NORTH EAST
CATCHMENT
MANAGEMENT
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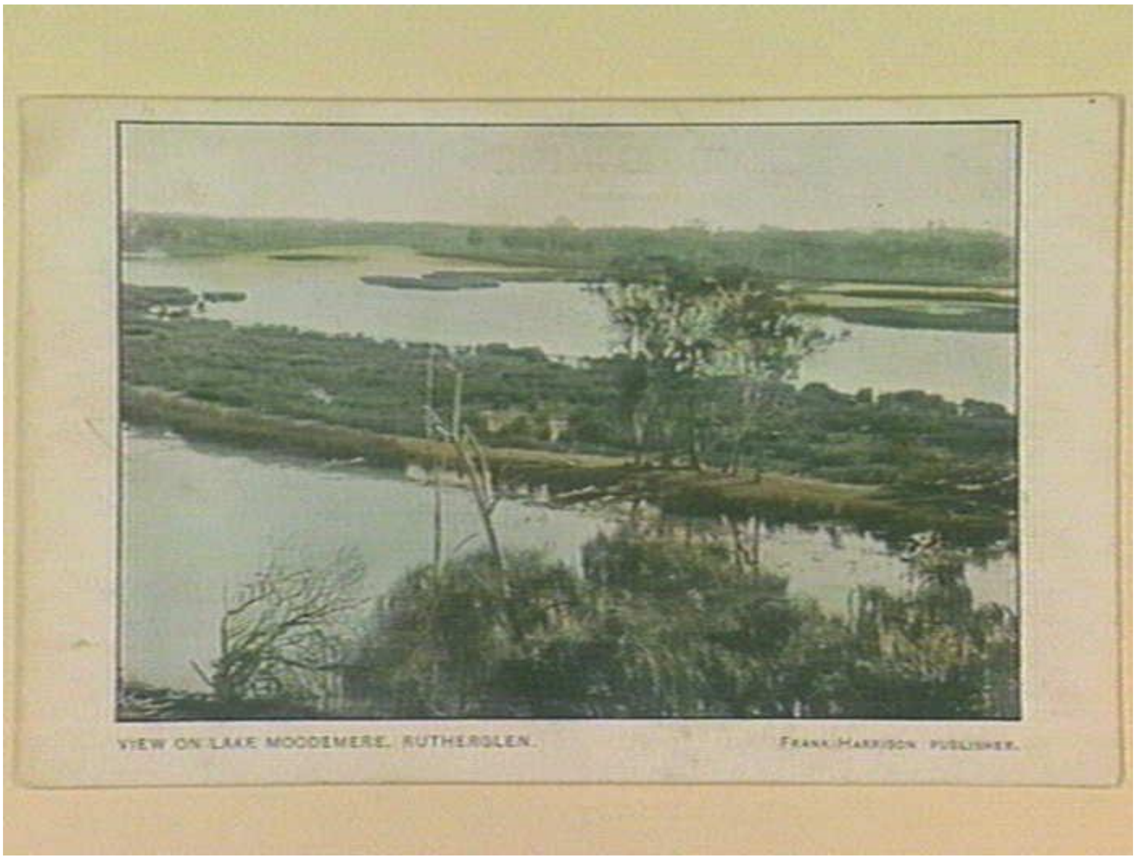
# Lake Moodemere
# Environmental Watering Plan

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## PROJECT DETAILS

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# EXECUTIVE SUMMARY

Lake Moodemere is a natural lake on the Victorian floodplain of the River Murray approximately 6.5 km downstream of Wahgunyah. The current hydrologic regime of the Lake Moodemere system is impacted by the regulation of flows in the Murray River and locally by the operation of irrigation infrastructure (pumps and regulators) used to manage inflows from the Murray River to Lake Moodemere for subsequent extraction from Sunday Creek by members of the Sunday Creek Irrigators Syndicate (the SCIS). The SCIS has proposed alterations to the existing irrigation infrastructure to improve operational efficiency and potentially yield some water savings.

The hydrologic regime of the Moodemere system is modified from natural conditions due to regulation of flows in the Murray River and management of the Moodemere system for delivery of water for irrigation. The current environmental values are derived from the current hydrologic regime and historic land management practices. The proposal to modify irrigation infrastructure and management impacting on the hydrologic regime of the Lake Moodemere system provides opportunities to improve the environmental condition but may also pose risks to current environmental assets which are either reliant upon or tolerant of the existing regime.

This environmental watering plan (EWP) has been developed to inform the future hydrologic management of Lake Moodemere and Sunday Creek (the Lake Moodemere system). The EWP seeks to document the current environmental values of the system and identify critical watering regime requirements to sustain and enhance significant environmental values.

Lake Moodemere and the surrounding area form a significant wetland asset supporting a range of flora and fauna species and providing a major drought refuge in the Hume to Yarrawonga reach of the Murray River. The North East Regional Wetland Management Strategy identifies Lake Moodemere as a high value wetland.

A range of scientific investigations were undertaken in parallel to the development of the EWP to provide site specific information on the biologic diversity of the Lake Moodemere system. Key findings included:

- Eight native aquatic vertebrates (three turtles, one large bodied native fish and four small bodied native fish) were found. Of these only the broad shelled turtle and the flyspecked hardyhead are listed as 'threatened' under the Victorian Flora and Fauna Guarantee Act, 1998. No EPBC listed species were found to be present. The littoral zones (macrophyte beds around the lake) were found to support most of the native biodiversity and significantly higher abundances of native fish and turtles than the pelagic areas.
- The vegetation communities within the project area were assessed through desktop and field work. EVCs present are identified as vulnerable and depleted within the Victorian Riverina bioregion. Of the 278 vascular flora species identified during the field work 169 species were indigenous, with 14 of these being rare or threatened.

- None of the four frogs found to occur at the site are listed as rare or threatened in Victoria. The Growling Grass Frog, an EPBC listed species, endangered in Victoria was not found to occur at the site. The current hydrologic regime and relatively low diversity of wetland vegetation is inferred to be a potential constraint on frog biodiversity within the site.
- A total of 73 bird species were identified at the site includes a total of 17 threatened species of which 12 are wetland species.

Recognising that the environmental value of the site is derived from the overall diversity of the species and communities present at the site, rather than being focussed on a single “icon” feature we propose an objective:

> **To maximise the overall biodiversity of the site by reducing current hydrological constraints on the viability of native flora and fauna communities and species.**

The proposal to modify irrigation infrastructure and management impacting on the hydrologic regime of the Lake Moodemere system provides an opportunity to reduce the detrimental impacts of the current managed hydrologic regime on the environmental condition of the site, specifically within and adjacent Lake Moodemere. Analysis of the natural and current hydrology of the Lake Moodemere systems indicates that inflows to, and water levels within, Lake Moodemere and Sunday Creek are significantly higher under current conditions through summer and autumn (irrigation season) than under natural conditions. While there is a corresponding reduction in the occurrence of winter / spring high flows (as a result of river regulation) there is little potential for local changes in irrigation infrastructure to significantly influence the occurrence of these larger flows.

The modified irrigation operations currently under consideration provide an opportunity to separate the operation of Lake Moodemere and Sunday Creek. In essence this would result in a continuation of the current water level regime within Sunday Creek to facilitate seasonal irrigation extraction. While this essentially precludes the implementation of a drawdown regime within Sunday Creek (as the desired drawdown period coincides with the irrigation season) it means that, subject to consideration of other social and economic factors, a drawdown of Lake Moodemere over summer / autumn can be considered. The benefits and risks of such a drawdown regime for Lake Moodemere have been reviewed and the likely benefits to site biodiversity have been found to outweigh the risks.

In summary, the key findings are:

- All turtle species are expected to benefit from an increase in macrophyte diversity. The turtle community may change, with more ephemeral conditions potentially favoring the Eastern long-necked turtle over the less common Broad shelled turtle and Murray River turtle. This is predicated on the fact that both the Broad shelled turtle and the Murray River turtle prefer permanent water bodies and it is noted that even under a drawdown scenario Lake Moodemere will still retain a permanent pool.
- Native fish (small and large bodied) are expected to benefit from a drawdown regime due to increased zooplankton productivity. There is some risk to the Flyspecked hardyhead (Threatened Vic FFG) associated with reduced access to wetland macrophytes during the breeding season.
- Exotic fish species may benefit from the drawdown as they are generally more tolerant of poor water quality and warm water.
- Aquatic fringing vegetation diversity, currently low within and around Lake Moodemere, is expected to increase as a result of a summer / autumn drawdown. The main risk is the potential for increased dominance by Juncus ingens in the fringing vegetation.

- Frog diversity is expected to benefit from implementation of a drawdown regime. No risks to frog communities have been identified.
- Bird communities are expected to benefit from increased habitat productivity and food sources and increased shallow wetland habitat. Some temporary relocation of wetland species may occur if the lake and wetlands become too shallow.

While the introduction of a summer / autumn drawdown period is recommended to increase the diversity and overall condition of the Lake Moodemere system it must be recognised that social and economic factors including impacts on recreational, boating, skiing and rowing activities must be taken into account in development and implementation of the future watering regime.

# 1. INTRODUCTION

## 1.1 Project background

Lake Moodemere is a natural lake on the Victorian floodplain of the River Murray approximately 6.5 km downstream of Wahgunyah. The current hydrologic regime of the Lake Moodemere system is impacted by the regulation of flows in the Murray River and locally by the operation of irrigation infrastructure (pumps and regulators) used to manage inflows from the Murray River to Lake Moodemere for subsequent extraction from Sunday Creek[1] by members of the Sunday Creek Irrigators Syndicate (the SCIS). The SCIS has proposed alterations to the existing irrigation infrastructure to improve operational efficiency and potentially yield some water savings.

## 1.2 Purpose of the plan

This environmental watering plan (EWP) has been developed to inform the future hydrologic management of Lake Moodemere and Sunday Creek (the Lake Moodemere system). The EWP seeks to document the current environmental values of the system and identify critical watering regime requirements to sustain and enhance significant environmental values.

# 2. SYSTEM OVERVIEW AND CONTEXT

## 2.1 Introduction

Lake Moodemere is a large natural lake on the Victorian floodplain of the Murray River approximately 6.5 km downstream of Wahgunyah. With a surface area of approximately 60 ha when the water level is at about RL129.5 (approximately 300 mm below the regulator crest level) it is the largest floodplain lake in the highly regulated reach of the Murray River between Lake Hume and the Ovens River. Lake Moodemere is popular for water skiing, rowing (there is an annual regatta in early January), swimming, fishing and bird watching (Barrow and Raulings 2007). The lake and surrounds are managed by Parks Victoria. Land use and land management is discussed further in Section 2.4.

## 2.2 Spatial information and geomorphic setting

Lake Moodemere lies within the contemporary River Murray floodplain, occupying a crescent shaped oxbow billabong (Meathrel et al 2002). Lake Moodemere lies near the floodplain margin defined by the Shepparton formation sediments which lie generally to the north, south and east of Lake Moodemere. Lake Moodemere and the surrounding area form a significant wetland asset supporting a range of flora and fauna species and providing a major drought refuge in the Hume to Yarrawonga reach of the Murray River.

Lying within the floodplain of the Murray River, Lake Moodemere is inundated during major flood events in the Murray River. At lower levels inflows from the Murray River to Lake Moodemere occur via a number of floodplain features:

- A regulator near the Murray River bank and an excavated channel extending from the regulator to the north-west end of Lake Moodemere. Within this report, this regulator is

[1] The creek system between Wahgunyah and Lake Moodemere is known as Sandy Creek in the upstream ephemeral reach and Sunday Creek within the reach flooded by the Lake Moodemere backwater. The reach within the project area is therefore referred to as Sunday Creek within this report.

referred to as the Lake Moodemere Regulator. A pump at this location can also be used to divert water from the Murray River to Lake Moodemere when water levels in the Murray River are too low to allow gravity diversion.

- Flooding from the Murray River at Hiskins Bend through Forest Swamp (now controlled by the Hiskins Bend regulator) and via floodplain depressions connecting to the excavated channel near the Lake Moodemere Regulator.
- Overtopping of the Murray River bank in Willow Park, Wahgunyah results in flows through Sunday Creek and subsequently to Lake Moodemere (Earth Tech 2008).
- Under higher river levels flows from the Murray River enter Lake Moodemere via floodplain depressions to the north of the lake.

Flow connectivity with the Murray River is discussed further in Section 3.3.

## 2.3 Project area

The project area encompasses those portions of the Murray River floodplain where the ecological character or condition may be influenced by the hydrologic management of Lake Moodemere and Sunday Creek. The total project area is approximately 517 ha based on the boundaries discussed below and indicated in Figure 2-1.

- To the south and east of Lake Moodemere, the terrace formation bordering the Murray River floodplain generally forms the boundary. An unnamed wetland to the east of Sunday Creek within the Murray River floodplain is excluded from the project area as it is in private ownership and is unlikely to be impacted by managed watering of the Moodemere system.
- To the west, the Murray River defines the western boundary. A managed watering regime for the Lake Moodemere system will not result in hydrologic impact on the Murray River channel or the New South Wales floodplain.
- To the north, Hyde Road is adopted as the boundary of the project area. The current operation of the Moodemere system produces backwater flooding downstream of this point in Sunday Creek. The proposal by SCIS includes a pump from the Murray River discharging to Sunday Creek downstream of Hyde Road. The upstream reach of Sunday Creek is inundated only during high Murray River flows (above approximately 33,000 ML/D) when overflow in the vicinity of Willow Park in Wahgunyah commences.

The features of the Lake Moodemere system are shown in Figure 2-1.

The identified project area correlates closely with the area of public land managed by Parks Victoria (refer Section 2.4) but includes an area of private freehold in the northern portion of the project area.


**Figure 2-1 The Lake Moodemere system**

## 2.4 Land use and management

The majority of the project area lies within Public Land managed by Parks Victoria as summarised in Table 2-1 and mapped in Figure 2-2.

**Table 2-1 Public Land Reserves within the project area**

| Asset | Reserve Category | Location | Ha *1 |
|---|---|---|---|
| Lake Moodemere Lake Reserve *2 | Natural Features Reserve | Lake Moodemere and the area directly to the north of Lake Moodemere. | 264.4 |
| Moodemere Nature Conservation Reserve *2 | Nature Conservation Reserve | Moodemere NCR to north of Lake Moodemere Lake Reserve, added under VEAC (2008) recommendations (not included in Barrow and Raulings (2007)) | 61.1 |
| Murray River Water Frontage | Natural Features Reserve | Along Sunday Creek between Lake Moodemere Lake Reserve and Distillery Road | 1.4 |
| Moodemere Nature Conservation Reserve | Nature Conservation Reserve | Moodemere NCR at McDonalds Road to east of Lake Moodemere (outside of current project area) | 11.7 |
| River Murray Reserve *2 | Natural Features Reserve | Forest Swamp and Hiskins Bend area and Murray River frontage. | 345.8 |
| Gravel Reserve | Earth Resources | To west of access road, approximately 500 m south of the Boat Ramp. | 2.4 |
| Hyde Road | Services and Utilities | Hyde Road between Sunday Creek and the Murray River | 2.7 |

*1 From DSE Biodiversity Interactive Map (DSE 2011)

*2 Now part of the River Murray Reserve based on VEAC recommendations

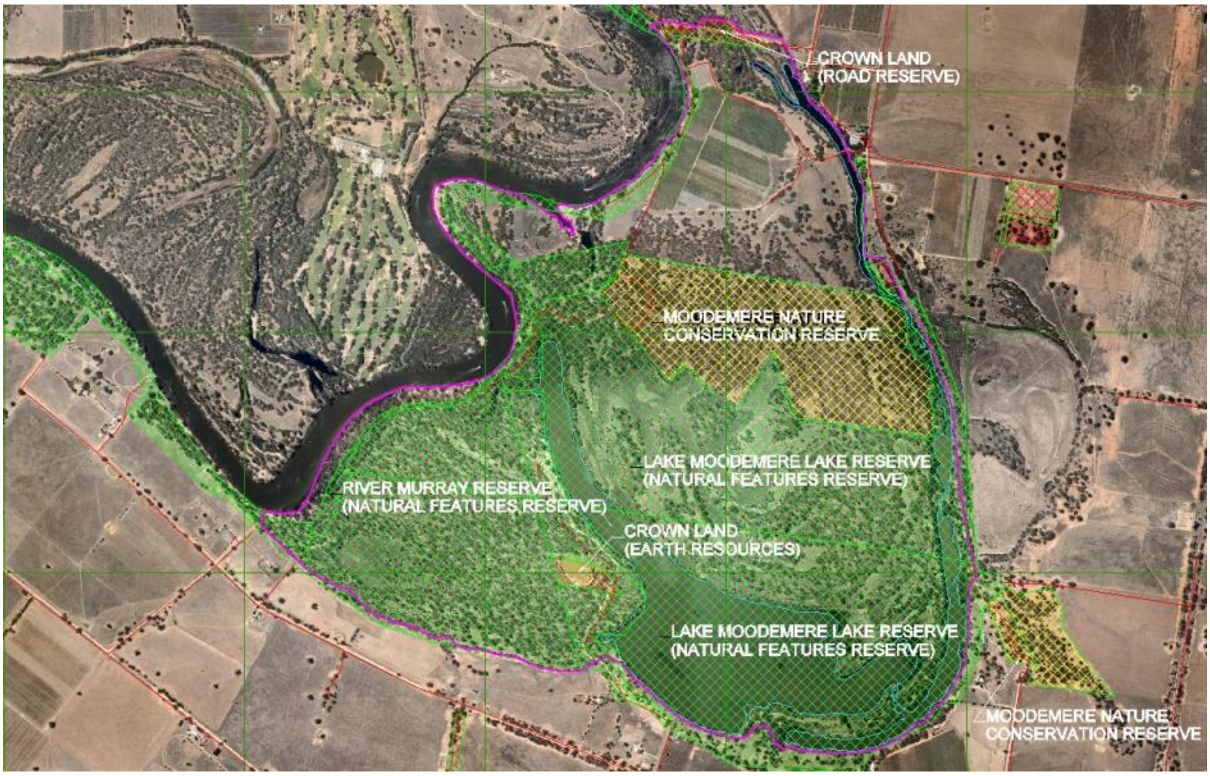


**Figure 2-2 Public land reserves within the project area**

The current management and documented management objectives of relevance to the EWP are discussed in Section 6.1.2.

## 2.5 Wetland values

### 2.5.1 Mapping and characterisation of wetlands

The occurrence, distribution and significance of wetland systems in the North East CMA region are documented in the Wetland Inventory and Assessment for the North East CMA Region, Volume 1 (BMT WBM 2007a). The Lake Moodemere system comprises floodplain wetlands occupying naturally formed floodplain depressions resulting from historic movement of the Murray River. As such the hydrologic regime is characterised by episodic events linked with bank-full and over-bank flows (BMT WBM 2007a).

BMT WBM (2007a) utilised a number of sources to identify wetlands for inclusion on the Wetland Inventory. The DSE Wetland_1994 geospatial layer (DSE 1994) developed from statewide wetland classification and mapping commencing in 1980, is the most comprehensive wetland data set for the state of Victoria. This layer also includes a basic wetland categorisation based on water regime and dominant vegetation (BMT WBM 2007a). The Wetland_1994 layer for the Hume to Yarrawonga reach of the River Murray and adjacent Victorian tributaries (including the Kiewa River, Black Dog Creek and Ovens River within this reach) is shown in Figure 2-3 (from DSE 2011). Lake Moodemere is the largest floodplain wetland mapped on this reach of the River Murray, excluding Lakes Hume and Mulwala. BMT WBM (2007a) notes that floodplain wetlands are less common downstream of Corowa than upstream due to the more highly cohesive sediments, and hence less mobile river channel in the reach downstream of Corowa.

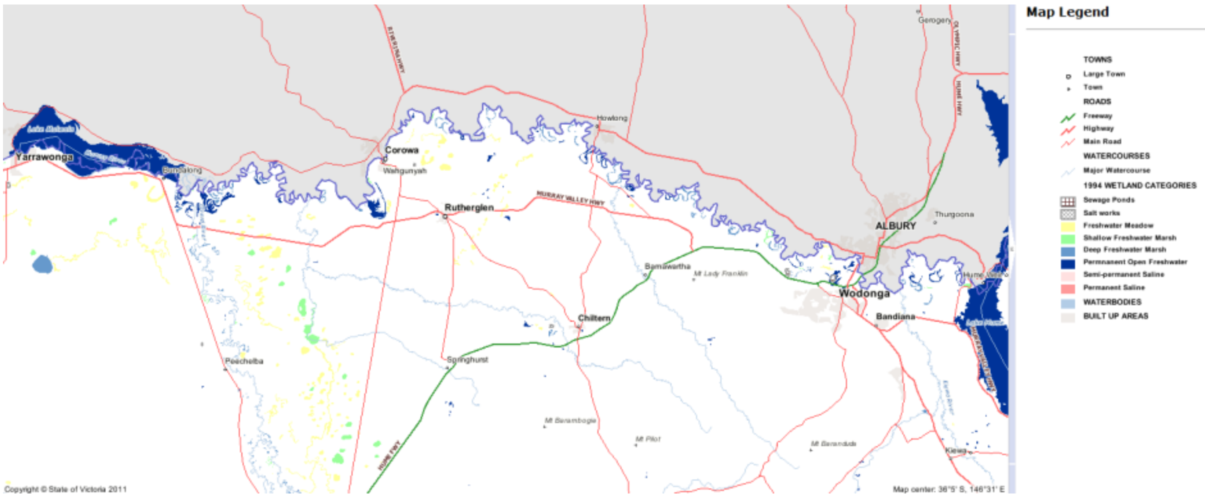


**Figure 2-3 DSE Wetland_1994 layer from Lake Hume to Yarrawonga**

A more detailed view of the Wetland_1994 layer within the current project area is provided in Figure 2-4. The entirety of Lake Moodemere and Sunday Creek is classified (after Corrick and Norman 1980, Norman and Corrick 1988) as "Permanent Open Freshwater", Forest Swamp (to the west of Lake Moodemere) is classified as "Deep Freshwater Marsh", while the floodplain feature to the east of Sunday Creek is classified as "Freshwater Meadow", reflecting the reduced duration of inundation for this higher level feature. The wetland attributes are summarised in Table 2-2.

