge of the activity;
- The person in charge of the activity must then suspend any relevant works at the location of the discovery and within 5m of the relevant place extent;
- In order to prevent any further disturbance, the location will be isolated by safety webbing or an equivalent barrier and works may recommence outside the area of exclusion;
- The person in charge of the activity must contact the and the Mallee CMA Indigenous Facilitator
- Within a period not exceeding 1 working days a decision/ recommendation will be made by the Mallee CMA Indigenous Facilitator and the Aboriginal stakeholder;
- As to the process to be followed to manage the Aboriginal cultural heritage in a culturally appropriate manner, and how to proceed with the works;

Separate contingency plan has been developed in the event that suspected human remains are discovered during the conduct of the activity.

Notification of the Discovery of Skeletal Remains during the carrying out of the Activity

a. Discovery:

- If suspected human remains are discovered, all activity in the vicinity must stop to ensure minimal damage is caused to the remains, and,
- The remains must be left in place, and protected from harm or damage.

b. Notification:

- Once suspected human skeletal remains have been found, Victoria Police (use the local number) and the Coroner's Office (1300 309 519) must be notified immediately;
- If there is reasonable grounds to believe that the remains could be Aboriginal, the DSE Emergency Co-ordination Centre must be immediately notified on 1300 888 544; and
- All details of the location and nature of the human remains must be provided to the relevant authorities.

- If it is confirmed by these authorities that the discovered remains are Aboriginal skeletal remains, the person responsible for the activity must report the existence of the human remains to the Secretary, DPCD in accordance with s.17 of the Act.

3. Impact Mitigation or Salvage:

- The Secretary, after taking reasonable steps to consult with any Aboriginal person or body with an interest in the Aboriginal human remains, will determine the appropriate course of action as required by s.18(2)(b) of the Act.
- An appropriate impact mitigation or salvage strategy as determined by the Secretary must be implemented.

4. Curation and Further Analysis:

- The treatment of salvaged Aboriginal human remains must be in accordance with the direction of the Secretary.

5. Reburial:

- Any reburial site(s) must be fully documented by an experienced and qualified archaeologist, clearly marked and all details provide to AAV;

Appropriate management measures must be implemented to ensure that the remains

are not disturbed in the future