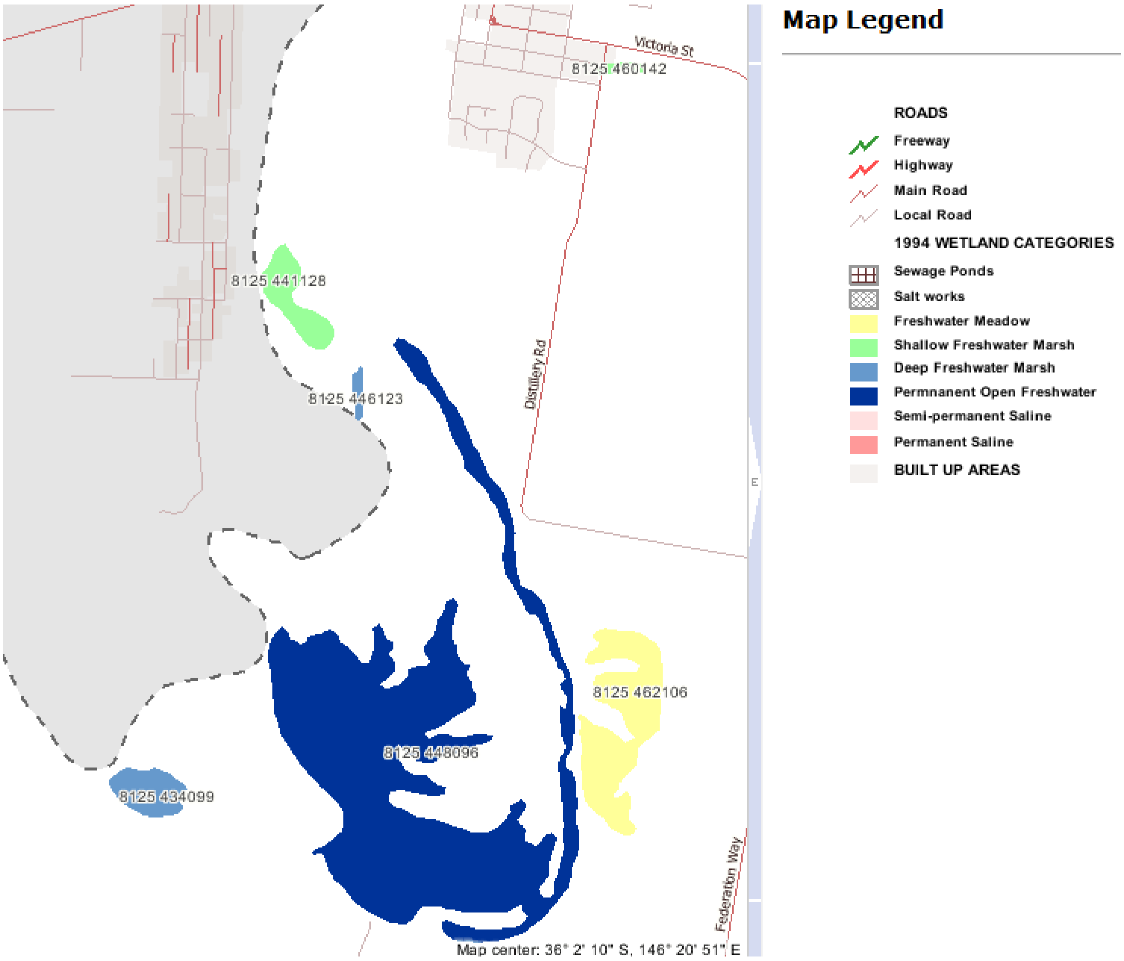


**Figure 2-4 DSE Wetland_1994 layer within the current project area**

**Table 2-2 DSE Wetland_1994 layer information for wetlands in the project area**

| | Lake Moodemere and Sunday Creek | Forest Swamp | East of Sunday Creek |
|---|---|---|---|
| Map Sheet | 8125 | 8125 | 8125 |
| Wetland ID | 448096 | 434099 | 462106 |
| Area (ha) | 160.72 | 7.2 | 33.74 |
| Name | Lake Moodemere | - | - |
| Wetland Category (1994) | Open water | Deep Marsh | Meadow |
| Wetland Sub-Category | Shallow (<5m) | Red gum | Herb |

In addition to the Wetlands_1994 layer, BMT WBM (2007a) utilised statewide Ecological Vegetation Class (EVC) mapping (discussed further in Section 5.3) and information from the Directory of Important Wetlands in Australia (Environment Australia 2001). No wetlands within the project area are included in the Directory of Important Wetlands in Australia.

### 2.5.2 Wetland significance

The North East Wetland Management Strategy (BMT WBM (2007b)) provides broad strategic directions for the future management of wetlands within the North East. The Wetland Management Strategy aims to provide a framework for the protection and enhancement of the biodiversity and ecological values of the wetlands within the North East region.

The Vision identified within the Strategy is "To ensure that wetlands on public and private land are protected, rehabilitated, managed and used sustainably so that, collectively, they provide the complete range of ecological, biodiversity, community, social and economic values for present and future generations of the region and for the wider Australian and international community."

The Strategy adopts a "protect the best" approach to managing wetland priorities and allocating resources. This approach involved identifying the most significant high value wetland assets and subsequently focussing management strategies and works on those high value wetland assets to ensure their continued health and survival. Lake Moodemere is identified as a high value wetland within BMT WBM (2007b) based on a comparative ranking of wetlands across the region using five criteria:

- Listing in government registers or location in protected areas.
- Rarity of wetland type, and size.
- Biodiversity value, based mostly on bird data.
- The presence of rare or threatened species.
- Ecological Vegetation Class (EVC) conservation status.

The North East Regional Wetland Management Strategy (North East CMA 2009) identifies Lake Moodemere as a high value wetland while the Lower Ovens Biodiversity Action Plan (BAP) (DSE 2004) identify Lake Moodemere as a bioregionally significant wetland, based on its listing in the Australian Terrestrial Biodiversity Assessment (NLWRA 2002). The basis for this listing cannot be determined from currently available information however Todd (1999) (cited in DSE 2004) identified Lake Moodemere NFR as a priority area for protection within the Victorian Riverina Bioregion due to its flora values and use by Freckled Duck and White-bellied Sea-eagle and Clark (1996) (cited in DSE 2004) identified several "relict box" woodland sites within Lake Moodemere NFR.

The specific wetland and biodiversity values identified within the project area are further discussed in Section 5

In addition to the environmental values identified above, Lake Moodemere is listed on the Register of the National Estate (RNE) (accessed via the EPBC Protected Matters Search Tool at http://www.environment.gov.au/arcgis-framework/apps/pmst/pmst-region.jsf) as a Historic Indicative Place for its social significance because of its recreational and natural qualities.

## 2.6 Previous relevant natural resource management studies and strategies

### 2.6.1 The North East Regional River Health Strategy

The North East Regional River Health Strategy (NERRHS) (North East CMA 2006) provide strategic direction for the management of waterways in the North East CMA region, consistent with local community objectives and the broader strategic direction of the Victorian government. Lake Moodemere and Sunday Creek lie within the River Murray Tributaries Management Unit 2 as designated in the NERRHS (North East CMA 2006). Specific actions relating to the Murray River and the associated anabranch system are not identified in North East CMA (2006) as the anabranches and floodplain assets of the River Murray are managed jointly by the North East CMA, River Murray Water and the NSW Office of Water. Prioritisation of actions for these jointly managed assets is undertaken through development of River Management Plans (RMPs) and thus specific targets or priorities for Lake Moodemere are not documented in North East CMA (2006).

### 2.6.2 River Management Plan

For management purposes, the NSW Office of Water divides the Hume to Yarrawonga (Lake Mulwala) reach of the River Murray into fifteen management zones, with Lake Moodemere located within the Corowa Common Management Zone. The River Management Plan (Earth Tech 2008) identifies Lake Moodemere as a shallow lake lacking depth diversity to support significant populations of large bodied native fish species, with woody habitat restricted to the margins and the Sunday Creek end of the lake. The existing Lake Moodemere Regulator is identified as a potential constraint on movement of native fish from the Murray River into Lake Moodemere however it is also recognised that modification of the barrier to enable fish movement may increase the Carp population within Lake Moodemere. Overall the instream habitat value of Lake Moodemere is rated as “good”. The vegetation community around Lake Moodemere is described as River Red Gum overstorey with an understorey of exotic grasses and herbs. The shores of Lake Moodemere were described as being dominated by rushes (*Juncus ingens*) with young and mature River Red Gums on higher ground adjacent the lake. The hydrologic regime of the Lake Moodemere system is not discussed in the RMP and the objectives for management and recommended actions are generic, comprising fencing and revegetation and weed management. The RMP thus does not provide significant direction for the development of the EWP.

### 2.6.3 The North East Regional Wetland Management Strategy

The North East Regional Wetland Management Strategy (North East CMA 2009) has the following objectives:

- Provide the North East CMA with a strategy to establish current management guidelines and recommendations for wetlands in the region.
- Encourage, guide and provide a mechanism for an integrated approach for the future management of wetlands.
- Ensure that wetlands are given appropriate status and are managed accordingly.
- Provide guidance with regard to funding for wetland management and to fill key knowledge and data gaps.

The significance of individual wetlands within the region was ranked based on:

- Listing in government registers or location in protected areas.
- Rarity of wetland type and size.
- Biodiversity value, based mostly on bird data
- The presence of rare or threatened species
- Ecological Vegetation Class (EVC) conservation status.

Through this process Lake Moodmemere was identified as one of the 23 highest value wetlands within the North East CMA region.

### 2.6.4 Lake Moodemere Water Management Plan

The Lake Moodemere Water Management Plan (Robley 1996), developed as part of the Integrated Watering Strategy project (IWS) for the mid-River Murray floodplain documents the hydrologic requirements for maintenance and enhancement of the wetland systems at Lake Moodemere. Robley (1996) draws upon information contained in the Interim Water Management Strategy for Lake Moodemere (Beovich and Lloyd 1993) and represents the most recent detailed review of hydrologic and ecologic interactions at Lake Moodemere at the time of development of this EWP.

The hydrologic review undertaken in development of this EWP (Section 3) is similar to that documented in Robley (1996) but is updated to use currently available data. Similarly, the review of ecological assets (Section 5 – fish, turtles, frogs, vegetation) within the Lake Moodemere project area provides additional information not contained in Robley (1996). The current EWP could thus be seen to represent a further development of the work contained in Robley (1996).

## 2.7 Previous relevant irrigation and infrastructure management studies and strategies

A series of technical investigations and reports have been prepared with assistance from Goulburn Murray Water during the development of the SCIS proposal to alter the management of irrigation from the Lake Moodemere system. While these reports focussed largely on the infrastructure and operational aspects of the Lake Moodemere system they also provide an overview of environmental condition and values. These reports are discussed sequentially in the following sections, focussing specifically on investigations and outcomes which are of relevance to the development of the EWP.

It is noted that these previous reports were based on desktop assessments and reviews of historic data. While the Lake Moodemere system is recognised as a significant environmental asset, there is a relative paucity of recent scientific assessment of the system. A range of field assessments of the system were therefore commissioned to support the development of this EWP as discussed in Sections 4 and 5.

### 2.7.1 Lake Moodemere Water Savings Feasibility Assessment – Inception Report (SKM 2008a)

This initial report, prepared by Sinclair Knight Merz on behalf of Goulburn-Murray Water provides a brief overview of the operation and management of the Lake Moodemere system and considers the feasibility of changing the current operating arrangements. The report is based on consultation with stakeholders and review of literature. Specifically, the feasibility assessment considers the impact of providing for extraction of irrigation water from Sunday Creek via one of two options:

- Option 1 – the construction of a new pump station to convey water from the Murray River to Sunday Creek at Hyde Road and the construction of a regulator at Hells Gate (between

Sunday Creek and Lake Moodemere) to allow Sunday Creek water levels to be increased above the level of Lake Moodemere

- Option 2 – the construction of a new pump station to convey water from the Murray River near Hyde Road to a pipeline supplying each of the Sunday Creek irrigators. This would negate the need to operate either Lake Moodemere or Sunday Creek as a component of the irrigation system.

### 2.7.2 Lake Moodemere Water Savings Feasibility Assessment – Conceptual Design Report (SKM 2008b)

This report determined a concept layout for the works options identified in SKM (2008a) and determined capital and operating costs for each option. The limited economic analysis indicated that Option 1 is significantly more economically attractive than Option 2.

### 2.7.3 Lake Moodemere Water Savings Impact Assessment Report – Stage One – Preliminary Investigations & Legislative Requirements (GHD 2009a)

This investigation review the impacts of the adoption of Option 1 (from SKM 2008a and SKM 2008b), namely the provision of a pump station to divert water from the Murray River to Sunday Creek at Hyde Road and the construction of a regulator at Hells Gate. The review of impacts was more detailed than that provided in SKM (2008a). Specific outcomes from the investigation were:

- Development of the concept design of the regulator structure at Hells Gate. The proposed structure comprising box culverts and aluminium stoplogs within an earth embankment was significantly more complex than that envisaged in SKM (2008a). The recommended works included the provision of a small fish ramp on the Lake Moodemere side of the structure.
- Mapping indicates that probable acid sulphate soils are likely to be present within parts of the site. Further investigation including soils sampling, laboratory testing and risk assessment were recommended to assess the implications of acid sulphate soils specifically with regard to construction related impacts and potential wetting and drying operations.
- No salinity or hydrogeological risks were identified as a result of changes in the operating regime (recognising that the likely operating regime had not been identified at the time of this investigation).
- Flora and fauna desktop assessments indicated a number of rare and threatened species likely to occur in proximity to Lake Moodemere. Field assessment was recommended to confirm the likely presence of threatened species and communities and to identify appropriate measures to avoid or minimise impact.
- It was noted that the fish communities of Lake Moodemere were not well understood.
- Relevant environmental assessments and approvals required for construction and management of the proposed works were identified.

### 2.7.4 Report for Lake Moodemere Flora, Fauna and Net Gain Assessment (GHD 2009b)

A Flora, Fauna and Net Gain desktop assessment was undertaken to investigate the impact of the proposed infrastructure works under consideration (Option 1 as presented in SKM 2008a and SKM 2008b).

The review considered likely impacts on Matters of National Environmental Significance (MNES) under the Environment Protection and Biodiversity Conservation Act, 1999. It was concluded that appropriate mitigation measures could be developed to prevent impact on Ramsar sites (on the Murray River downstream of Lake Moodemere) and migratory species. Seven EPBC Act listed fauna species were identified, of which it was considered that the project would not have a significant impact on six of these species if appropriate design were adopted (i.e. avoiding all native vegetation). The likely impact of the project on the Growling Grass Frog (an EPBC Act listed species) could not be determined as the presence of the Growling Grass Frog at the site was not well understood.

The legislative requirements for approval or permits under the Flora and Fauna Guarantee Act 1988, the Planning and Environment Act 1987, the Wildlife Act 1975, the Environment Effects Act 1978 and the Catchment and Land Protection Act 1994 were also reviewed.

### 2.7.5 Other

The following reports have been reviewed but were not found to yield significant relevant information for development of the EWP:

- Report for Lake Moodemere Water Savings Impact Assessment – Acid Sulphate Soil Assessment (GHD 2010a)
- Report for Lake Moodemere Water Savings Project: Phase 2 Water Resources Report (GHD 2010b)
- Lake Moodemere Water Savings Scheme, Rutherglen – Cultural Heritage Management Plan Number: 11001 (Terraculture 2010)

# 3. HYDROLOGY

## 3.1 System overview

Lake Moodemere is a natural floodplain feature of the Murray River. As such, the hydrologic regime of the wetland is derived from the timing, sequence and magnitude of flows in the Murray River. The modification to the hydrologic regime of the Murray River as a result of river regulation has therefore had a significant impact on the wetting and drying regime of the Lake Moodemere system. The hydrology of the Lake Moodemere system is further impacted by historic works and the use of regulator structures to manipulate water levels within Lake Moodemere and Sunday Creek to facilitate irrigation extractions. The current management relies upon the following anthropogenic system modifications:

- The excavation of a channel (Hells Gate) between Sunday Creek and Lake Moodemere breaching the low level bar between the lower reaches of Sunday Creek and Lake Moodemere. Recent bathymetric survey (refer Section 4) indicates that the invert level and cross-section is relatively uniform throughout the length of Hells Gate. Hells Gate is shown in Figure 3-2. GHD (2009a) indicates that this connection was formed during the early period of farming development in the area. Hells Gate is visible in a 1941 aerial photograph taken under low flow conditions so has clearly been present for greater than 70 years. Lake Moodemere and Sunday Creek have thus operated with a similar modified hydrologic regime over this period.
- The Lake Moodemere regulator on the Murray River near the north-western end of Lake Moodemere. The current structure constructed in 1979 (according to the date marked in the concrete structure) comprises 2 x 750 mm diameter culverts through the bank of the Murray River and a concrete structure with 3 x 610 mm wide x 470 mm high gated outlets. The Lake Moodemere regulator is shown in Figure 3-3 and Figure 3-4. A diesel powered pump is located on the bank of the Murray River adjacent the Lake Moodemere regulator. This pump is used (by the SCIS) to pump water into the downstream channel when Murray River water levels are too low to allow gravity diversion. Robley (1996) notes that the channel between the regulator and Lake Moodemere was deepened in association with construction of the regulator.
- SKM (2008a) indicates that prior to construction of the current Lake Moodemere regulator water was pumped from the Murray River to Sunday Creek in the vicinity of Hyde Road.
- An excavated channel approximately 150 m long between the Lake Moodemere regulator and Lake Moodemere.
- The Hiskins Bend regulator, constructed in 2008, operated to control flows from the Murray River to Forest Swamp and hence, under high Murray River levels, to Lake Moodemere. This regulator is shown in Figure 3-5.

The location of these features is indicated in Figure 3-1.


**Figure 3-1 Project area showing regulator structures**

**Figure 3-2 Hells Gate, looking from Lake Moodemere toward Sunday Creek**

**Figure 3-3 Lake Moodemere regulator viewed from the Murray River side, looking toward Lake Moodemere via the excavated channel downstream of the regulator**

**Figure 3-4 Lake Moodemere regulator looking toward the Murray River and twin culverts through the river bank**

**Figure 3-5 Hiskins Bend regulator looking toward the Murray River. The abutments of the structure were damaged in the 2010/2011 floods.**

## 3.2 Structure levels and hydraulic controls

### 3.2.1 Hydraulic control features and levels

The hydrologic regime of Lake Moodemere is controlled by natural hydraulic controls and, more significantly, the infrastructure described in Section 3.1. A comprehensive listing of hydraulic control levels is not provided in the literature preceding the development of this EWP (refer Section 2.7). Where information on control and operating levels is provided it commonly refers to levels relative to a local gauge at “Chambers Pump” on Sunday Creek. GHD (2009a) states that Chambers Gauge 0 level is at RL 127.1 m AHD. This relationship has been adopted in converting Chambers Gauge levels to AHD levels throughout the development of this EWP. It is noted however that the bathymetric survey (discussed further in Section 0) undertaken as part of the EWP process suggests that Chambers Gauge 0 is at RL 127.00. A 0.1 m potential error exists in relation to the levels quoted below.

Critical levels identified from previous reports and / or determined from the bathymetric survey are summarised in Table 3-1 and Figure 3-6

**Table 3-1 Level of key site features**

| **Information source** | **Feature** | **Level (Chambers Gauge)** | **Level (RL m AHD)** |
|---|---|---|---|
| Bath survey | Lowest invert level in Sunday Creek long section | -1.30 | **125.80** |
| Bath survey | Lowest surveyed lake invert level | -0.16 | **126.94** |
| GHD 2009a | McDonalds Intake level (pump off Sunday Creek) | 0.50 | **127.60** |
| Bath survey | Murray culverts to regulator - Murray side invert level | 0.74 | **127.84** |
| Bath survey | Murray culverts to regulator - regulator side invert level | 0.84 | **127.94** |
| Bath survey | Regulator – downstream slab | 1.04 | **128.14** |
| Bath survey | Regulator - outlet invert | 1.14 | **128.24** |
| GHD 2010b | Min for Jan rowing regatta | 1.50 | **128.60** |
| GHD 2010a | Invert level of Hells Gate | 1.50 | **128.60** |
| GHD 2009a | SCIS min normal operating range (GHD) | 1.60 | **128.70** |
| GHD 2009a | SCIS max normal operating range (GHD) | 1.85 | **128.95** |
| Robley 1996 | Recommended December drawdown level | 1.90 | **129.00** |
| LiDAR info | Forest Swamp inundation commences | 2.10 | **129.20** |
| SKM 2008 data | 50%ile level (Chambers gauge) | **2.15** | 129.25 |
| LiDAR info | Northern marshes commence inundation | 2.20 | **129.30** |
| LiDAR info | Substantial inundation of northern marshes | 2.40 | **129.50** |
| SKM 2008a data | Average Sep-Nov lake level (Chambers gauge) | **2.40** | 129.50 |
| Bath survey | Water level day of bathymetry survey | 2.44 | **129.54** |
| LiDAR info | Lowest connection to Murray River via Forest Swamp | 2.60 | **129.70** |
| Bath survey | Regulator - top of overflow wall | 2.71 | **129.81** |
| Bath survey | Regulator - top of wing walls | 2.85 | **129.95** |
| A Trott pers comm | Nominal level of Dec 2010 flood (approx 0.3m above carpark) | 3.50 | **130.60** |

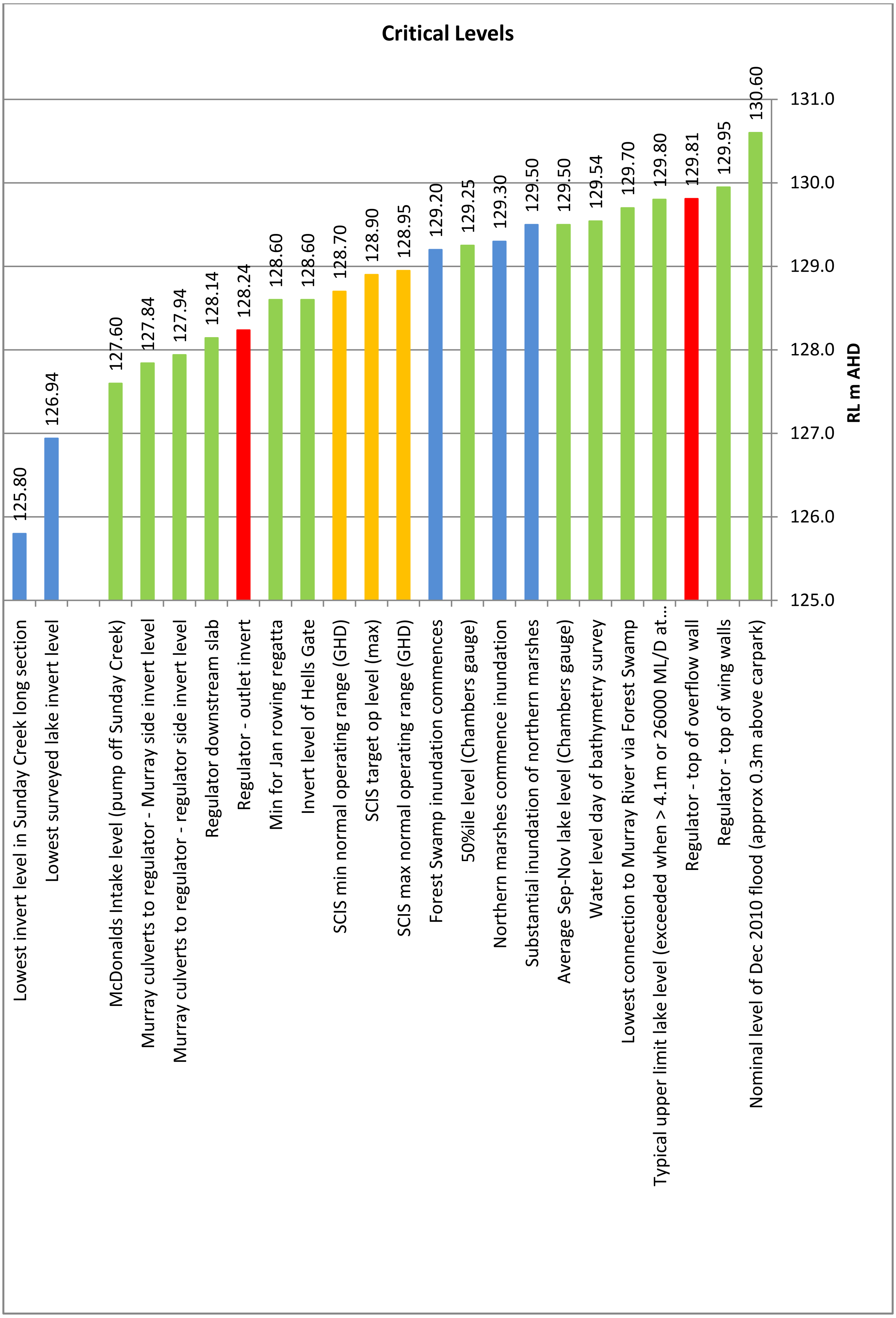


**Figure 3-6 Level of key site features**

## 3.3 Commence to flow information

Available commence to flow (CTF) information describing the connectivity of the various elements of the Lake Moodemere system is discussed in the following sections. The commence to flow information then forms the basis for assessment of the natural and current hydrologic regime of the system as presented in Section 3.5.

### 3.3.1 Commence to flow under natural conditions

Assessment of commence to flow magnitudes under natural conditions is complicated by the lack of available data and contradictory information provided in available literature as discussed below.

The occurrence of inflows to Lake Moodemere under natural conditions would have been determined by the level of the lowest connection between the Murray River and Lake Moodemere. Robley (1996) identifies a natural commence to flow threshold of 25,000 ML/D (at Albury) based on the Lake Moodemere Interim Water Management Strategy (Beovich and Lloyd 1993). The basis for this threshold is not specifically stated in Robley (1996) but is presumed to relate to the commencement of inflows via Forest Swamp and the area of low lying ground between Forest Swamp and Lake Moodemere, for which Robley (1996) indicates a flow of 24,400 ML/D (presumably at Albury). A review of the LiDAR information indicates that this connection becomes active once water levels at Hiskins Bend exceed RL 129.8 m AHD.

Some contradictory evidence is offered in Robley (1996) which indicates that the Northern Channel connects between the Murray River and the northern marshes area of Lake Moodemere once flows exceed 23,000 ML/D. The LiDAR information for this area indicates a water level of RL 130.3 m AHD or higher is required to achieve this connectivity, suggesting that it should be connected only at flows significantly higher than those connecting through Forest Swamp. An aerial photograph mosaic of the November 1971 flood (which peaked at 102,478 ML/D at Doctors Point and 86,509 ML/D at Corowa) suggests that the area around the northern channel was dry at the time of the photograph while the area between Forest Swamp and Lake Moodemere was inundated. While the aerial photography may not have captured the peak flow magnitude at this location, it does indicate that the connectivity via the northern channel occurs at a significantly higher magnitude than that via Forest Swamp and thus the 23,000 ML/D connectivity via the northern channel is not adopted for the development of this EWP.

**In conclusion, a commence to flow magnitude of 25,000 ML/D under natural conditions for Lake Moodemere has been adopted for development of this EWP.**

Broader inundation associated with inflows via Sunday Creek would have occurred naturally in larger flood events. The Murray Wetlands Working Group information (further discussed in Section 3.3.2) indicates a commence to flow magnitude of 32,918 ML/D for the reach of Sunday Creek from the Murray River (commencing at Willow Park in Wahgunyah) to Hells Gate. By comparison, Robley (1996) citing Beovich and Lloyd (1993) indicates a flow of 43,000 ML/D (at Corowa) results in flows down Sunday Creek to Lake Moodemere. Further contradictory information is provided in GHD (2010) citing information from SKM (2008a) but indicating a commence to flow magnitude for Sunday Creek of 48,000 ML/D (presumably due to a change in, or mis-interpretation of, the rating curve). The discrepancy between these stated flows is not significant to the EWP as flows of this magnitude are not influenced by current or future operation of infrastructure within the project area.

### 3.3.2 Commence to flow under current conditions

The NSW Murray Wetlands Working Group (MWWG) has developed a River Murray Wetland Database (RMWD) containing environmental information on over 4000 River Murray wetlands

(Green and Alexander 2006). Of specific relevance to the current project, it includes commence-to-flow information identifying the river flow at which each wetland begins to receive water. This information was compiled from field assessments, anecdotal information, agency staff, satellite information and previous studies (http://www.mwwg.org.au/database ). The accuracy of information is known to vary between wetlands. The commence to flow information presented by the MWWG for Lake Moodemere system was evidently determined based on information contained in the Lake Moodemere Interim Water Management Strategy (Beovich and Lloyd 1993) and field observations.

The identified commence to flow magnitudes for the Lake Moodemere system, as contained in the RMWD, are summarised in Table 3-2 and shown in Figure 3-7.

**Table 3-2 Commence to flow information from MWWG River Murray Wetland Database**

| Feature | MWWG ID | Gauge | CTF (ML/D) | CTF (Gauge Level) |
|---|---|---|---|---|
| Sunday Creek - channel (upstream) | 7750 | Doctors Point | 32918 | 4.5 |
| Sunday Creek - channel (middle) | 7903 | Doctors Point | 32918 | 4.5 |
| Sunday Creek - channel (downstream) | 7978 | Doctors Point | 32918 | 4.5 |
| Sunday Creek feature (between Murray and Creek) | 7888 | Doctors Point | 33378 | 4.51 |
| Sunday Creek feature (between Murray and Creek) | 7939 | Doctors Point | 33378 | 4.51 |
| Sunday Creek - unnamed east wetland | 8111 | Doctors Point | 33378 | 4.51 |
| Lake Moodemere | 8116 | Doctors Point | 15908 | 3.2 |
| Lake Moodemere - Northern marshes | 8117 | Doctors Point | 21998 | 3.7 |
| Lake Moodemere (connection to Forest Swamp) | 8121 | Doctors Point | 106679 | 6.43 |
| Northern channel from Murray to Moodemere | 8058 | Corowa | 9882 | 2.22 |
| Northern channel from Murray to Moodemere | 8071 | Corowa | 9882 | 2.22 |
| Forest Swamp | 8150 | Corowa | 15717 | 3.12 |

The MWWG information (Table 3-2) for current commence to flow magnitudes is consistent with other sources. Specifically, the commence to flow magnitude for Lake Moodemere (15,908 ML/D at Doctors Point) is based on information in Beovich and Lloyd (1993) cited in Robley (1996). Subsequent analyses by SKM and GHD (refer Section 2.7) also adopted very similar thresholds and there is thus less contradiction than is the case for natural commence to flow information.

The commence to flow magnitude for Lake Moodemere is determined by the level and operation of the Lake Moodemere regulator, or more specifically the invert level of the outlets through the regulator wall (given that these are at a higher level than the invert of the culverts through the Murray River bank (refer Section 3.2.1). By inference, the 15,908 ML/D flow (at Doctors Point) results in a water level at or above RL 128.24 m AHD (Chambers Gauge Level 1.14 m) at the Lake Moodemere regulator. This is consistent with SKM (2008a) which suggests a water level 0.2-0.3 m above the "Lake pipe inlet" equates to an Albury gauge level of 2.5 m, which corresponds to a flow of 15,500 ML/D at Albury (GHD 2010b). This correlates reasonably well with observations from an inspection undertaken on 8 July 2011 when the Murray River water level approximately matched the invert level of the regulator outlet (refer Figure 3-8) as a result of a discharge at Corowa of 12,200 ML/D[2] (or approximately 11,400 ML/D at Doctors Point 2 days earlier). Increasing flows from 12,000 ML/D to 15,000 ML/D at Corowa results in a water level increase of approximately 0.35 m, approximating the 0.2-0.3 m above pipe invert level identified in SKM (2008a).

[2] Based on MDBA Liver River Data (http://www.mdba.gov.au/water/live-river-data/upstream-of-yarrawonga)

It should be recognised that operation of the regulator by definition alters the commence to flow magnitude. The commence to flow magnitude identified above should be correctly seen as the flow at which water can enter the Lake Moodemere system via the regulator. If however the regulator is left closed, inflow to Lake Moodemere will not commence until either the top of the regulator wall is overtopped (RL 129.81 m AHD from Table 3-1) or inflows commence via the Forest Swamp system once water levels at Hiskins Bend exceed RL 129.8 m AHD, corresponding to a flow of 24,400 ML/D (being the level of the highest point in the connecting channels between Forest Swamp and Lake Moodemere as discussed in Section 3.3.1) it can thus be seen that the current Lake Moodemere regulator could be operated to prevent inflows to Lake Moodemere for Murray River flows of up to approximately 25,000 ML/D, matching the estimated natural commence to flow magnitude.

A water level approximately 0.5 m above the invert of the regulator is required to fill the lake by gravity inflows only to the approximate operating range of the SCIS (nominal Chambers Gauge Level 1.6-1.9m). When water levels in the Murray River are insufficient for gravity operation a diesel pump is used to achieve high water levels in Lake Moodemere.

**In conclusion, a commence to flow magnitude of 15,908 ML/D under current conditions for Lake Moodemere has been adopted for development of this EWP.**

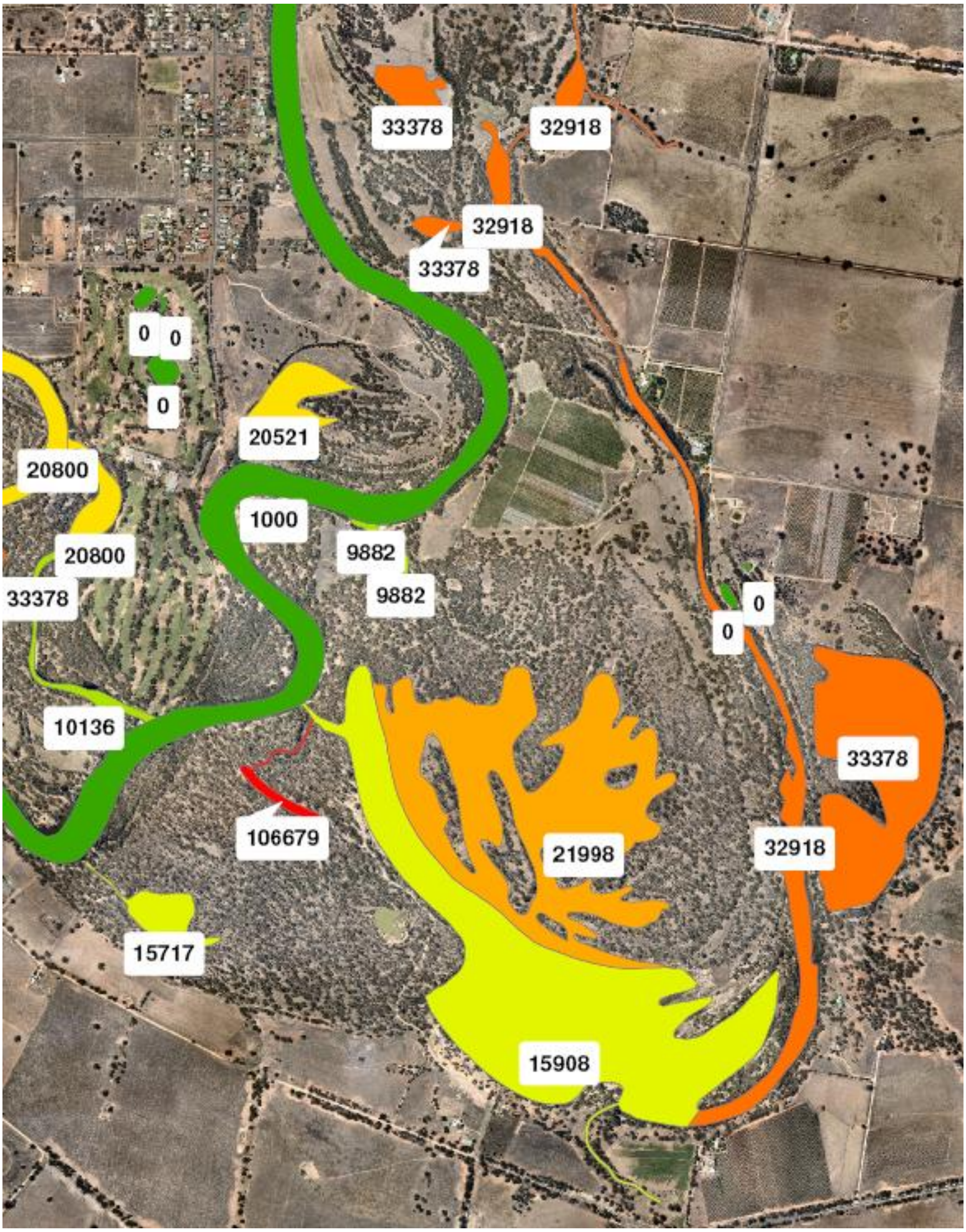


**Figure 3-7 MWWG commence to flow magnitudes (ML/D)**

**Figure 3-8** **Water level downstream of the Lake Moodemere regulator on 8 July 2011 with Murray River flow of 12,200 ML/D at Corowa or 11,400 ML/D at Doctors Point**

## 3.4 Overview of hydrologic regimes

### 3.4.1 Impact of river regulation

Lake Moodemere lies within the Hume to Yarrawonga Reach of the River Murray. Erskine et al (1993) identifies this reach as being subject to greater hydrologic modification as a result of river regulation than any other reach of the Murray River. The hydrologic modification takes the form of reversed seasonality, with natural high flows in Spring and low flows during Summer and Autumn being replaced by high flows in Summer and Autumn (the irrigation season) with a corresponding reduction in flows in Winter and early Spring. The duration, magnitude and frequency of overbank flooding are also reduced due to the operation of Lake Hume during flood events.

River regulation has thus impacted on the hydrologic regime of channel and floodplain features throughout the length of the Hume to Yarrawonga reach. For Lake Moodemere and Sunday Creek, this effect has been amplified by the historic operation of irrigation infrastructure (Section 3.1) tending to retain high and relatively stable water levels in the Lake Moodemere system over Summer and Autumn, even after the recession of high flows in the Murray River.

The natural and current hydrologic regimes of the Murray River based on flow data for Doctors Point are presented in Section 3.5 to provide a context for discussion of the current environmental assets at the site.

### 3.4.2 Current operation

Under current conditions Lake Moodemere is maintained at a consistently high water level through summer to allow extraction from Sunday Creek by members of the SCIS (SKM 2008a). This high level is maintained either through gravity diversion from the Murray River via the Lake Moodemere regulator or by pumping under low river flow conditions (SKM 2008a). Water for irrigation (primarily wine grape production) and stock & domestic use is extracted from Sunday Creek between Wahgunyah and Lake Moodemere. High water levels are maintained in Lake Moodemere to provide backwater flooding throughout the length of Sunday Creek to ensure continuity of water supply at all pump locations. Irrigation extraction is metered at each of the pumps drawing water from Sunday Creek however the irrigators operate on Murray River licences.

### 3.4.3 Proposed future operation

The Sunday Creek Irrigators Syndicate (SCIS) have proposed modification to the infrastructure used to supply water to Sunday Creek for subsequent irrigation extraction. This proposal seeks to provide for more efficient delivery of water to Sunday Creek by construction of a pump station to deliver water directly from the Murray River to Sunday Creek at Hyde Road, approximately midway between Wahgunyah and Lake Moodemere. The proposal also includes the construction of a regulator at Hells Gate[3], the current connection between Lake Moodemere and Sunday Creek. Construction of the regulator will enable water levels in Sunday Creek to be maintained at a level independent of the level in Lake Moodemere. While this proposed change in management could facilitate the return of a more natural wetting and drying regime to Lake Moodemere the benefits and risks of altering the current watering regime (to which the current environmental assets have adapted over approximately the last 70 years) have not been fully explored in development of the proposal to date.

## 3.5 Natural and current hydrologic regimes

The natural hydrologic regime for the Murray River at Lake Moodemere is discussed based on modelled data representing stream flows in the absence of infrastructure and catchment impacts. Data for this assessment was derived from the MDBA BIGMOD river simulation model, using the flow sequence for Doctors Point gauge (409017) between the Kiewa River confluence and Albury. Doctors Point was used in preference to the Corowa gauge (409002) as the Corowa BIGMOD data was not available to Water Technology at the time of the analysis. Additionally, the majority of the previously identified commence to flow levels for the wetland features within the project area are defined relative to Doctors Point (refer Section 3.3). There are no major inflows to the Murray River between the Doctors Point and Corowa gauges and a review of the historic gauge records for Doctors Point and Corowa indicated only minor differences in flow regime between the two stations, typically with a small reduction in flood peak magnitude between Doctors Point and Corowa due to attenuation within this reach. While the BIGMOD data covers the period from 1895 to 2009, the analysis period was restricted to 1961 to 2009 to enable direct comparison with the gauged flow record for Doctors Point.

The current hydrologic regime was assessed based on the gauged flow record for Doctors Point for the period from 1961 to 2009. The gauged record includes the impact of river regulation resulting from operation of existing infrastructure and fully describes the Murray River flow regime influencing the current character and condition of the Lake Moodemere system.

### 3.5.1 Monthly and seasonal average flows

The modelled natural and gauged current flow sequences were analysed using RAP to generate monthly and seasonal flow statistics. Average monthly mean flows at Doctors Point under natural and current conditions are shown in Figure 3-9 and Table 3-3 while seasonal statistics are shown in Figure 3-10 and Table 3-4. Under natural conditions the low flow period extends from January to

[3] Additional regulators or block banks may be required at other low points along the low feature which separates Lake Moodemere from Sunday Creek.

May, with average monthly flows of less than 6100 ML/D, increasing to a peak in September – October of approximately 27,000 ML/D before declining again in November and December. Under current conditions flows are significantly increased in the December – April period, reflecting the delivery of Summer – Autumn irrigation demands.

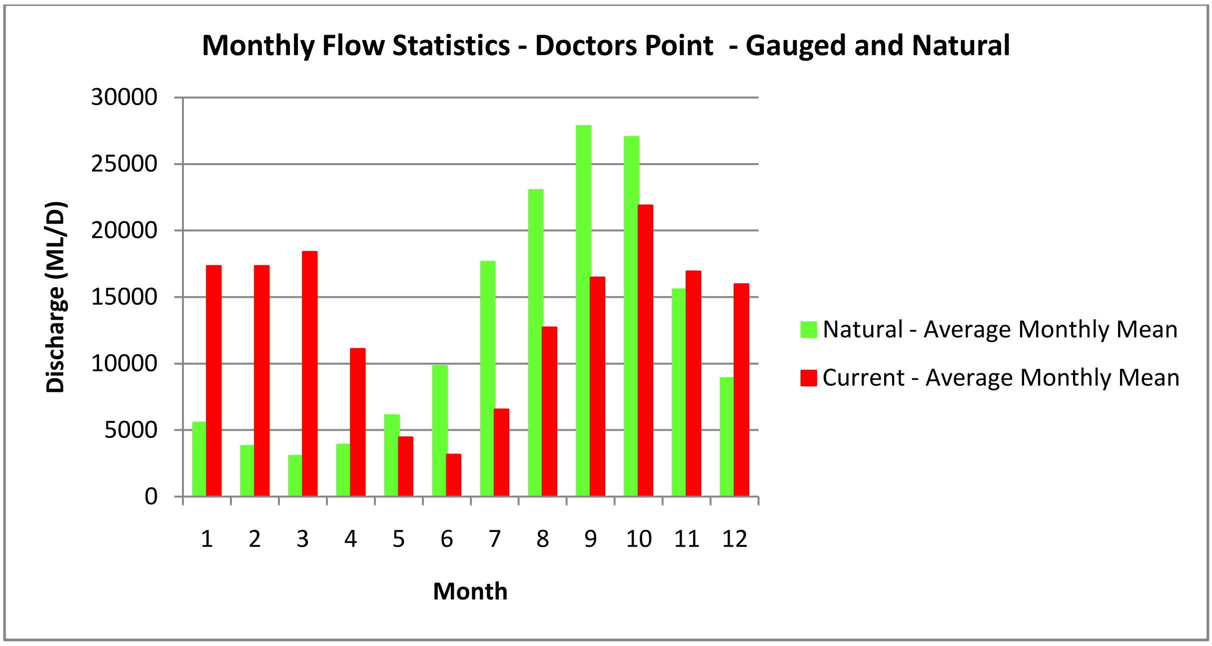


**Figure 3-9** **Average monthly mean flow - natural and current conditions**

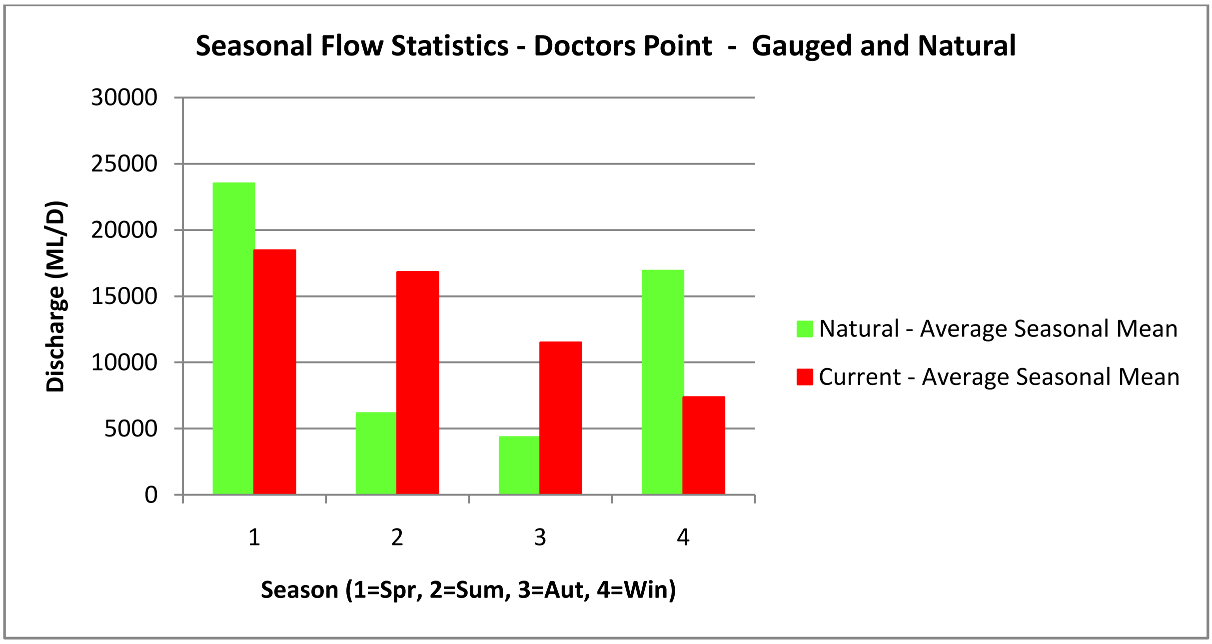


**Figure 3-10** **Average seasonal mean flow - natural and current conditions**

**Table 3-3 Average monthly mean flow**

| Month | Average monthly mean flow (ML/D) | |
|---|---|---|
| | Natural | Current |
| January | 5557 | 17343 |
| February | 3815 | 17338 |
| March | 3067 | 18400 |
| April | 3903 | 11109 |
| May | 6107 | 4464 |
| June | 9828 | 3148 |
| July | 17656 | 6556 |
| August | 23031 | 12719 |
| September | 27850 | 16469 |
| October | 27028 | 21891 |
| November | 15581 | 16930 |
| December | 8909 | 15960 |

**Table 3-4 Average seasonal mean flow**

| Month | Average seasonal mean flow (ML/D) | |
|---|---|---|
| | Natural | Current |
| Spring | 23525 | 18477 |
| Summer | 6163 | 16825 |
| Autumn | 4364 | 11499 |
| Winter | 16915 | 7379 |

### 3.5.2 Seasonal flow duration curves

Seasonal flow duration curves at Doctors Point under natural and current conditions are shown in Figure 3-11. The flow duration curves can be used to identify the percentage of time a specific flow (such as a wetland commence to flow magnitude) is exceeded in a given season under natural and current conditions.

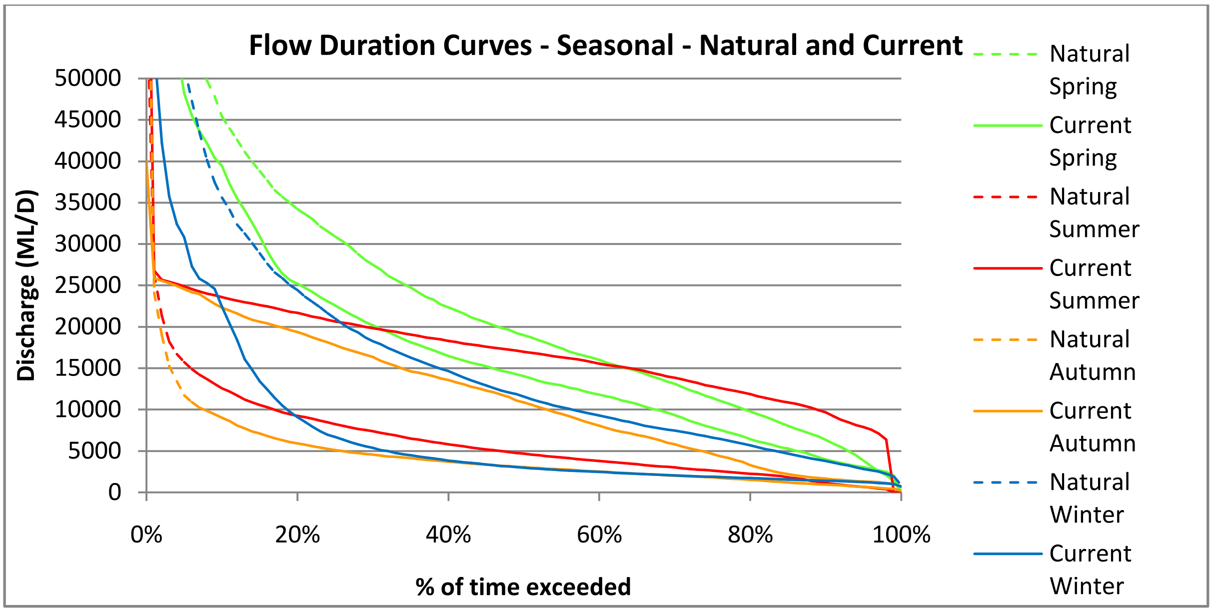


**Figure 3-11 Seasonal flow duration curves for Doctors Point - natural and current**

### 3.5.3 Spells analysis and commence to flow exceedances

Adopting the commence to flow thresholds for inflows to Lake Moodemere as discussed in Section 3.3 a Spells analysis characterises the change in connectivity of the Lake Moodemere system between the natural and current flow records. Results of the Spells analysis are shown in Table 3-5. The spells analysis indicates that flows exceeding the commence to flow threshold for Lake Moodemere are much more frequent and longer lasting under current conditions than under natural conditions. This reflects the reduction in commence to flow level under current conditions and also the impact of regulation in increasing the duration of flows in the 15,000 to 25,000 ML/D range particularly during the irrigation season.

**Table 3-5 Spells analysis results - natural and current commence to flow**

| Measure | Natural | Current |
|---|---|---|
| Analysis period | 19/5/1961 – 30/6/2009 | |
| High spell threshold (ML/D) | 25000 | 15908 |
| Number of high spells | 158 | 226 |
| Longest high spell (days) | 129 | 238 |
| Mean of high spell peaks (ML/D) | 47196 | 27030 |
| Mean duration of high spell (days) | 15 | 27 |
| Mean period between high spells (days) | 92 | 44 |
| Longest period between high spells (days) | 1052 | 569 |

Further analysis of the Doctors Point record identifies the months in which exceedances of the commence to flow level are most common under natural and current conditions. Figure 3-12 indicates the average number of days per month where the Lake Moodemere commence to flow magnitude is exceeded under natural and current conditions. This figure clearly demonstrates that the incidence of inflows to Lake Moodemere (assuming the Lake Moodemere regulator is open) is significantly higher under current conditions than under natural conditions. The increase in potential connectivity is most significant in December to March, reflecting the irrigation season.

Figure 3-13 shows the percentage of years in which the commence to flow level is exceed in any given month. From this it can be seen that exceedances under current conditions occur in greater than 70% of years from October to March and greater than 50% of years from September to April. This contrasts strongly with the natural sequence where inflows dominantly occurred only between July and November.

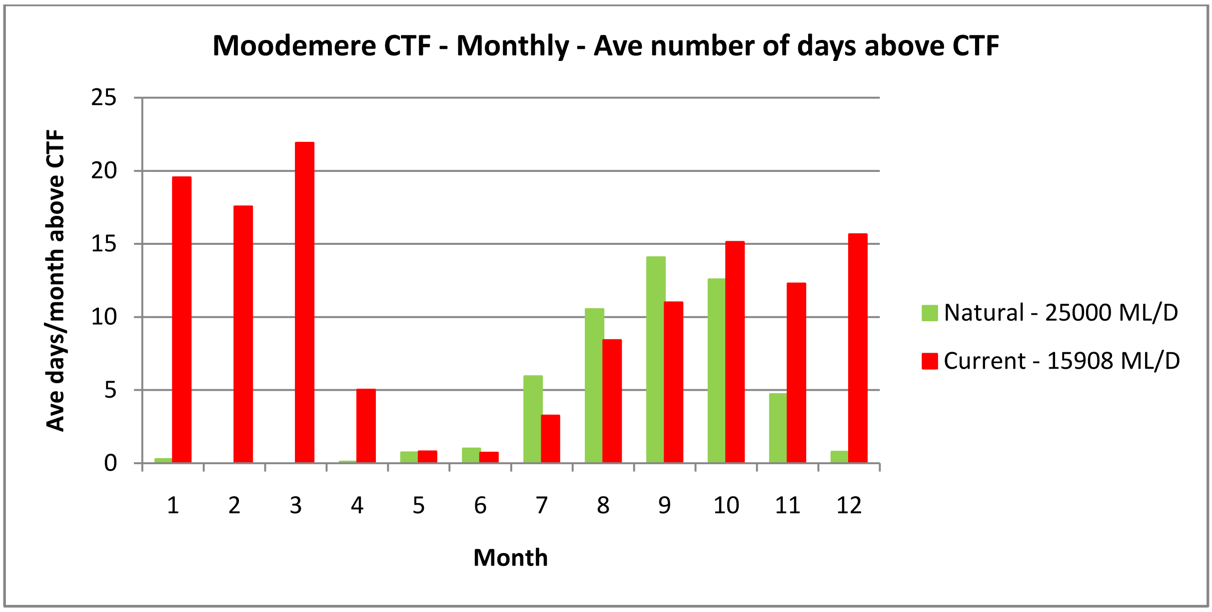


**Figure 3-12 Average number of days per month exceeding Lake Moodemere commence to flow magnitude – Natural and current**

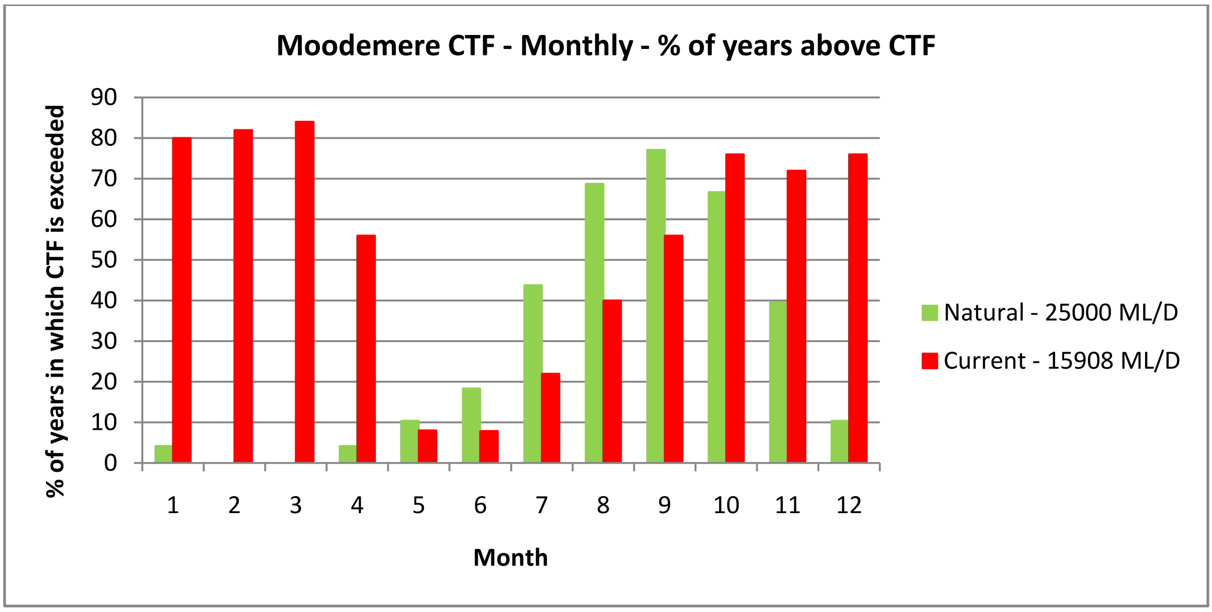


**Figure 3-13 Percentage of years in which Lake Moodemere commence to flow magnitude is exceeded in any month – Natural and current**

## 3.6 Lake levels (from Chambers Gauge)

### 3.6.1 Review of data

The discussion and analysis presented in Section 3.5 is based on the hydrologic regime of the Murray River. While this is critical in identifying the impact of river regulation on the potential for inflows to Lake Moodemere, the operation of the Lake Moodemere regulator has a significant additional impact on lake levels. SKM (2008a) contains monthly readings of lake level measured at “Chambers Gauge” for the period from April 1965 – May 2006 (missing 6 months in 1973/1974). This data is understood to have been gathered by members of the SCIS. While monthly data does not capture short term variations in water level the data provides a useful record of the managed hydrologic regime of the lake over a long period. The recorded monthly water levels (converted to RL m AHD) are shown in Figure 3-14. Also shown in Figure 3-14 are the nominal operating ranges as identified in GHD (2009a). It is apparent that there are significant fluctuations in lake water level above the target maximum level however there are few occasions when the lake drops significantly below the target minimum operating level. Between approximately 1983 and 1996 the record shows that the lake was consistently held at or above a level of RL 129.0 m AHD and generally closer to RL 129.5 m AHD. More recently (2001 – 2006) when drought conditions have prevailed it appears that the lake has been operated more consistently within the target operating range. The minimum and maximum levels over the period of record are RL 128.04 m AHD and RL 131.50 m AHD respectively.

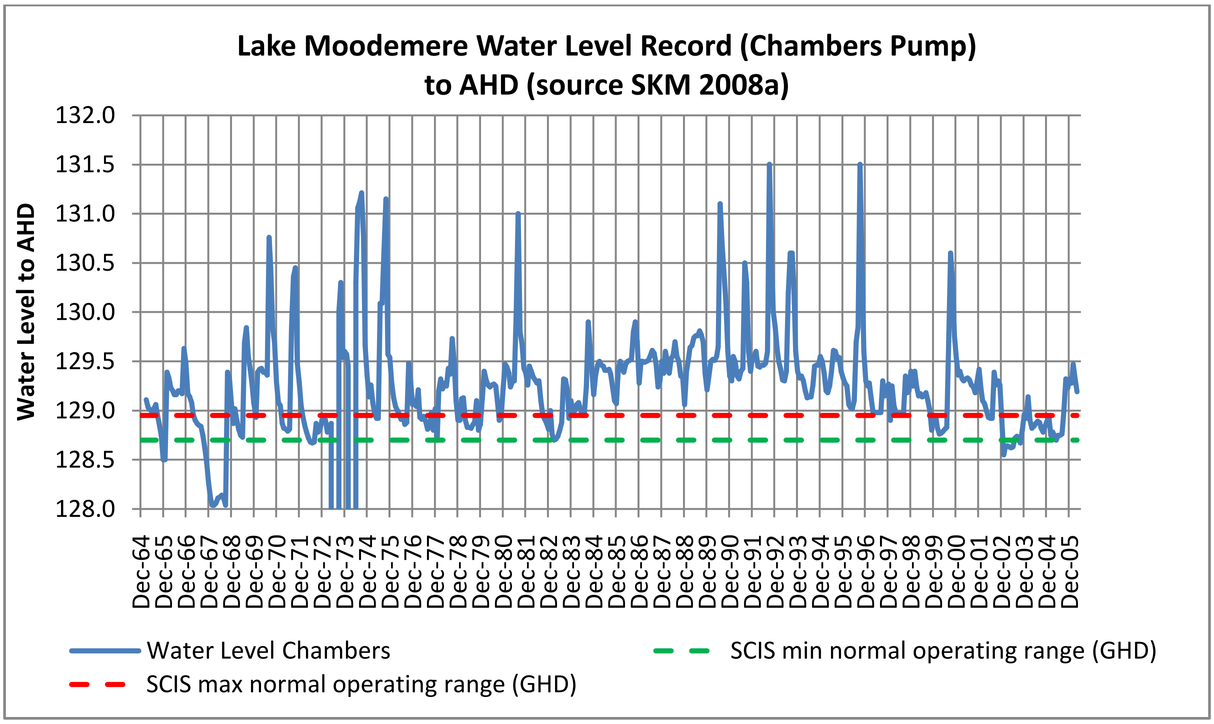


**Figure 3-14 Lake Moodemere / Sunday Creek water levels at Chambers Gauge**

A lake level duration curve is shown in Figure 3-15, indicating the percentage of time (based on the monthly lake level record) that a given lake level is exceeded. It can be seen for example that the minimum normal operating range is exceeded approximately 95% of the time while the maximum normal range is exceeded approximately 74% of the time. This suggests that the maximum normal operating range (as identified in GHD 2009a) is an underestimate of the typical upper limit on lake level.

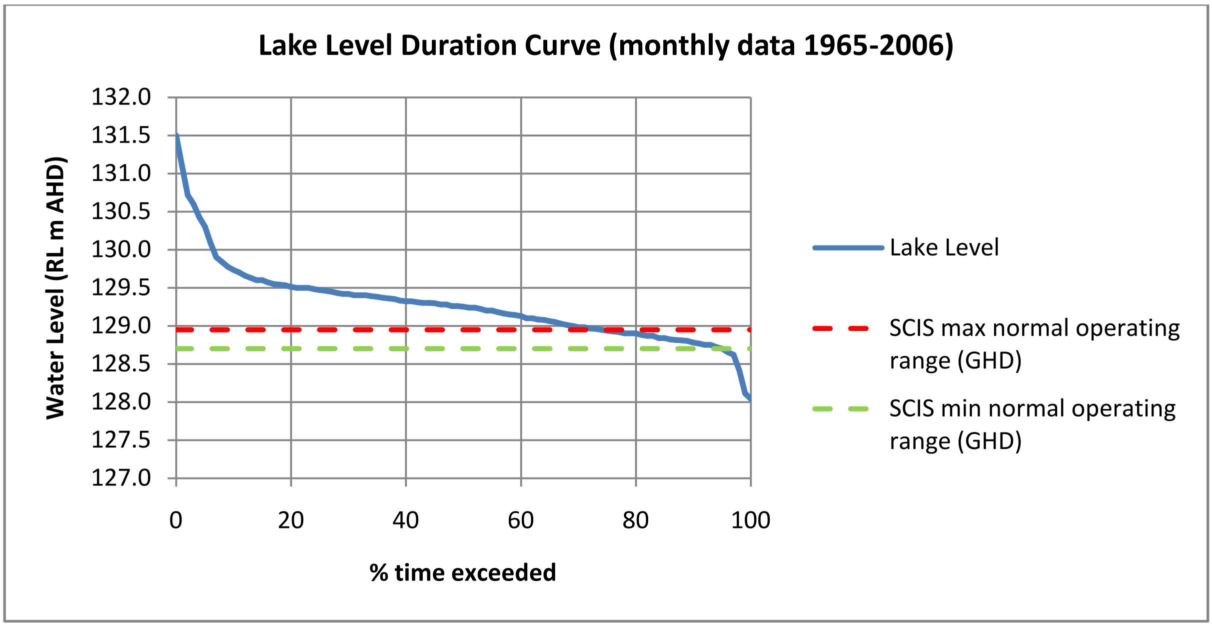


**Figure 3-15 Lake Moodemere / Sunday Creek water level duration curve**

Figure 3-16 presents the same lake level information as shown in Figure 3-14 but also shows the flows recorded in the Murray River at the Corowa gauge. This highlights the impact of flood events in rapidly increasing lake level significantly above the target operating range. Flows above approximately 25,000 ML/D at Corowa typically result in a rapid increase in lake level. This corresponds well with the discussions in Section 3.3.2 wherein a flow of approximately 25,000 ML/D is identified as the threshold at which overtopping of the Lake Moodemere regulator commences and hence uncontrolled inflow to Lake Moodemere commences.

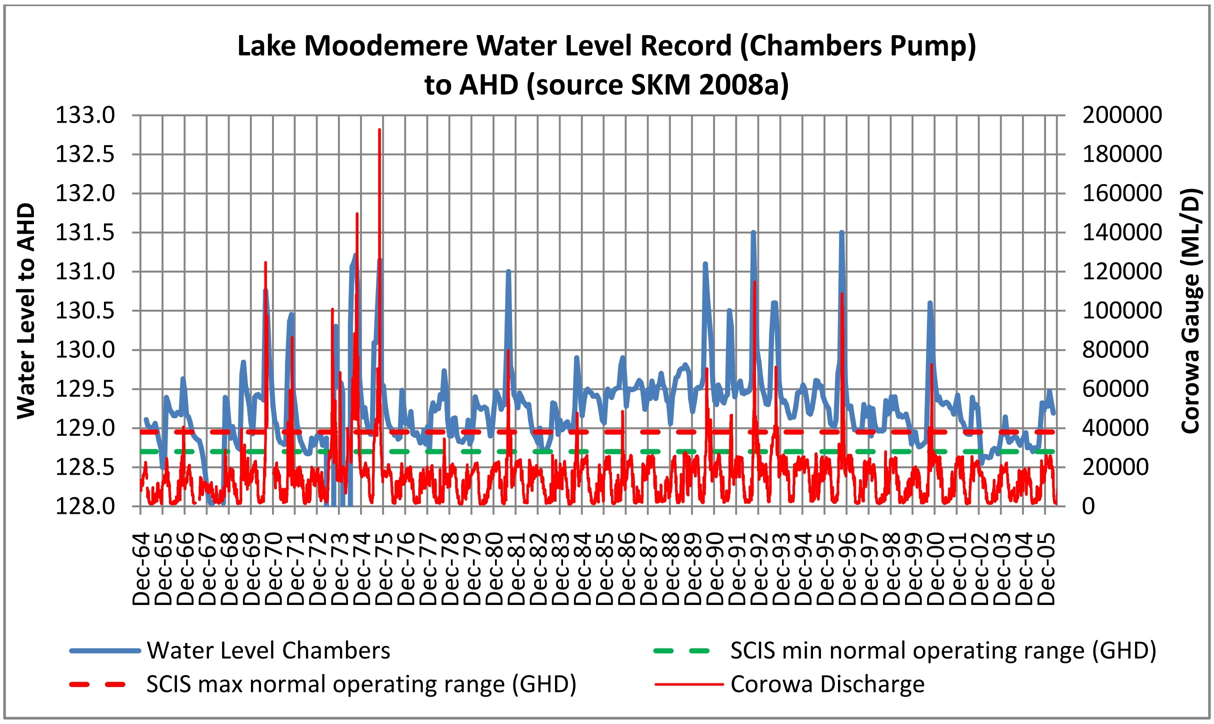


**Figure 3-16 Lake Moodemere / Sunday Creek water levels at Chambers Gauge plotted with recorded Murray River discharge at Corowa**

The Chambers Gauge record was further analysed to assess typical monthly variations in lake water level, with results shown in Figure 3-17. Consistent with the general understanding of the operation of the Lake Moodemere system, this indicates that the highest levels are typically September to November, when the lake is typically filled and then drawing down over December and January as irrigation demand peaks.

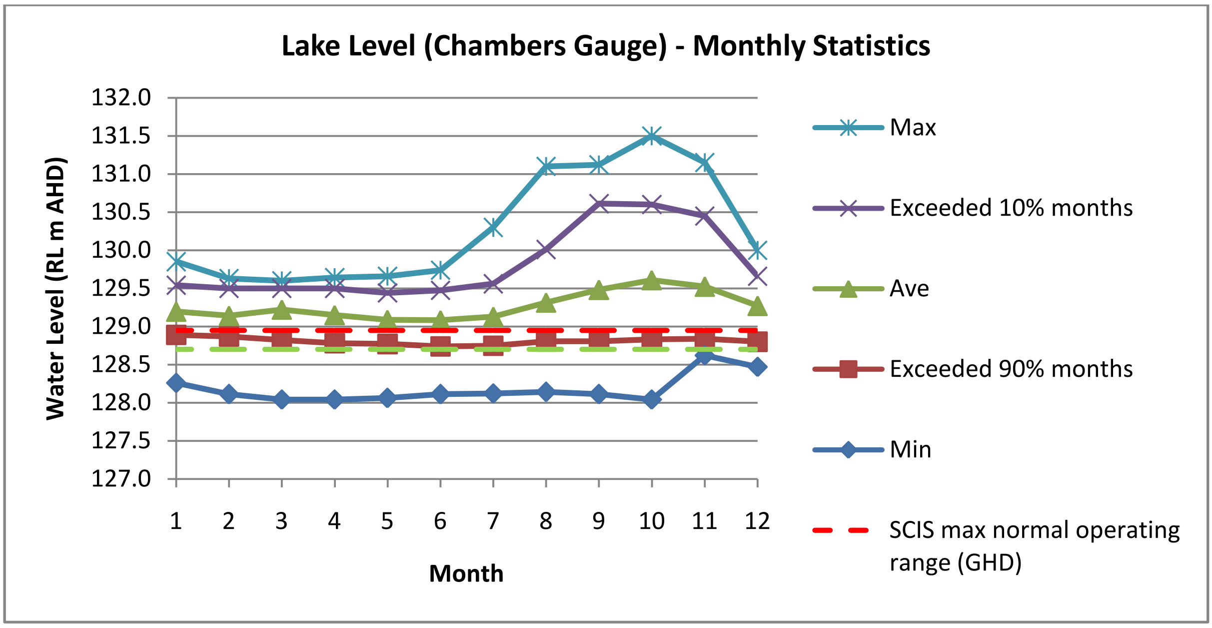


**Figure 3-17 Lake Moodemere / Sunday Creek – typical monthly levels**

Finally, the Chambers Gauge record was analysed to determine typical month to month variations in level. This analysis is presented in Figure 3-18 indicating that month to month variations in level are typically small (-0.5 to +0.5m) between January and July. From August to October, lake levels typically increase, with the larger increases resulting from flood inflows. In November and December, lake levels typically reduce by anything up to about 1 m.

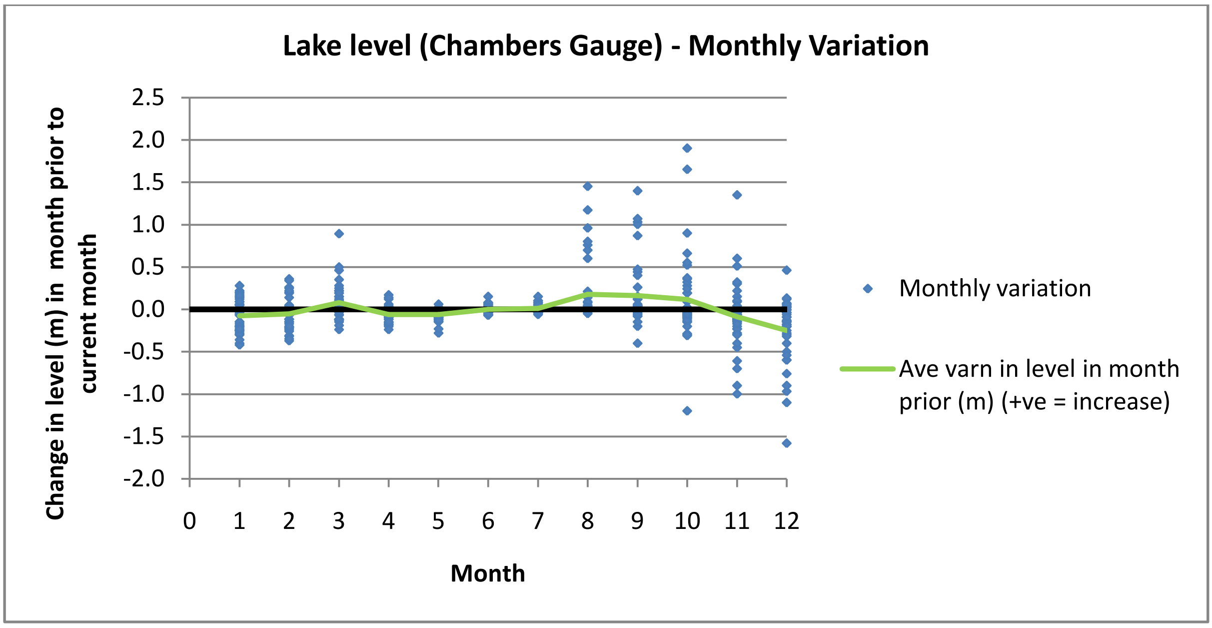


**Figure 3-18 Lake Moodemere / Sunday Creek – typical month to month level variation**

### 3.6.2 Discussion

While the available lake level data provides only a monthly snapshot of conditions (rather than showing daily fluctuations in lake level) it provides a basis for discussion of the typical operating regime of the system. Most significantly, it provides an indication of the historic fluctuations relative to the supposed "maximum" and "minimum" operating levels. Figure 3-15 (the lake level duration curve) indicates that the stated minimum operating level (gauge 1.6 m or RL 128.7 m AHD) is accurate, given that approximately 95% of the recorded levels exceed this. By contrast, approximately 74% of recorded levels exceed the stated maximum operating level (gauge 1.85 m or RL 128.95 m AHD). The monthly level data (Figure 3-17) indicates that the average monthly level for the period from January to July (RL 129.1-129.2) reasonably approximates the stated maximum operating level. Between August and December levels well above the stated maximum operating level are common, presumably due to Spring floods in the Murray River and high river flows during the summer regulated flow period. Lake levels above RL 129.5 m AHD are recorded in only 20% of the record and thus floodplain areas above this level are only infrequently inundated.

# 4. BATHYMETRIC SURVEY

## 4.1 Introduction

A bathymetric survey of Lake Moodemere and Sunday Creek was undertaken to inform the development of the EWP. This bathymetric survey was intended to address a knowledge gap related to the variability of lake and creek invert levels within the system. Specifically, the bathymetric survey was used to:

- Refine the understanding of the hydraulic controls influencing the hydrologic interactions within the Lake Moodemere system.
- Identify and approximate the dimensions of refuge pool habitat within Lake Moodemere and Sunday Creek in the event of the lake level being drawn down.

## 4.2 Method

### 4.2.1 Level control and survey of Lake Moodemere regulator

In order to obtain bathymetric data consistent with the available LiDAR data within the project area, it was necessary to link the bathymetric survey to Australian Height Datum (AHD). This was done by surveying the lake water level on the day of the survey (4 August 2011) relative to the ground surface level in the vicinity of the carpark at the boat ramp, for which AHD levels were determined from existing LiDAR data obtained from the current DSE statewide LiDAR project. By this process the water level on the day of the survey was determined to be RL 129.54 m AHD. The remainder of the bathymetric survey was undertaken relative to water level.

Critical levels on the Lake Moodemere regulator structure were surveyed to inform the hydrologic review. This survey using a survey staff and level was undertaken relative to the water level on the day of the survey to enable identification of levels to AHD. Levels were thus obtained for the culverts through the bank of the Murray River, the regulator outlets and overflow levels.

### 4.2.2 Spatial coverage of bathymetric survey

Proposed cross-section locations were established in the office prior to commencement of the field work. Cross-sections were located so as to cover the range of habitats likely to be encountered in the system i.e. the areas of deepest and shallowest habitat. The cross-section locations were determined initially with reference to a 1941 aerial photograph supplied by North East CMA showing Lake Moodemere under low flow conditions (Figure 4-1) which suggested that the most substantial deep habitat occurred in the narrow western end of the lake and in three “fingers” extending eastward into the broader section of the lake.

The locations of the surveyed cross-sections are shown in Figure 4-2.

A longitudinal section was undertaken over the length of Sunday Creek to identify variations in stream depth. The path followed in surveying this longitudinal section followed the estimated likely channel thalweg alignment so as to capture the deepest portions of the channel. In addition to the longitudinal section, 5 randomly located cross-sections were taken within Sunday Creek.

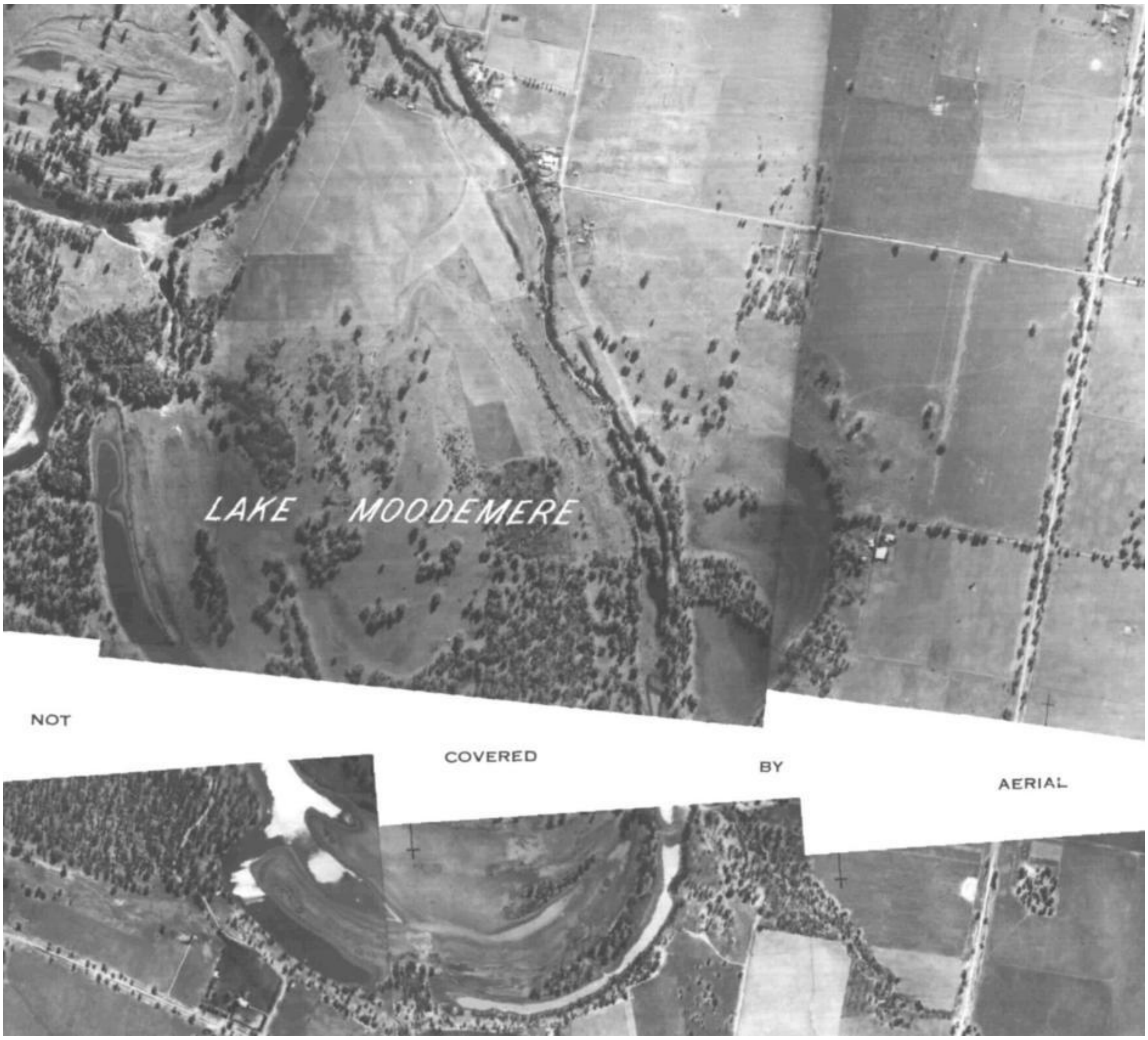


**Figure 4-1 1941 aerial photograph showing Lake Moodemere under low water level conditions**

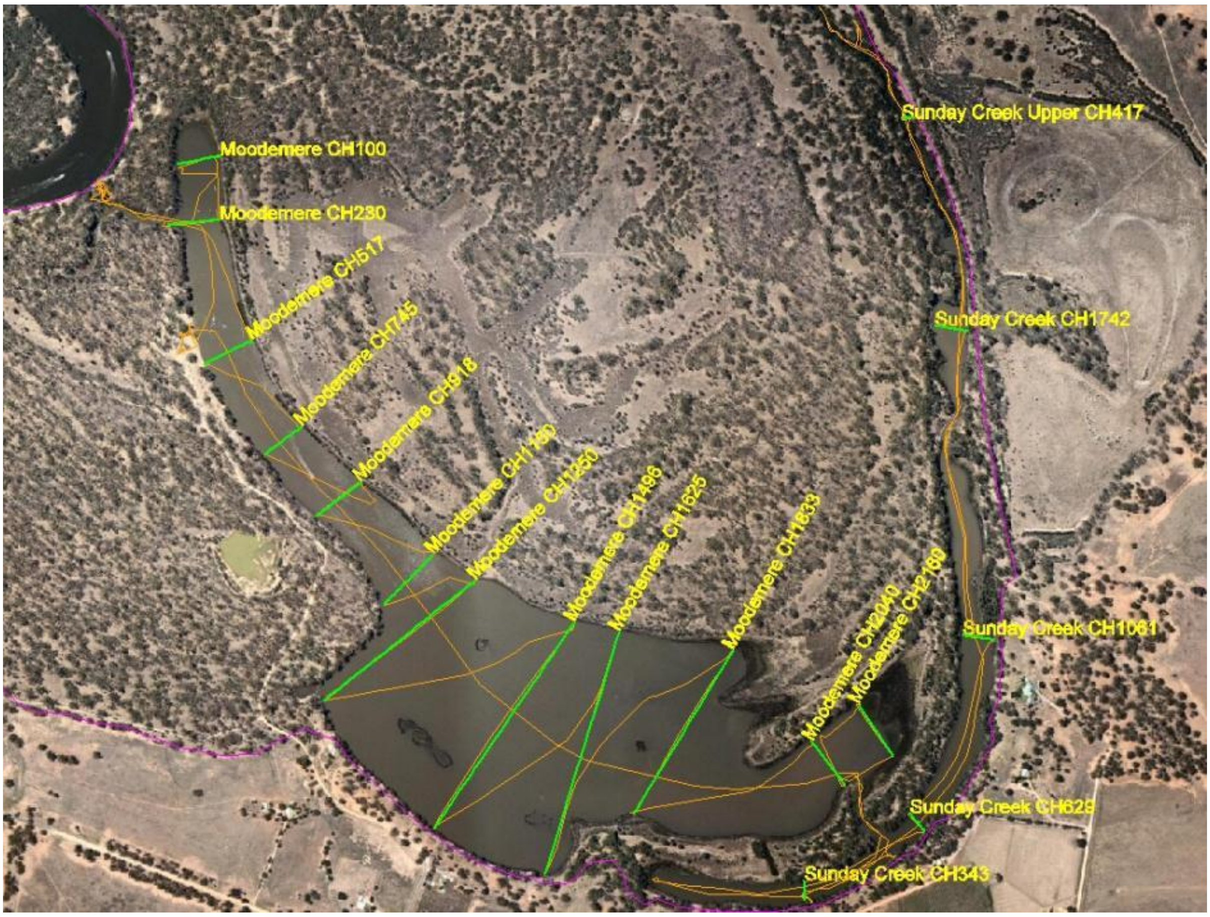


**Figure 4-2 Final section locations for bathymetric survey**

### 4.2.3 Depth sounding

The bathymetric survey was undertaken using a depth sounder on a small powered boat (tinny) with a crew of three – driver, navigator and data recorder.

Data was gathered in the form of depth below water level (as indicated by the depth sounder) at points spaced along the length of the section. The location of points on each section was determined using a handheld GPS to measure the distance to a waypoint at the start of the cross-section.

The spacing of points varied depending on the variability of depth encountered. The average point spacing for the sections on Lake Moodemere was 12.1 m (minimum 1 m, maximum 47 m). For the sections within Sunday Creek the average point spacing was 5.5 m (minimum 1 m, maximum 22 m).

The depth measurements determined using the sounder were verified by direct measurement of depth using a survey staff below water level. This technique indicated depths approximately 0.2 m greater than that shown with the depth sounder. This was likely a result of penetration of the survey staff into a loose layer of mud on the lake bed, with the depth sounder picking up the top layer of the bed. It was decided to adopt the depths determined using the depth sounder as a more conservative (lower limit) estimate of the quantity of habitat that would be available as the lake was drawn down.

## 4.3 Results

### 4.3.1 Structure levels

Levels for the Lake Moodemere regulator as determined from the bathymetric survey are summarised in Table 4-1.

**Table 4-1 Structure levels – Lake Moodemere regulator**

| Feature | Level |
|---|---|
| Murray water level (on day of survey) | 127.70 |
| Culvert invert, Murray side (lowest of 2 culverts by 100 mm) (2x750 mm diameter) | 127.84 |
| Culvert invert, regulator side of Murray bank | 127.94 |
| Top of Murray bank (average of 2 shots taken) | 131.38 |
| Regulator downstream slab | 128.14 |
| Regulator outlet invert (3 x 470W x 610H) | 128.24 |
| Regulator top of overflow wall (3 m width) | 129.81 |
| Top of regulator wing wall beyond overflow section | 129.95 |
| Moodemere water level (on day of survey) | 129.54 |

### 4.3.2 Lake Moodemere cross sections

A total of 12 cross-sections were surveyed within Lake Moodemere – 6 within the narrow western arm, 4 within the broader portion of the lake and 2 adjacent Sunday Creek. Cross-section profiles are provided in Figure 4-3.

Within the narrow western arm (cross sections CH100-CH1150) cross-sections were U-shaped with relatively steep profiles (approximately 20H:1V) near the edge of the lake with the lowest invert elevations varying between approximate RL 127 and RL 128.0.

The 4 sections within the broader portion of the lake (cross sections CH1250-CH1833) were more variable, reflecting the deeper "fingers" discussed in Section 4.2.2. Again the lowest invert elevations varied typically between approximate RL 127 and RL 128.0, with the exception of CH1833 which was notably shallower and more uniform, with a lowest invert elevation of approximate RL 128.3.

The 2 final sections adjacent Sunday Creek (cross-sections CH2040 and CH2160) were found to be comparable in depth and form to that at CH1833, suggesting that these three sections have experienced deposition or infilling relative to the remaining sections in Lake Moodemere.

It is noted that the invert elevation of the outlets at the Lake Moodemere regulator (RL128.24) is above the invert level at the majority of the surveyed cross-sections indicating that even under a full drawdown scenario substantial pool habitat would remain within Lake Moodemere.

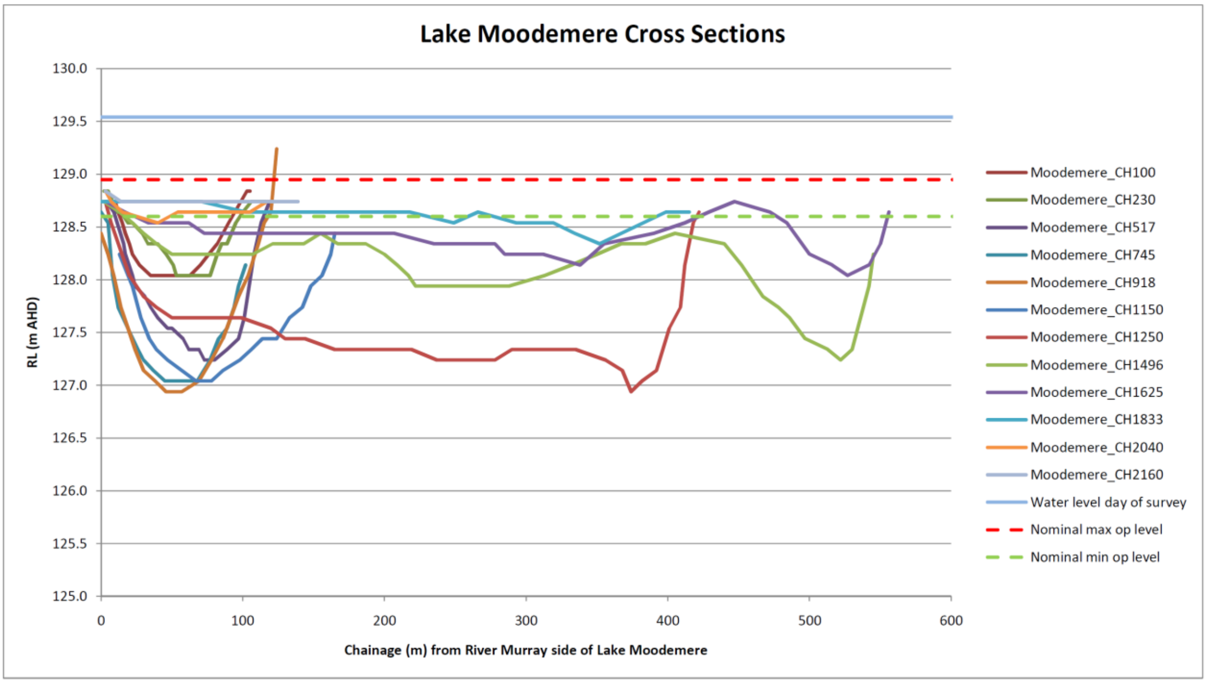


**Figure 4-3 Lake Moodemere – Bathymetric survey cross-sections**

### 4.3.3 Sunday Creek longitudinal section

A longitudinal survey of Sunday Creek was undertaken to develop an understanding of the variation in channel form throughout the system. A total of 94 depth points were obtained over the 2350 m length (average 25 m point spacing). The survey followed the estimated channel thalweg. The resultant longitudinal section is shown in Figure 4-4. The longitudinal section indicates that the channel invert level is relatively uniform (around RL 127.5-RL128.0) over the downstream 1 km of Sunday Creek. Moving upstream the channel invert elevation increases to approximate RL 128.5 around "The Narrows". Upstream of The Narrows the channel invert was found to be more variable with depths varying between 1 and 3.5 m.

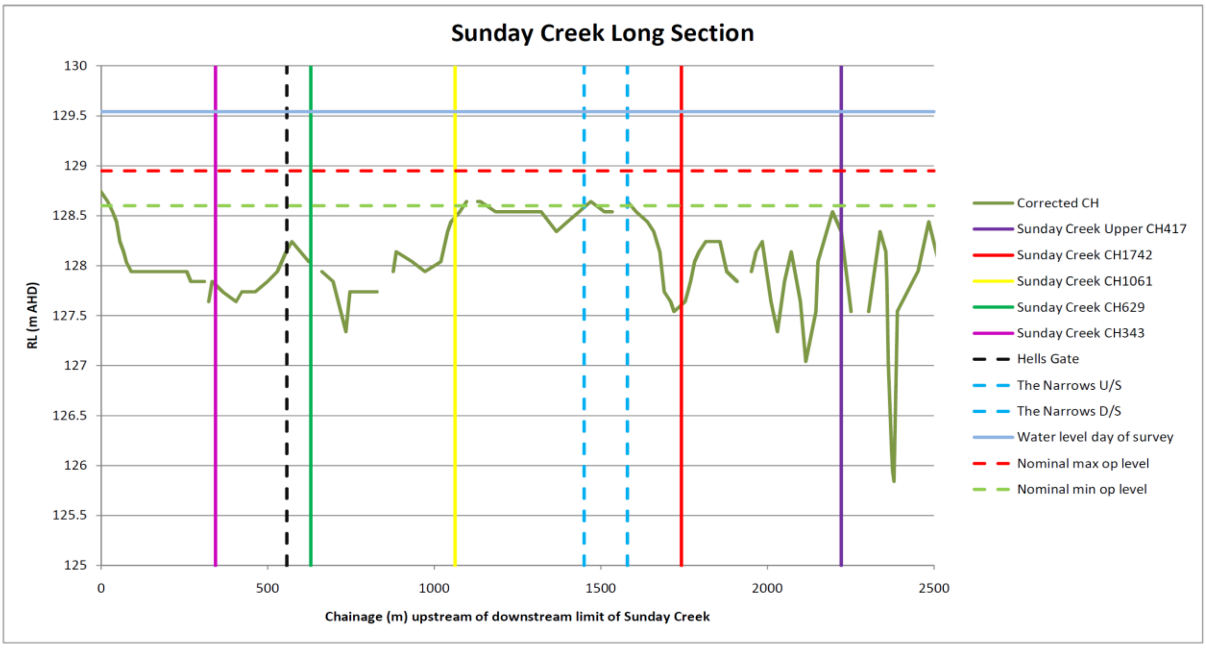


**Figure 4-4 Sunday Creek – Bathymetric survey long section.**

### 4.3.4 Sunday Creek cross sections

A total of 6 cross-sections were surveyed in Sunday Creek as indicated in Figure 4-5. Invert elevations varied between RL 128.5 (CH1061) and CH127.5 (CH1742). Bank profiles were found to be typically steepest on the eastern bank of Sunday Creek and flatter on the western side (adjacent Lake Moodemere).

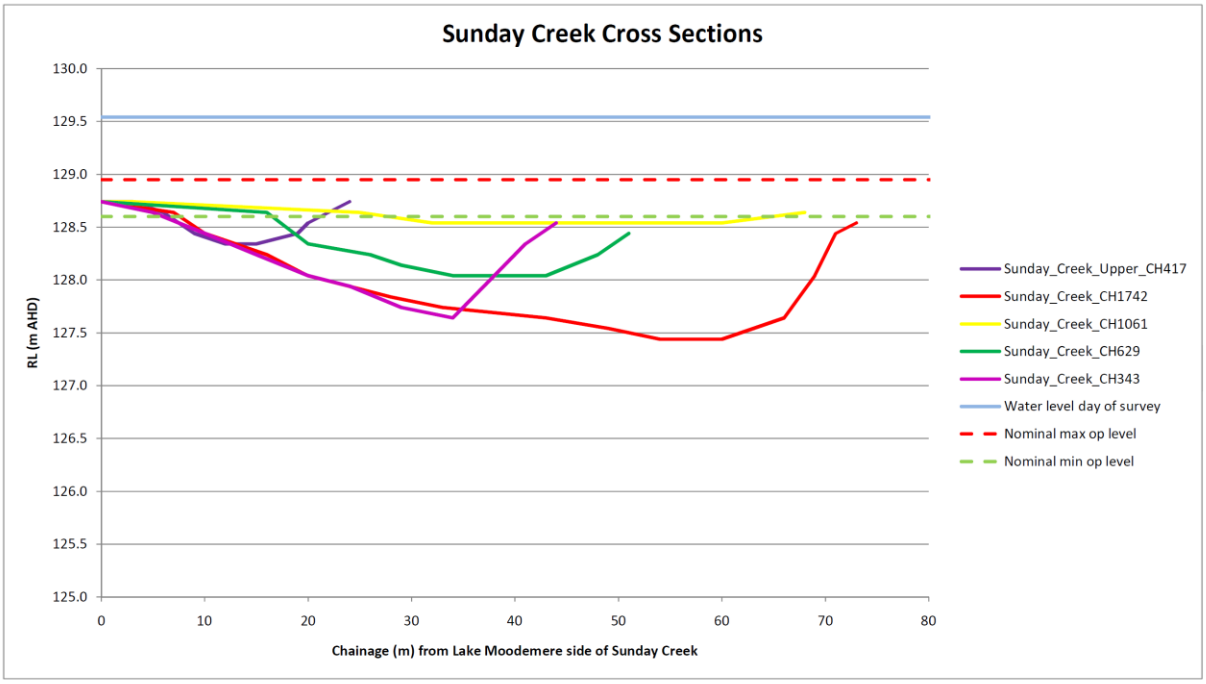


**Figure 4-5 Sunday Creek – Bathymetric survey cross-sections**

## 4.4 Critical outcomes from bathymetric survey

The bathymetric survey provides information on the variability of bed levels within Lake Moodemere and Sunday Creek. Of the 302 cross-section points surveyed 50% of the bed levels measured were found to be below RL 128.25. This corresponds with the invert level of the outlet on the Lake Moodemere regulator. As such, it is apparent that significant pool habitat remains below the lowest regulator drawdown level.

# 5. CURRENT CONDITION AND VALUES

## 5.1 Introduction

Despite the size and significance of the Lake Moodemere system the ecology and environmental assets supported within the wetland system are not extensively documented in current literature. To address this shortcoming, DSE through the North East CMA initiated additional investigations running in parallel to the development of the EWP to identify the current environmental assets of the Lake Moodemere system. These investigations comprised:

- An aquatic vertebrate survey, with particular emphasis on fish and turtle species. This investigation was undertaken by the Murray-Darling Freshwater Research Centre (MDFRC) and is reported in Richardson and Stoffels (2011b). The full report is provided in Appendix A. This investigation extended the work undertaken in late 2010 and early 2011 by MDFRC for North East CMA (Richardson and Stoffels 2011a). The results of both investigations are discussed in Section 5.2.
- A flora survey, with particular emphasis on flora species likely to be impacted by an altered hydrologic regime. This investigation was also undertaken by Australian Ecosystems and is reported in Australian Ecosystems (2011). The full report is provided in Appendix B while the results of the investigation are discussed in Section 5.3.
- A fauna survey, with particular emphasis on frog and bird species. This investigation was undertaken by Australian Ecosystems Pty Ltd (Australian Ecosystems) and is reported in Australian Ecosystems (2011). The full report is provided in Appendix B while the results of the investigation are discussed in Sections 5.4 and 5.5.
- A bathymetric survey. This investigation was undertaken by Water Technology, with the method and results documented in Section 4 of this report.

## 5.2 Aquatic vertebrates – Fish and turtles

### 5.2.1 Introduction

MDFRC was engaged by North East CMA in 2010 to investigate the aquatic vertebrate biodiversity of Lake Moodemere (excluding Sunday Creek) and to identify key uncertainties in relation to the biodiversity values of Lake Moodemere. This investigation (Richardson and Stoffels 2011a) was initially prompted by anecdotal reports of freshwater catfish (*Tandanus tandanus*), an endangered species under the Fisheries Management Act 1994 (NSW) and the Flora and Fauna Guarantee Act 1998 (VIC), being present in Lake Moodemere. Freshwater catfish were not recorded in the surveys undertaken during three surveys over a ten-week period between November 2010 and January 2011 (summer) however a total of four native and five non-native fish species were collected and three species of native freshwater turtles were found.

The second round of assessments (Richardson and Stoffels 2011b) provided for a similar investigation of the aquatic biodiversity of Sunday Creek, with sampling undertaken in June and July 2011 (winter). Sampling was also undertaken in Lake Moodemere during this same time period to enable comparison with the summer sampling results reported in Richardson and Stoffels (2011a).

### 5.2.2 Species recorded within the project area

The aquatic vertebrates found during the summer and winter sampling periods as reported in Richardson and Stoffels (2011b) are summarised in Table 5-1. Additional data on habitat preferences, size classes and seasonal variations in aquatic vertebrate diversity are provided in Richardson and Stoffels (2011b).

**Table 5-1 Aquatic vertebrate sampling results – Catch per unit effort (CPUE) (from Richardson and Stoffels 2011b, Table 2)**

| Species | | Lake Moodemere | | | | Sunday Creek | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Coarse-mesh fyke net | | Fine-mesh fyke net | | Coarse-mesh fyke net | | Fine-mesh fyke net | |
| | | Summer | Winter | Summer | Winter | Summer | Winter | Summer | Winter |
| | | CPUE | CPUE | CPUE | CPUE | CPUE | CPUE | CPUE | CPUE |
| ***Turtles*** | | | | | | | | | |
| Broad shelled turtle | *Chelodina expansa* (Threatened, Vic FFG) | 0.0306 | 0.0039 | | | NS* | 0.0013 | NS* | |
| Eastern long-necked turtle | *Chelodina longicollis* | 0.0047 | | | | NS* | | NS* | |
| Murray River turtle | *Emydura macquarii* (Data deficient, Vic FFG) | 0.0753 | | | | NS* | | NS* | |
| ***Native fish*** | | | | | | | | | |
| Golden perch | *Macquarie ambigua* | | 0.0082 | | | NS* | 0.0013 | NS* | |
| Australian smelt | *Retropinna semoni* | | | 0.0864 | 0.3391 | NS* | | NS* | 0.0218 |
| Flyspecked hardyhead | *Craterocephalus stercusmuscarum* (Threatened, Vic FFG) | | | 0.1111 | 0.0758 | NS* | | NS* | 0.0083 |
| Flathead gudgeon | *Philypnodon grandiceps* | | | 0.0829 | | NS* | | NS* | |
| Carp gudgeon | *Hypseleotris* spp. | | | 7.9746 | 2.0083 | NS* | | NS* | 0.8986 |
| ***Non-native fish*** | | | | | | | | | |
| Goldfish | *Carassius auratus* | 0.0457 | 0.0163 | 0.0574 | 0.0046 | NS* | 0.0338 | NS* | 0.0220 |
| Common carp | *Cyprinus carpio* | 0.1318 | 0.1071 | 0.5243 | | NS* | 3.4396 | NS* | 1.0309 |
| Redfin | *Perca fluviatilis* | 0.0018 | 0.0458 | 0.0134 | 0.0039 | NS* | 0.0211 | NS* | |
| Oriental weatherloach | *Misgurnus anguillicaudatus* | | | 0.0853 | | NS* | | NS* | |
| Eastern gambusia | *Gambusia holbrooki* | | | 0.1388 | 0.0599 | NS* | | NS* | 0.1005 |

* NS = Not sampled

### 5.2.3 General observations

Key outcomes from the aquatic vertebrate survey (Richardson and Stoffels 2011b) include:

- Eight native aquatic vertebrates were found within the Lake Moodemere system
  - Three turtles – broad shelled turtle, eastern long-necked turtle and Murray River turtle.
  - One large bodied native fish – golden perch
  - Four small bodied native fish – Australian smelt, flyspecked hardyhead, flathead gudgeon and carp gudgeon
- Of the species found within the Lake Moodemere system, only the broad shelled turtle and the flyspecked hardyhead are listed as 'threatened' under the Victorian Flora and Fauna Guarantee Act, 1998. No EPBC listed species are present.
- Through comparison with previous assessments of aquatic biodiversity in wetland systems within the mid-Murray region Richardson and Stoffels (2011b) concludes that the biodiversity of the Lake Moodemere system:

  *"may be high within a regional context – it contains a diverse turtle community, including threatened species, and the small-bodied fish community is at least the equal of other wetlands situated between lakes Hume and Mulwala. Also, given that it is the largest wetland between lakes Hume and Mulwala (Green and Alexander 2006), the regional importance of the Lake Moodemere – Sunday Creek complex is expected to be considerably greater during dry periods."* (Richardson and Stoffels 2011b)

- The littoral zones support most of the native biodiversity and significantly higher abundances of native fish and turtles than the pelagic areas. This is attributed to the dense macrophytes beds (primarily Juncus ingens) and associated epiphyton supporting invertebrate prey communities for small-bodied native fish which in turn provide nutrition for carnivorous turtles. The macrophytes beds also provide breeding habitat and refuge for small-bodied native fish species.
- Comparison of the aquatic biodiversity of Sunday Creek and Lake Moodemere is complicated due to the timing of the surveys (summer vs winter) and poor water quality in Sunday Creek during the winter assessments (following the preceding sequence of floods). It is considered likely that Sunday Creek supports similar aquatic vertebrate fauna to Lake Moodemere however this is not confirmed by the data.
- Water quality within Lake Moodemere and Sunday Creek was investigated during in both stages of the aquatic vertebrate survey. Specifically in the winter 2011 sampling period (June-July), the variation in water quality with distance from the Lake Moodemere regulator was assessed. This indicated a deterioration in water quality in the upstream end of the system. While Lake Moodemere generally displayed good water quality – slightly alkaline, low conductivity, 8-11 mg/L dissolved oxygen, the downstream end of Sunday Creek was found to display poorer water quality than Lake Moodemere but the most significant deterioration occurred upstream of The Narrows where dissolved oxygen levels reduced to levels detrimental to many fish species. It is not clear from the data whether the hypoxic conditions resulted from the recent input of organic material during the spring-summer 2010/2011 flood period or whether such conditions are typical for the upper reaches of Sunday Creek within the project area.
- Water quality, particularly dissolved oxygen is known to have a major limiting effect on fish physiology. The observed fish community distribution is consistent with the water quality data, with hypoxia tolerant species (common carp and goldfish) most abundant at the upstream end of Sunday Creek. The hypoxic conditions favour these exotic species over the small bodied native species which are less hypoxia tolerant.

## 5.3 Vegetation

### 5.3.1 Introduction

Australian Ecosystems was engaged by North East CMA to "identify, describe and map (where appropriate) the vegetation communities of Lake Moodemere and Sunday Creek, highlighting any Victorian Rare or Threatened (VROT) species, with particular emphasis on flora species likely to be impacted on by an altered hydrology regime." Existing vegetation mapping, based on Ecological Vegetation Classes (EVCs) was reviewed prior to site assessment. EVCs were re-mapped through field work and review of aerial photography. EVCs were described based on data gathered within a 30 m x 30 m quadrat within each EVC and the condition of each EVC was assessed using the Index of Wetland Condition method. Incidental observations of rare or threatened species were recorded during this assessment process.

### 5.3.2 Existing statewide EVC mapping

Ecological Vegetation Class (EVC) mapping is a vegetation classification system, derived from groupings of vegetation communities based on floristic, structural and ecological functions. Mosaics (combinations of EVCs) are a mapping unit, where the individual EVCs could not be separated, at the scale of 1:100,000 (Berwick 2003).

Statewide mapping of current (at 2005) EVC distribution is available on the DSE Biodiversity Interactive Map (DSE 2011). Mapping within the project area is shown in Figure 5-1. The bioregional conservation status and occurrence within the project areas is summarised in Table 5-2 with the conservation status reflecting the rarity or degree of depletion of each EVC within a given bioregion (Table 5-3).

**Table 5-2 EVCs within the project area (based on DSE mapping)**

| EVC | EVC Name | Bioregional conservation status (1) | Occurrence in EWP project area based on DSE Biodiversity Interactive Map |
|---|---|---|---|
| 814 | Riverine Swamp Forest | Depleted | Around northern marsh area – north of Lake Moodemere |
| 815 | Riverine Swampy Woodland | Vulnerable | Isolated pocket on eastern boundary of project area |
| 816 | Sedgy Riverine Forest | Vulnerable | North of Lake Moodemere |
| 56 | Floodplain Riparian Woodland | Vulnerable | Around northern perimeter of Lake Moodemere and east of Sunday Creek |
| 168 | Drainage-line Aggregate | Endangered | Along Sunday Creek |
| 172 | Floodplain Wetland Aggregate | Vulnerable | Northern marsh area – north of Lake Moodemere, adjacent existing inlet, linear features to west of Sunday Creek |
| 1087 | Tall Marsh / Aquatic Herbland Mosaic | Vulnerable | Forest Swamp / Hiskins Bend |
| 803 | Plains Woodland | Endangered | Scattered remnants on higher terrace (adjacent project area) |
| 295 | Riverine Grassy Woodland | Vulnerable | Northern end of project area between Sunday Creek and Murray River |

* In the Victorian Riverina Bioregion

**Table 5-3 EVC bioregional conservation status (from DSE spreadsheet "2007_EVC_bioreg_bcs_gps.xls")**

| Code | Status | Definition |
|---|---|---|
| X | Presumed extinct | Probably no longer present in the bioregion<br>OR if present, below the resolution of available mapping. |
| E | Endangered | Less than 10% of former range<br>OR less than 10% of pre-European extent remains (or a combination of depletion, loss of quality, current threats and rarity that gives a comparable status e.g. 10 to 30% pre-European extent remains and severely degraded over a majority of this area). |
| V | Vulnerable | 10 to 30% of pre-European extent remains (or a combination of depletion, loss of quality, current threats and rarity that gives a comparable status e.g. greater than 30% and up to 50% pre-European extent remains and moderately degraded over a majority of this area). |
| D | Depleted | Greater than 30% and up to 50% of pre-European extent remains (or a combination of depletion, loss of quality, current threats and rarity that gives a comparable status e.g. greater than 50% pre-European extent remains and moderately degraded over a majority of this area). |
| R | Rare | Rare (as defined by geographic occurrence) but neither depleted, degraded nor currently threatened to an extent that would qualify as endangered, vulnerable or depleted. |
| LC | Least concern | Greater than 50% or pre-European extent exists and subject to little to no degradation over a majority of this area. |
| na | Not applicable | The map unit is not a distinct native vegetation type and conservation status is not applicable. |

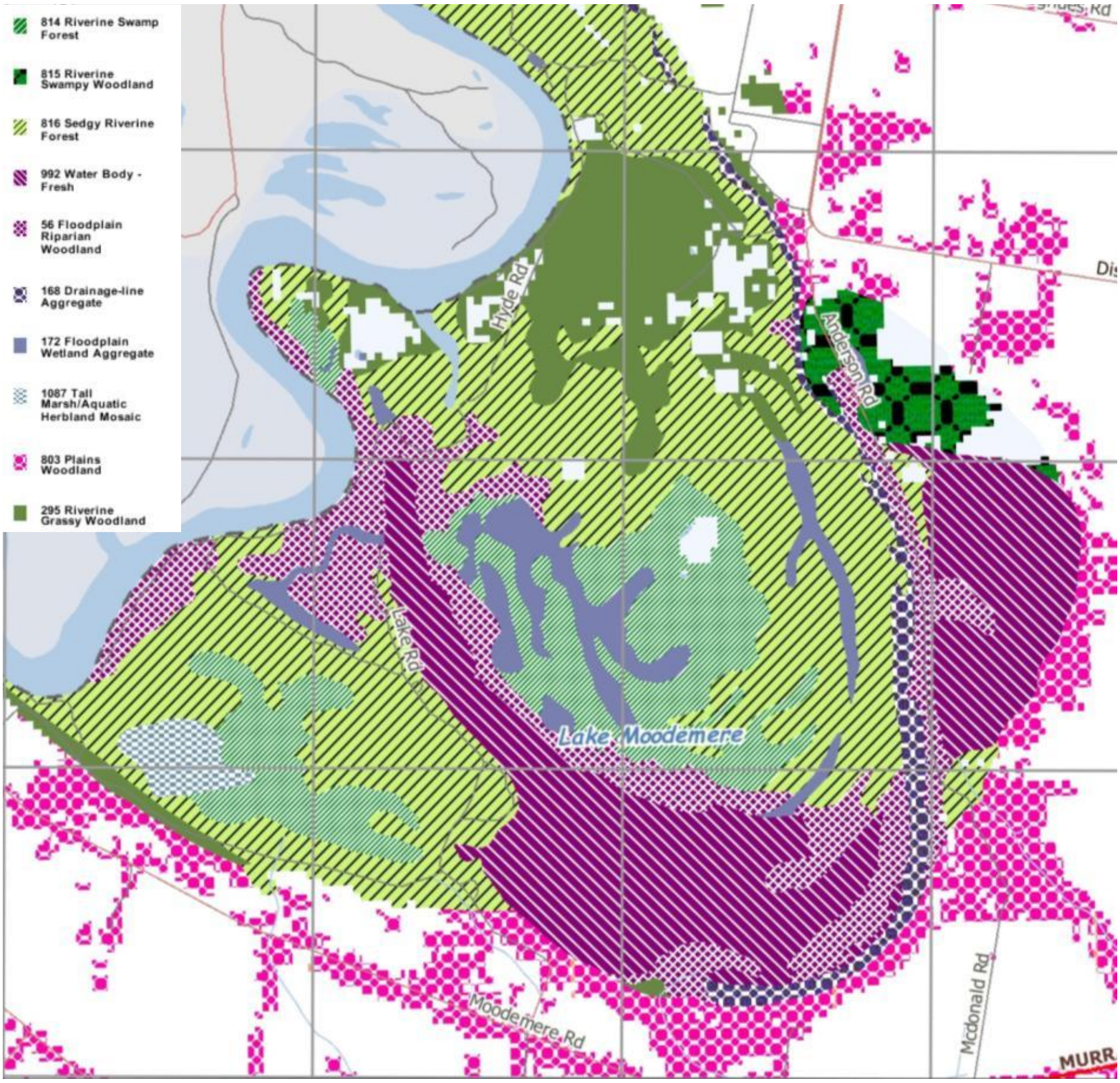


**Figure 5-1 2005 EVC mapping within the project area (from DSE Biodiversity Interactive Map)**

### 5.3.3 EVC mapping based on 2011 site assessment

The current distribution of EVCs within the project area as mapped by Australian Ecosystems, based on field assessment and desktop review is shown in Figure 5-2. The Bioregional Conservation Status, Index of Wetland Condition (IWC) score and condition category (based on the IWC score) for each flood dependent EVC within the project area are summarised in Table 5-4. There are substantial differences between the 2005 EVC mapping (Figure 5-1) and the recent field based mapping (Figure 5-2) in terms of both the spatial extent of EVCs and the suite of EVCs present. The recent field based mapping has been adopted for the further discussion and development of the EWP.


**Figure 5-2 EVC mapping within the project area based on Australian Ecosystems site mapping**

**Table 5-4 EVCs within the project area (based on Australian Ecosystems mapping) (from Australian Ecosystems 2011, Table 1)**

| EVC | EVC Name | Bioregional conservation status in Victorian Riverina | IWC biota score | Condition category |
|---|---|---|---|---|
| 56 | Floodplain riparian woodland | Vulnerable | 14.9 | Moderate |
| 804 | Rushy riverine swamp | Depleted | 15.3 | Moderate |
| 945 | Floodway pond herbland / Riverine swamp forest complex | Depleted | 18.6 | Excellent |
| 821 | Tall marsh | Depleted | 17.5 | Good |
| 815 | Riverine swampy woodland | Vulnerable | 14.0 | Moderate |
| 653 | Aquatic herbland | Depleted | 5.0 | Very poor |
| 106 | Grassy riverine forest | Depleted | 11.9 | Poor |
| 816 | Sedgy riverine forest | Vulnerable | 14.9 | Moderate |
| 810 | Floodway pond herbland | Vulnerable | Not assessed – not currently present but likely to develop on lake bed if water levels were allowed to draw down | |
| 803 | Plains woodland | Endangered | Not assessed – not flood dependent | |
| 295 | Riverine grassy woodland | Vulnerable | Not assessed – not flood dependent | |

### 5.3.4 Rare and threatened plant species

Australian Ecosystems (2011) identified 278 vascular flora species during the field survey of the project area. Of these, 169 species were indigenous, with 14 of these being rare or threatened as summarised in Table 5-5.

**Table 5-5 Rare and threatened plant species present within the project area (from Australian Ecosystems 2011, Table 2)**

| Common name | Scientific name | EPBC | FFG | VROTS | IUCN | EVCs |
|---|---|---|---|---|---|---|
| River Swamp Wallaby-grass | *Amphibromus fluitans* | V | L | | EN | 653, 945 |
| Late-flower Flax-lily | *Dianella tarda* | | | v | CR | 56 |
| Pale Swamp Everlasting | *Helichrysum aff. rutidolepis (Lowland Swamps)* | | | v | | 56, 815 |
| Hypsela | *Hypsela tridens* | | | k | CR | 945 |
| River Red-gum | *Eucalyptus camaldulensis* | | | | EN | All except 803 |
| Hydrilla | *Hydrilla verticillata* | | | r | CR | 653 |
| Hornwort | *Ceratophyllum demersum* | | | k | | 653 |
| Floodplain Fireweed | *Senecio campylocarpus* | | | r | | 56, 816 |
| Winged Water-starwort | *Callitriche umbonata* | | | r | CR | 945 |
| Buloke | *Allocasuarina luehmannii* | | L | | CR | 803 |
| Buloke Mistletoe | *Amyema linophylla subsp. orientale* | | | v | EN | 803 |
| Wavy Marshwort | *Nymphoides crenata* | | L | v | EN | 653 |
| Mueller Daisy | *Brachyscome muelleroides*[1] | V | L | e | CR | 816 |
| Riverina Bitter-cress | *Cardamine moirensis* | | | k | CR | 945 |

1 Identified as potentially being in the area by the EPBCA protected matters search tool, but no known records for the site

**Conservation Status in Australia**

EX Extinct: A taxon is extinct when there is no reasonable doubt that the last individual of the taxon has died.

CR Critically Endangered: A taxon is critically endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.

EN Endangered: A taxon is endangered when it is not critically endangered but is facing a very high risk of extinction in the wild in the near future.

VU Vulnerable: A taxon is vulnerable when it is not critically endangered or endangered but is facing a high risk of extinction in the wild in the medium-term future.

**Conservation Status in Victoria**

x Presumed Extinct in Victoria: not recorded from Victoria during the past 50 years despite field searches specifically for the plant, or, alternatively, intensive field searches (since 1950) at all previously known sites have failed to record the plant.

e Endangered in Victoria: at risk of disappearing from the wild state if present land use and other causal factors continue to operate.

v Vulnerable in Victoria: not presently endangered but likely to become so soon due to continued depletion; occurring mainly on sites likely to experience changes in land-use which would threaten the survival of the plant in the wild; or, taxa whose total population is so small that the likelihood of recovery from disturbance, including localised natural events such as drought, fire or landslip, is doubtful.

r Rare in Victoria: rare but not considered otherwise threatened - there are relatively few known populations or the taxon is restricted to a relatively small area.
k Poorly Known in Victoria: poorly known and suspected, but not definitely known, to belong to one of the above categories (x, e, v or r) within Victoria. At present, accurate distribution information is inadequate.
f listed under the Flora and Fauna Guarantee Act 1988

### 5.3.5 Hydrologic requirements

Australian Ecosystems (2011) defines the hydrologic requirements (frequency, maximum depth, duration, timing, maximum flood duration, ideal dry period and maximum dry period) for each of the flood dependent EVCs mapped at the site and for each rare or threatened flora species. The implications of these hydrologic dependencies in establishing a desired watering regime for the Lake Moodemere project area are discussed further in Section 7.

## 5.4 Frogs

### 5.4.1 Species recorded within the project area

The frog community composition within the Lake Moodemere project area was investigated by Australian Ecosystems within the 2011 fieldwork programme as documented in Australian Ecosystems (2011). Frog species found to occur within the project area are summarised in Table 5-6:

**Table 5-6 Frog species identified within the project area (from Australian Ecosystems 2011)**

| Common name | Scientific name |
|---|---|
| Common froglet | *Crinia parinsignifera* |
| Plains froglet | *Crinia signifera* |
| Sloans froglet | *Crinia sloanii* |
| Spotted marsh frog | *Limnodynastes tasmaniensis* |

### 5.4.2 General observations

None of the frogs found to occur at the site are listed as rare or threatened in Victoria. Australian Ecosystems (2011) states that other species are likely to be present and more readily recorded at the site during warmer periods, requiring further surveys in spring, summer and autumn to confidently identify all species utilising Lake Moodemere and surrounds. Of particular note, the Growling Grass Frog (*Litoria raniformis*), an EPBC listed species, endangered in Victoria, is identified as potentially being within the project area by the EPBC Act protected matters search tool however there are no known records for the site.

Australian Ecosystems (2011) indicates that no frogs were heard calling from within or around the lake, with frog choruses detected only at Forest Swamp and in the area of Riverine Swamp to the north east of Lake Moodemere (the northern marshes). Noting that "frogs are often most abundant in wetlands that have regular drying periods and aquatic vegetation made up of a diversity of lifeforms, including emergent, floating-leaved and submerged species" (Australian Ecosystems 2011), the current hydrologic regime and relatively low diversity of wetland vegetation is inferred to be a potential constraint on frog biodiversity within the site.

## 5.5 Birds

### 5.5.1 Species recorded within the project area

The bird community composition within the Lake Moodemere project area was investigated by Australian Ecosystems within the 2011 fieldwork programme as documented in Australian Ecosystems (2011).

The Victorian Fauna Database (Viridians 2011, cited in Australian Ecosystems 2011) lists a total of 133 bird species recorded at Lake Moodemere, of which 43 are considered to be wetland species (Australian Ecosystems 2011). The 2011 fieldwork program identified 73 bird species within the project area during 5 days in the last week of July. A compilation of species from the Victorian Fauna Database (Viridians 2011) and the 2011 fieldwork program includes a total of 17 threatened species of which 12 are wetland species. The threatened wetland species occurring at Lake Moodemere are summarised in Table 5-7.

**Table 5-7 Wetland bird species identified within the project area (from Australian Ecosystems 2011)**

| Common name | Scientific name | EPBC | FFG | VROTS |
|---|---|---|---|---|
| **Wetland species** | | | | |
| Australasian Shoveler | *Anas rhynchotis* | | | v |
| Australian Painted Snipe[1] | *Rostratula australis* | V | L | ce |
| Azure Kingfisher | *Alcedo azurea* | | | n |
| Blue-billed Duck | *Oxyura australis* | | L | e |
| Eastern Great Egret | *Ardea modesta* | | L | v |
| Freckled Duck | *Stictonetta naevosa* | | L | e |
| Hardhead | *Aythya australis* | | | v |
| Musk Duck | *Biziura lobata* | | | v |
| Nankeen Night Heron | *Nycticorax caledonicus* | | | n |
| Pied Cormorant | *Phalacrocorax varius* | | | n |
| Royal Spoonbill | *Platalea regia* | | | v |
| White-bellied Sea-Eagle | *Haliaeetus leucogaster* | | L | v |
| **Terrestrial species** | | | | |
| Barking Owl | *Ninox connivens* | | L | e |
| Black Falcon | *Falco subniger* | | | v |
| Black-chinned Honeyeater | *Melithreptus gularis* | | | n |
| Brown Treecreeper (south-eastern ssp.) | *Climacteris picumnus victoriae* | | | n |
| Hooded Robin | *Melanodryas cucullata* | | L | n |

1 Identified as potentially being in the area by the EPBCA protected matters search tool, but no known records for the site

### 5.5.2 General observations

The following observations of bird presence and distribution within the project area are drawn from Australian Ecosystems (2011).

- The greatest abundance and diversity of wetland birds observed during field work conducted for this study were observed in open water habitats on Sunday Creek and the open, eastern section of Lake Moodemere. Wetland bird communities in these areas were dominated by species characteristic of deeper water habitats including Grebes and Cormorants. During the study water levels in the lake were high, providing limited shallow water habitat for wading species.

- The shallower wetland area to the north-east of the main lake supported the greatest numbers of ducks observed during the study and also provided habitat for large wading species such as Herons and Egrets. The dense beds of Giant Rush in this area also provided habitat for secretive species such as the Little Grassbird and Purple Swamphen. A large River Red Gum in this area supported a White-bellied Sea Eagle nest.
- Only a few species of wetland birds in low numbers were observed in the Rushy Riverine Swamp habitat of Forest Swamp.
- Bird transects were conducted through other habitats present on the site, though due to lack of recent inundation these areas did not support wetland birds. They did however support diverse and abundant woodland bird communities.
- Of particular note was the presence of White-throated Gerygone. This species is mostly a summer migrant to Victoria (Emerson et al), with birds moving further north in winter from most areas. Populations of White-throated Gerygone overwintering in Victoria are restricted to few localities in the centre and north-east of the state (RAOU), including the forest around Lake Moodemere.
- The persistence of water in Lake Moodemere, even in times of drought, makes the area an important drought refuge for the region's wetland birds. Habitat diversity at the lake is increased when water levels are lower, when deep water, shallow water and mudflat habitats are present simultaneously. Therefore restoring a more natural hydrological regime to the lake, allowing draw down in summer, is likely to provide habitat to a greater diversity of birds.

# 6. MANAGEMENT OBJECTIVES

## 6.1 Previously documented management objectives

Previously documented management objectives for the Lake Moodemere system are briefly summarised in the following sections to provide a context for the development of objectives guiding the development of the EWP.

### 6.1.1 1996 Lake Moodemere Water Management Plan

The Lake Moodemere Water Management Plan (Robley 1996) identifies water management objectives and ecological management objectives for the Lake Moodemere system and states

> *"The provision of 'natural' water regimes in the Albury to Yarrawonga section of the River Murray are an appropriate objective for wetland water management. As this may not be possible every year, an alternative goal would be to supply water regimes as near to 'natural' as possible."*

The following water management objectives (developed with reference to Beovich and Lloyd 1993) are subsequently advocated by Robley (1996):

- To allow natural drawdown in summer of the lake and forest-swamp, with consideration of current uses.
- To ensure unnaturally long periods of inundation do not occur for the lake and forest-swamp.
- To increase the frequency and duration of winter-spring floods.

The following ecological objectives are defined by Robley (1996):

- To maintain or enhance the biodiversity of each wetland system at Lake Moodemere.
- To ensure there is no significant shift in the balance of vegetation communities.

The resultant operating guidelines defined in Robley (1996) are:

- For Lake Moodemere:
  - "Close the regulator gates on *(31st)* December each year, drawing the lake down to 1.9 m *(RL 129.0 m AHD based on Section 3.2)* by the end of January through irrigation and drainage."
  - "If the lake falls to a level which creates irrigation supply difficulties, operate regulating structure to restore level to a maximum of 1.9 m."
  - "Open regulator gates between May 1st and August 31st each year, to allow for variation in the lake level."
- For Forest Swamp:
  - "Close the regulator from December 15 to April 1 each year. These time periods should be varied to accord with natural variation in flooding patterns to simulate the natural variation in flooding of the Forest Swamp."

The objectives and resultant operating guidelines essentially target a natural condition, subject to constraints imposed by (then) current uses (irrigation and recreation during summer/autumn).

### 6.1.2 Public Land – Management objectives

Management objectives and activities for public land are outlined in the Parks Victoria Management Statements, specifically for the Lake Moodemere Lake Reserve (Barrow and Raulings 2007) and the Moodemere Nature Conservation Reserve (NCR) (Robertson and Fitzsimmons 2005). The portion of the Moodemere NCR lying within the project area was added to the NCR in 2008 following the VEAC River Red Gum Forests Investigation completed in 2008. There is currently no documented management statement for this northern portion of the NCR however Barrow and Raulings (2007) identifies an overall operational objective to manage all of the reserve in the Moodemere bend as a single management unit. It is therefore likely that management of the entire public land estate within the project area will be consistent with the management objectives documented in Barrow and Raulings (2007) as summarised below.

Barrow and Raulings (2007) identify management objectives for ecological, heritage and indigenous values for the Lake Moodemere Lake Reserve and, by extension, the other public land within the project area. The following high level ecological management objectives are identified:

- Manage Lake Moodemere Reserve as Plains Woodland EVC and Riverine Grassy Woodland / Sedgy Riverine Forest / Wetland Formation Mosaic EVC and maximise species diversity of flora and fauna, while allowing the natural processes of succession to occur
- Encourage and support community groups to survey and record natural values of Lake Moodemere and upload into Parks Victoria's Environmental Information System (EIS)
- Encourage and support community groups to undertake activities e.g. revegetation in line with conservation objectives
- Measure the condition of the extant vegetation every 5-10 years using a standardised and repeatable measure
- Evaluate the effectiveness of achieving the short term conservation objectives and risk targets at regular intervals and revise.

More specific objectives and risk targets (or resultant management activities) from Barrow and Raulings (2007) are summarised in Table 6-1. These objectives were developed based largely on the experience and observations of the authors informed by previous desktop reviews but without a significant field investigation.

**Table 6-1 Ecological management objectives, highlighting those related to the hydrologic regime (from Barrow and Raulings 2007)**

| Type | Conservation objective | Risk target (excluding those unrelated to the hydrologic regime) |
|---|---|---|
| Water regime and water quality (Short term 0 - 10 years) | Restore a hydrologically dynamic water regime in Lake Moodemere Reserve | Decrease frequency of flooding through regulating structure by 45% over the summer-autumn period<br><br>Allow water levels to decrease in summer through evaporation and allow wetland area to dry out to cracking clays once every 3-5 years for several months in consultation with irrigators and recreational users<br><br>Work with the Murray Darling Basin Commission, CMAs, adjacent landholders and local community groups to restore environmental flows to the Murray River, especially large floods in late winter / early spring<br><br>Encourage CMAs, Murray Darling Basin Commission, adjacent landholders and |

| Type | Conservation objective | Risk target (excluding those unrelated to the hydrologic regime) |
|---|---|---|
| | | community groups to decrease flows along the Murray River in summer and early autumn |
| | Improve the water quality of Lake Moodemere Reserve (and in turn, the Murray River) | |
| | Improve biotic connectivity between the Murray River and its floodplain and associated wetlands in Lake Moodemere Reserve | Work with CMAs, adjacent landholders and local community groups to restore environmental flows to the Murray River, especially large floods in late winter / early spring that connect Lake Moodemere and the Murray River |
| Water regime and water quality (Long term 10 - 100 years) | Maintain appropriate water regimes, water quality and aquatic habitats in Lake Moodemere Reserve | |
| Vegetation communities (Short term 0 – 10 years) | Increase the cover of native understory vegetation in Lake Moodemere Reserve | |
| | Restore the overstorey and understorey of the northern portion of the McDonalds Road unit | |
| | Investigate the presence of submerged vegetation, and restore if deemed necessary | Identify the watering requirements of different life stages of aquatic vegetation, and where possible, implement to encourage germination and establishment |
| Fauna (Short term 0 – 10 years) | Maintain or increase populations of indigenous and migratory waterfowl and other birds and encourage successful breeding of colonial waterbirds in at least three years in ten | Regularly assess change in water regime on waterbird population |
| | Maintain or increase populations of ground dwelling mammals and reptiles | |
| | Increase the population size and breeding events of native fish in Lake Moodemere Reserve and in the Murray River | Conduct a fish survey of Lake Moodemere to establish baseline data<br><br>Reduce the carp population in Lake Moodemere by installing carp barriers and drying wetland to cracking one in every five years |
| Fauna (Long term 10 – 100 years) | Maintain or increase populations of indigenous and migratory fauna | |

### 6.1.3 Hiskins Bend / Forest Swamp operating plan

The Draft Operating Plan for Hiskins Bend Regulator (Lake Moodemere Forest Swamp) (Ward 2009) aims to reinstate a more natural flooding regime in Forest Swamp to:

- re-create a wetland type that was once common but now rare within the regulated floodplain;
- facilitate the establishment of greater biodiversity;
- assist the development of a habitat for a range of indigenous flora and fauna that specifically require a natural hydrological regime in the frequent (annual) return period end of the scale;
- form the development of ecological (physical, chemical and biological) processes that may benefit the riverine system following seasonal connection with the river;
- provide an ability to establish carp screens on the regulator to reduce the number of carp (particularly the more destructive large size classes) from re-entering the wetland;
- provide a demonstration site within the mid Murray region for the wetland benefits of a natural flood regime and exclusion of carp.

The resultant proposed operating regime comprises:

- Having the regulator open between May and October – enabling connection with the Murray River during the winter-spring flood period
- Having the regulator closed from October to the following May – enabling drawdown of the lake (by evaporation and seepage) while preventing flooding by high unseasonal (irrigation period) river levels.

Consistent with Robley (1996) (as discussed in Section 6.1.1) the proposed operating regime targets a natural flood regime by exclusion of unseasonal flooding by high Murray River flows during the irrigation season. The period of regulator closure is longer than that envisaged by Robley (1996), presumably as hydrologic management of Forest Swamp is not as constrained as Lake Moodemere by competing uses.

## 6.2 Relevance of existing objectives to the EWP process

The previously defined objectives for the Lake Moodemere system (Section 6.1) are broadly consistent in:

- Identifying the natural hydrologic regime as an appropriate target for future management where overall improvements in environmental condition are targeted.
- Aiming to minimise unseasonal flooding of the Lake Moodemere system by high irrigation flows during summer-autumn, by closing regulators during this period.
- Allowing flooding during the natural high flow period (winter-spring), by opening regulators during this period.

These three objectives are considered to be of direct relevance to the development of the EWP. The merits of restoring natural hydrology, given that the current environmental values are reliant on a highly modified hydrologic regime are further discussed in Section 6.3.

In addition to the above, Barrow and Raulings (2007) suggests:

- Working with stakeholders to achieve restoration of natural Murray River floods in late winter / early spring. These floods are currently impacted by flow regulation within the Murray system and are typically reduced in magnitude and frequency.
- Working with stakeholders to reduced Murray River flows in summer and early autumn.

- Providing for drying events in (undefined) wetland areas every 3-5 years for a period of several months

Of these objectives, modification of the regulated flow regime of the Murray River while likely to be ecologically beneficial, is beyond the scope of the EWP and therefore not likely to be adopted within this process. The suggestion that drying periods be provided is considered reasonable and likely to be incorporated into the EWP process. In this context SKM (2008a) indicates that there is a requirement for the lake to be retained above 1.6 m (RL 128.7 m AHD) during the peak recreational season of December – February.

## 6.3 Rationale for development of objectives for the EWP

### 6.3.1 Context

The Lake Moodemere system is a regionally significant wetland in a highly regulated reach of the Murray River (Hume to Yarrawonga).

The hydrologic regime of the Moodemere system is modified from natural conditions due to regulation of flows in the Murray River and management of the Moodemere system for delivery of water for irrigation.

The current environmental values are derived from the current hydrologic regime and historic land management practices. The proposal to modify irrigation infrastructure and management impacting on the hydrologic regime of the Lake Moodemere system provides opportunities to improve the environmental condition but may also pose risks to current environmental assets which are either reliant upon or tolerant of the existing regime. Specifically the modified irrigation infrastructure provides an opportunity to operate Sunday Creek and Lake Moodemere independently from one another. In this circumstance the operational requirements of the irrigation extraction would determine the hydrologic regime of Sunday Creek while the hydrologic regime of Lake Moodemere could be managed with a focus on improved environmental condition through the provision of an appropriate drying regime.

### 6.3.2 Current values

The current environmental values of the Lake Moodemere system are discussed in Section 5. While the discussion of values focuses on rare and threatened species and high value assets, the overall environmental value of the system is derived from the overall diversity of the site. Through discussion with the specialists providing input to the EWP process, the maintenance of the current environmental values has been attributed to the following site characteristics:

- a large area of open water habitat
- permanent water throughout the year even in dry years, providing drought refuge habitat for many endangered species
- relatively limited edge effects (broad floodplain expanse)
- no large aquatic weed infestation or dominant pest plant species
- permanent wetland habitat for significant flora and fauna species (although not EPBC or critically endangered)
- potentially unique nutritional environment for turtles and fish due to large stands of flooded aquatic vegetation
- thermal refuge (buffered from unseasonal variations in the river temperature)

While the current values are significant, it is considered that they are limited by the following factors:

- historic and current hydrologic modification reducing hydrologic variability
- limited extent of habitat experiencing variable wetting and drying cycles
- historic management practices (grazing, clearing, firewood collection) contributing to loss of species diversity from direct impacts (pugging, trampling, grazing) and indirect impacts (nutrient inputs, loss of habitat niches)
- dominance of Juncus ingens to detriment of species variability, principally at the margins of permanent water
- hypoxic conditions in the upper reaches of Sunday Creek (presumably due to permanent inundation and occasional flood pulses)
- regional degradation of surrounding wetland network hence reduced spatial and temporal biodiversity.

### 6.3.3 Potential benefits of restoring natural seasonality within Lake Moodemere

The following potential benefits of restoring natural seasonality to water levels within Lake Moodemere have been identified:

- An increase in diversity of vegetation communities around the fringes of Lake Moodemere, specifically the northern marshes, contributing to:
    - opportunities for regeneration of threatened and uncommon vegetation species currently present but not prevalent,
    - greater diversity of vegetation lifeforms, favouring fauna currently absent (i.e. Southern pygmy perch because of their association with wetlands with diverse lifeform),
    - greater availability of frog habitat due to variability in lifeforms and niches,
    - an increase in the width of the fringe of Tall Marsh,
    - an increase in the availability of feeding habitat for wading waterbird species as the wetland fringe becomes broader and more diverse,
    - restoration of a diverse seedbank (currently compromised by long term history of regulation),
    - restoration of soil carbon and nutrient cycling.
- Providing a niche comprising infrequently exposed muddy sediment (below typical current water level available for colonisation by Floodway Pond Herbland EVC which:
    - includes a range of specialist mud flat plant species, which germinate on drying mud,
    - is currently locally uncommon and would be utilised by wading and mud-probing bird species (i.e. Painted Snipe, Dotterels, Plovers).

### 6.3.4 Potential risks of restoring natural seasonality within Lake Moodemere

The following risks of restoring natural seasonality to water levels within Lake Moodemere have been identified:

- There may be a reduction in the extent of emergent aquatic vegetation, depending on response times for regeneration of vegetation within the ephemerally wetted zone.
- There may be an increase in the extent and quantity of Juncus ingens beds at the expense of other habitats.
- There is potential for localised reduction in the quantity of suitable habitat for certain threatened vertebrates (Fly specked hardyhead and Broad Shelled Turtle) contributing to a decline in numbers.
- There is potential for increased colonisation by invasive plant species within areas of wetting and drying habitats.

- Loss of drought refuge for a range of flora and fauna species (although the drying regime is unlikely to require drying every year and therefore may not need to dry in droughts).

### 6.3.5 Potential impacts on Sunday Creek

Continued operation of Sunday Creek to facilitate irrigation extraction is likely to result in a hydrologic regime similar to the historic regime. While this precludes the implementation of a drawdown period during summer and autumn and is therefore unlikely to contribute to an increase in aquatic and fringing biodiversity it should not compromise the current condition of assets within Sunday Creek.

## 6.4 Objectives and outcomes for EWP

Recognising that the environmental value of the site is derived from the overall diversity of the species and communities present at the site, rather than being focussed on a single “icon” feature we propose an objective:

> **To maximise the overall biodiversity of the site by reducing current hydrological constraints on the viability of native flora and fauna communities and species.**

Delivery of a watering regime consistent with this objective would be demonstrated through the following outcomes:

- Retaining and enhancing populations of native fish currently found at the site and providing stimulus for species currently restricted by hydrology or site attributes derived from the current hydrology.
- Reducing the dominance of exotic fish species.
- Protecting and enhancing conditions favouring a sustainable population of threatened turtle species which are currently found in the northern marshes area.
- Improving the viability of frog populations through provision of more variable habitat across a wider area of the site.
- Protecting the extent and viability of habitat utilised by wetland bird species, specifically increasing muddy edge habitat leading to development of Floodway Pond Herbland EVC around the perimeter of Lake Moodemere.
- Retaining and enhancing the diversity and condition of vegetation communities within the site to support the other asset classes.

# 7. DEVELOPMENT OF WATERING REGIME

## 7.1 Introduction

As discussed in Section 6.3, the proposal to modify irrigation infrastructure and management impacting on the hydrologic regime of the Lake Moodemere system provides an opportunity to reduce the detrimental impacts of the current managed hydrologic regime on the environmental condition of the site, specifically within and adjacent Lake Moodemere. The long history of hydrologic modification has however contributed to the establishment of environmental assets at least partially dependent on the current hydrology. Development of a watering regime focussed on the objective (Section 6.4) requires identification of both the benefits and risks of hydrologic restoration.

While the objective does not target a return to natural hydrology as an outcome, the natural hydrologic regime provides an appropriate benchmark for assessment of the potential benefits and risks to current assets which are either reliant upon or tolerant of the existing regime. As discussed in Section 3, the key departures from the natural regime are a reduction in winter / spring overbank flooding of the higher portions of the floodplain and the retention of high water levels throughout summer and autumn when there would naturally be a drawdown event within Lake Moodemere and Sunday Creek.

Restoration of winter / spring flooding on a frequency and duration closer to the natural regime would be of benefit but, being largely dependent on the regulated flow regime within the Murray River, is not readily achieved.

The modified irrigation infrastructure currently under consideration provides an opportunity to separate the operation of Lake Moodemere and Sunday Creek. In essence this would result in a continuation of the current water level regime within Sunday Creek to facilitate seasonal irrigation extraction. While this essentially precludes the implementation of a drawdown regime within Sunday Creek (as the desired drawdown period coincides with the irrigation season) it means that, subject to consideration of other social and economic factors, a drawdown of Lake Moodemere over summer / autumn can be considered. The benefits and risks of such a drawdown regime for Lake Moodemere are discussed in the following sections.

## 7.2 Implementation of a drawdown regime

The benefits and risks of providing for a summer / autumn drawdown of Lake Moodemere, replicating a component of the natural hydrologic regime, are discussed in the following sections and summarised in Table 7-1 to Table 7-5.

### 7.2.1 Overall comments – Aquatic vertebrates

Richardson and Stoffels (2011b) provides the following discussion of the overall benefits and risks of restoration of natural hydrology on aquatic vertebrate diversity:

- Some of the potential benefits for the aquatic vertebrates in Lake Moodemere are difficult to assess for each individual species as the effect (of altered hydrology) is likely to have implications throughout the food web. For example, ephemeral wetlands, and indeed ephemeral areas within wetlands, are known to be more productive than permanently inundated wetlands in terms of zooplankton (Nielsen *et al.* 2000; Nielsen *et al.* 2002). Zooplankton is an important food source for most small native fishes (Pusey *et al.* 2004). Turtles are likely to benefit from the expected resultant increase in small fish and macroinvertebrate productivity. The timing of wetting/flooding events will be critical such that peak zooplankton abundance coincides with spawning events of small native fish (Humphries *et al.* 2008).

- The potential benefits to the aquatic vertebrate community of Lake Moodemere extend beyond the species currently found there. Any increase in the diversity of submerged and floating macrophytes, as a result of restoring a more natural hydrology to the lake, may encourage the colonisation of certain fishes. For example, southern pygmy perch (*Nannoperca australis*) and the flat-headed galaxias (*Galaxias rostratus*) may benefit from restoration of the submerged and floating macrophyte community. Note, however, that for this to happen a supply of colonists must exist somewhere else in the riverine network between lakes Hume and Mulwala.
- A deleterious effect on native aquatic vertebrates currently in Lake Moodemere is the major risk associated with such an intervention. A positive effect on the exotic species currently in Lake Moodemere should also be viewed as a risk.

### 7.2.2 Overall comments – Vegetation communities

Of the 10 Ecological Vegetation Communities (EVCs) identified by Australian Ecosystems (Australian Ecosystems 2011) 8 are flood dependent. Floodway Pond Herbland (EVC 810) is not currently found at the site but would be likely to develop on the bed of the lake and its associated wetlands if water levels were allowed to draw down. The benefits and risks of a drawdown regime for the flood dependent EVCs (including EVC810) are documented in Table 7-3. Additional information on the optimum hydrological requirements for each EVC are provided in Australian Ecosystems (2011) in Appendix B.

### 7.2.3 Overall comments – Frogs

Australian Ecosystems (2011) indicates:

- Four frog species were detected during the site surveys although this likely under-represents the diversity of frogs present at the site.
- The Growling Grass Frog (EPBC listed, VROTS endangered) is listed on EPBCA protected matters search tool but there are no known records for the site and it was not detected in the recent surveys.
- No frogs were detected within or around the lake. Frog choruses were only present within Forest Swamp and the Riverine Swamp Forest north-east of the lake.
- Frogs are often most abundant in wetlands that have regular drying periods and aquatic vegetation made up of a diversity of lifeforms including emergent, floating leaved and submerged species. Frog diversity and abundance could likely be increased by returning a more natural hydrologic regime to Lake Moodemere and associated wetlands.
- Excluding the Growling Grass Frog there are no rare or threatened frog species known to be present at the site. While further survey may expand the species list, restoration of natural hydrology would be expected to favour frog diversity and there are no known risks to frogs.

### 7.2.4 Overall comments – Birds

Australian Ecosystems (2011) indicates:

- Wetland birds in the areas of greatest abundance and diversity (open water habitats on Sunday Creek and the open, eastern section of Lake Moodemere) were dominated by species characteristic of deeper water habitats including Grebes and Cormorants.
- The shallower wetland habitat to the north-east of the main lake supported the greatest numbers of ducks and also provided habitat for large wading species such as Herons and Egrets.

- The shallower wetland habitat to the north-east also provided habitat for secretive species such as the Little Grassbird and Purple Swamphen and a White-bellied Sea Eagle nest.
- The persistence of water in Lake Moodemere, even in times of drought, makes the area an important drought refuge for the region's wetland birds. Habitat diversity at the lake is increased when water levels are lower, when deep water, shallow water and mudflat habitats are present simultaneously. Therefore restoring a more natural hydrological regime to the lake, allowing draw down in summer, is likely to provide habitat to a greater diversity of birds

## 7.3 Summary of benefits and risks

The benefits and risks of a drawdown regime on each asset class are discussed in the following tables. In summary, the key findings are:

- All turtle species are expected to benefit from an increase in macrophyte diversity. The turtle community may change, with more ephemeral conditions potentially favoring the Eastern long-necked turtle over the less common Broad shelled turtle and Murray River turtle. This is predicated on the fact that both the Broad shelled turtle and the Murray River turtle prefer permanent water bodies and it is noted that even under a drawdown scenario Lake Moodemere will still retain a permanent pool.
- Native fish (small and large bodied) are expected to benefit from a drawdown regime due to increased zooplankton productivity. There is some risk to the Flyspecked hardyhead (Threatened Vic FFG) associated with reduced access to wetland macrophytes during the breeding season.
- Exotic fish species may benefit from the drawdown as they are generally more tolerant of poor water quality and warm water.
- Aquatic fringing vegetation diversity, currently low within and around Lake Moodemere, is expected to increase as a result of a summer / autumn drawdown. The main risk is the potential for increased dominance by Juncus ingens in the fringing vegetation.
- Frog diversity is expected to benefit from implementation of a drawdown regime. No risks to frog communities have been identified.
- Bird communities are expected to benefit from increased habitat productivity and food sources and increased shallow wetland habitat. Some temporary relocation of wetland species may occur if the lake and wetlands become too shallow.

**Table 7-1 Benefit / risk assessment for restoration of natural hydrology – Turtles (from Richardson and Stoffels 2011b)**

***Turtles*** ***Target outcome*** *: Protecting and enhancing conditions favouring a sustainable population of threatened turtle species which are currently found in the northern marshes area.*

| **Species** | **Restoration of natural hydrologic regime – Summer / Autumn drawdown of Lake Moodemere** | |
|---|---|---|
| | **Benefit** | **Risk** |
| Broad shelled turtle (Threatened, Vic FFG) | This species is a carnivorous ambush predator, so it may benefit from increased abundance of prey (e.g. small fish and crustaceans) associated with a (potentially) more diverse macrophyte assemblage. | May be at risk of a reduction in numbers as it prefers permanent waterbodies (Cann 1998) although it should be noted that a significant pool volume would remain under a drawdown scenario. Preferred diet consists of live aquatic prey (yabbies, prawns, small fish etc.) and this species' relative success in the lake may be linked to the large beds of emergent macrophytes and the high abundance of small fish therein (Chessman 1983). |
| Eastern long-necked turtle | May benefit from increased zooplankton productivity. It is generally associated with ephemeral wetlands, so it may benefit from increased ephemerality. | Currently occurs in low numbers but may be advantaged (see 'Benefits'). Increased numbers of this common turtle may impact on the two other rarer species. |
| Murray River turtle (Data deficient, Vic FFG) | No obvious benefit | May be at risk of a reduction in numbers as preferred habitat tends toward large permanent waterbodies although it should be noted that a significant pool volume would remain under a drawdown scenario. Diet consists mostly of plant-based material such as filamentous algae (Chessman 1986) and this species' success in the lake may be linked to the extensive emergent macrophyte beds. |

**Table 7-2 Benefit / risk assessment for restoration of natural hydrology – Fish (from Richardson and Stoffels 2011b)**

***Native fish*** ***Target outcome*** *: Retaining and enhancing populations of native fish currently found at the site and providing stimulus for species currently restricted by hydrology or site attributes derived from the current hydrology.*

| Species | Restoration of natural hydrologic regime – Summer / Autumn drawdown of Lake Moodemere | |
|---|---|---|
| | **Benefit** | **Risk** |
| Golden perch | May benefit from increased abundance of small fish and crustaceans | No obvious risk |
| Australian smelt | May benefit from increased zooplankton productivity | No obvious risk |
| Flyspecked hardyhead (Threatened, Vic FFG) | May benefit from increased zooplankton productivity | Reduced access to wetland macrophytes during breeding period (shrinking wetland) as well as the loss of an important spawning habitat (giant juncus beds). This species lays eggs with adhesive strands that attach to vegetation, and survival of eggs in vegetated areas is higher (Llewellyn 1979; Milton & Arthrington 1983a). |
| Flathead gudgeon | May benefit from increased zooplankton productivity | No obvious risk |
| Carp gudgeon | May benefit from increased zooplankton productivity | No obvious risk |

***Non-native fish*** ***Target outcome*** *: Reducing the dominance of exotic fish species.*

| | |
|---|---|
| Goldfish | May benefit from summer conditions if lake retreats and is not connected to river (low DO, high temp, hypoxic) |
| Common carp | May benefit from summer conditions if lake retreats and is not connected to river (low DO, high temp, hypoxic). Shallow and warm waters are ideal habitat for carp spawning. |
| Redfin | No obvious benefit. |
| Oriental weatherloach | May benefit from ephemeral conditions given ability to tolerate poor water quality and aestivate during dry periods. Particularly prevalent in rice fields in native range (see Keller & Lake 2007). |
| Eastern gambusia | May benefit as reproductive activity linked to higher water temperatures (Milton & Arthrington 1983b) and is a rapid coloniser of freshly inundated wetlands (pers. obs.) |

**Table 7-3 Benefit / risk assessment for restoration of natural hydrology – Vegetation communities (from Australian Ecosystems 2011)**

***<u>Vegetation communities</u>*** ***Target outcome*** *: Retaining and enhancing the diversity and condition of vegetation communities within the site to support the other asset classes.*

| Vegetation community | Restoration of natural hydrologic regime – Summer / Autumn drawdown of Lake Moodemere | |
|---|---|---|
| | **Benefit** | **Risk** |
| EVC804 – Rushy riverine swamp | Increased regeneration of indigenous under storey species, increased health and regeneration of River Red Gums. | Too much regeneration of River Red Gums, causing thick stands of saplings to develop. |
| EVC821 – Tall marsh | Increase in indigenous plant species diversity and creation of a greater area of habitat for certain birds such as Crakes and Rails. | Invasion of Giant Rush into other EVCs including Aquatic Herbland. |
| EVC653 – Aquatic herbland | Increased likelihood of regeneration of native aquatic herbs. Decreased likelihood of invasion by exotic aquatic species which require permanent inundation. | Invasion of Giant Rush. |
| EVC810 – Floodway pond herbland | Increased likelihood of regeneration of native mudflat species. | Invasion of Giant Rush. |
| EVC56 – Floodplain Riparian Woodland<br>EVC945 – Floodway pond herbland / Riverine swamp forest complex<br>EVC815 – Riverine swampy woodland<br>EVC106 – Grassy riverine forest<br>EVC816 – Sedgy riverine forest | None (would benefit from more wetting during winter and spring). | Decrease in health of River Red Gums. Lack of recruitment of indigenous understorey species. Increased weed invasion. *(This comment relates to a reduction in winter / spring flood frequency. As these EVCs are located on higher ground they will not be impacted by the summer / autumn drawdown*). |

**Table 7-4 Benefit / risk assessment for restoration of natural hydrology – Frogs (from Australian Ecosystems 2011)**

***Frogs*** ***Target outcome*** *: Improving the viability of frog populations through provision of more variable habitat across a wider area of the site.*

| Species | Restoration of natural hydrologic regime – Summer / Autumn drawdown of Lake Moodemere | |
|---|---|---|
| | **Benefit** | **Risk** |
| Common Froglet, Plains Froglet and Sloan's Froglet, Spotted Marsh Frog. Other species likely to be present but not detected in recent surveys due to seasonal factors. | Frogs are often most abundant in wetlands that have regular drying periods and aquatic vegetation made up of a diversity of lifeforms, including emergent, floating-leaved and submerged species. It is therefore likely that frog diversity and abundance at Lake Moodemere could be increased by returning a more natural hydrological regime to the lake and its associated wetlands. | No known risks. |

**Table 7-5 Benefit / risk assessment for restoration of natural hydrology – Birds (from Australian Ecosystems 2011)**

***Birds*** ***Target outcome*** *: Protecting the extent and viability of habitat utilised by wetland bird species, specifically increasing muddy edge habitat leading to development of Floodway Pond Herbland EVC around the perimeter of Lake Moodemere.*

| Species | Restoration of natural hydrologic regime – Summer / Autumn drawdown of Lake Moodemere | |
|---|---|---|
| | **Benefit** | **Risk** |
| Musk Duck | Potential increase in habitat productivity and therefore food sources. | This species will not remain in the area if the lake and wetlands become too shallow. However, it is a highly mobile species which will come and go from the area according to whether or not suitable habitat is available. |
| Blue-billed Duck | Potential increase in habitat productivity and therefore food sources. | |
| Eastern Great Egret | Increased area for foraging as a greater area of shallow wetland fringe would be created as the wetland and lake draw down.<br>Potential increase in habitat productivity and therefore food sources. | |
| Royal Spoonbill | Increased area for foraging as a greater area of shallow wetland fringe would be created as the wetland and lake draw down.<br>Potential increase in habitat productivity and therefore food sources. | |
| White-bellied Sea-Eagle | Potential increase in habitat productivity and therefore food sources | If drying caused a decrease in fish prey items the resident Sea Eagles would be forced to forage elsewhere, such as along the river or further afield. However it is likely they would return to the lake when suitable conditions returned. |
| Australian Painted Snipe | Increased area for foraging as a greater area of shallow wetland fringe would be created as the wetland and lake draw down.<br>Potential increase in habitat productivity and therefore food sources. | |
| Freckled Duck | Potential increase in habitat productivity and therefore food sources. | This species will not remain in the area if the lake and wetlands become completely dry. However, it is a highly mobile species which will come and go from the area according to whether or not suitable habitat is available. |

**Table 7-6 Benefit / risk assessment for continuation of irrigation derived hydrology in Sunday Creek– Aquatic vertebrates**

<table>
<tr><th rowspan="2">Species</th><th colspan="2">Restoration of natural hydrologic regime</th></tr>
<tr><th>Benefit</th><th>Risk</th></tr>
<tr><td>Overall comments</td><td colspan="2">The proposed change to current water management involves constructing a regulator at Hell's Gate, the point of connection between Lake Moodemere and Sunday Creek, and pumping water directly into the northern end of Sunday Creek from the Murray River. This will effectively result in the following scenario:<br>I. Wetland fragmentation — The frequency, duration and timing of connection between Lake Moodemere and Sunday Creek may be altered.<br>II. Changed water quality — The data collected here shows that the magnitude of change in water quality variables increases with distance from the Murray River connection. Assuming that this pattern is common throughout the wetland complex (this assumption needs testing), pumping water directly into Sunday Creek's northern end may change water quality. Sunday Creek's water temperature, for example, may more closely approximate that of the Murray River.<br>III. Habitat status quo —the most basic habitat features of Sunday Creek — water depths, in-channel structure, macrophytic community, etc. — will experience little, if any, change.</td></tr>
<tr><td></td><td>It is not clear, at this stage, how frequent and/or sustained the hypoxia event we encountered in Sunday Creek is. If low water quality is characteristic of Sunday Creek, then direct pumping into the north end from the Murray River may improve our ability to manage and restore water quality in Sunday Creek. In turn, improvement in water quality may reduce the abundance of noxious pest fish that are tolerant of such conditions (e.g. common carp and goldfish), while increasing the abundance of native fishes.<br>An opportunity that may be considered once water quality in Sunday Creek has been improved — and one which would be considered a benefit at a regional scale — is the possible re-introduction of native species. Sunday Creek is a long and narrow wetland with a relatively diverse macrophytic community and considerable and complex patches of instream woody debris. In short, Sunday Creek presents a habitat suitable for the re-introduction of rare species such as freshwater catfish (Tandanus tandanus).</td><td>Fragmentation of the wetland complex may result in a decline in fish biodiversity in Sunday Creek. For example, if episodes of low water quality (such as the hypoxia event encountered as part of this study) result in localised extinction of a species, re-colonisation and population recovery may be hampered by reduced connectivity with Lake Moodemere.<br><br>Clearly, if Sunday Creek acts as a thermal refuge from cold water releases from Lake Hume into the Murray River during spring/summer, then pumping water directly into Sunday Creek is a risk to certain fishes and turtles.</td></tr>
</table>

# 8. KNOWLEDGE GAPS

Key knowledge gaps and limitations are identified in the following sections.

## 8.1 Hydrology

The modelled natural and current flow regimes for the Murray River established by the MDBA BIGMOD modelling are well understood and provide a good representation of long term monthly and seasonal flows for Doctors Point and Corowa. The greatest difficulty in interpretation arises from the lack of a correlation between flow and Murray River water level at the Lake Moodemere regulator. The current project has provided an interpretation of Murray River flows relative to critical levels within the project area however the development of a rating curve for the Murray River at the Lake Moodemere regulator would be of benefit. This would confirm the flow magnitudes (at Doctors Point and Corowa) which produce water levels in the Murray which impact on the Lake Moodemere system (i.e. confirmation of CTF levels discussed in Section 3.3). This could be achieved by installation of a water level sensor and data logger in the Murray River at the Lake Moodemere regulator to enable subsequent review and analysis against the gauge records for Doctors Point and Corowa.

## 8.2 Bathymetry

The bathymetric survey undertaken to inform the development of the EWP provided a good spatial coverage of the Lake Moodemere system, sufficient to identify typical bed levels throughout the system. This information is sufficient to identify the presence of pool habitat which would remain below a given drawdown level however the spacing of cross-sections is insufficient to fully define the extent and volume of pools. If close definition of pool volume is considered critical further survey and processing of data to form a complete digital terrain model (DTM) of the lake bed would be required.

The detail provided in the near-bank region of the cross-sections was limited by the ability to access this area – shallow depth and macrophyte growth prevented boat access and use of the depth sounder typically within 10-20 m of the water's edge. This area will form a key part of the habitat exposed during a drawdown event. If specific definition of the bed form exposed by drawdown is considered critical then additional survey of this area would be required.

## 8.3 Aquatic vertebrates (fish and turtles)

Richardson and Stoffels (2011b) identifies several key knowledge gaps hindering the understanding of the whole Lake Moodemere–Sunday Creek wetland complex and the likely effects of the proposed changes to water delivery. These are as follows:

- "Regional context — poor knowledge of the aquatic vertebrate fauna in other regional wetlands, particularly along the Murray River between lakes Hume and Mulwala, make it difficult to properly determine the biodiversity value of Lake Moodemere. Also, we have little knowledge of the likely sources from which new species may re-colonise Lake Moodemere. Aquatic vertebrate surveys of regional wetlands required to address this knowledge gap.
- Sunday Creek aquatic vertebrate assemblage — as our only survey was conducted in winter, we probably only know a subset of the species that inhabit this wetland. Summer sampling is required and expected to result in a larger species list.
- Effects of summer 2010/11 flooding — this knowledge gap pertains to both the observed aquatic vertebrate assemblages in Lake Moodemere–Sunday Creek and to the hypoxic

blackwater event in the northern end of Sunday Creek. Was what we observed 'normal' of any given year, or as a result of the flooding event? Continued monitoring of aquatic vertebrates in Lake Moodemere–Sunday Creek is required to address the first question. A summer characterisation of the water quality gradient and aquatic vertebrate assemblage in Lake Moodemere–Sunday Creek is required to answer the second.

- Is Sunday Creek a thermal refuge — characterising the water quality gradient in winter did not adequately address this knowledge gap. Whilst we could demonstrate that the distributions of aquatic vertebrates in Lake Moodemere–Sunday Creek are linked to water quality, we could not determine how variable water temperature in the wetland complex is in comparison with the Murray River. A summer characterisation of the water quality gradient in Lake Moodemere–Sunday Creek is required to address this knowledge gap."

## 8.4 Frogs

It is likely that other species of frogs occur in the lake and wetlands and that these would be detected if the area was searched during seasons when frog species are active. In order to comprehensively survey the frogs of the area further surveys would have to be conducted in spring, summer and autumn (Australian Ecosystems 2011).

## 8.5 Birds and vegetation

No specific knowledge gaps in relation to birds and vegetation communities have been identified however as noted in Australian Ecosystems (2011) the re-instatement of a more natural hydrological regime to Lake Moodemere and its associated wetlands is accompanied by potential risks. A comprehensive program to monitor the condition of vegetation composition, structure and health and the associated diversity and abundance of fauna populations is recommended if any such change is to be implemented.

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# APPENDIX A AQUATIC VERTEBRATE ASSESSMENT

# APPENDIX B FLORA, BIRD AND FROG ASSESSMENT