
Lake Albert Scoping Study Literature Review



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1 Introduction

1.1 Purpose

The Lake Albert Scoping Study is one of 20 management actions under the Coorong, Lower Lakes and Murray Mouth (CLLMM) Recovery Project. The \$137 million CLLMM Recovery Project is part of the South Australian Government's \$610 million *Murray Futures* program, funded by the Australian Government's *Water for the Future* initiative.

The Lake Albert Scoping Study (The Study) is investigating potential options for the long-term management of Lake Albert water quality and the Narrung Narrows. The Study aims to identify flow and water level targets under different climatic scenarios to sustain water quality and ecological health in Lake Albert, including summarising environmental condition targets. The Study is being informed by a community-based reference group, and will culminate in the development of a future directions paper (Options Paper), and the preparation of a Business Case as required. The objectives of the Study are consistent with the outcomes of the CLLMM Recovery Project, including;

- The lake remains predominantly freshwater and operates at variable water levels;
- Its biological and ecological features are protected;
- There is a return of amenity for local residents and their communities;
- There are adequate flows of suitable quality water to maintain Ngarrindjeri cultural life;
- Tourism and recreation businesses can utilise the lake; and
- Productive and profitable primary industries continue

The outcomes of the CLLMM Recovery Project are consistent with the ecological objectives of the long-term plan for the CLLMM region (*Securing the Future: A long-term plan for the Coorong, Lower Lakes and Murray Mouth*).

The Lake Albert Scoping Study Literature Review forms part of Phase One of the Lake Albert Scoping Study, and is a deliverable under the *Deed of Variation to the Project Schedule for the South Australian Priority Project SA-07: Coorong, Lower Lakes and Murray Mouth Recovery Project*.

The purpose of the Literature Review is to review existing information and reports related to Lake Albert and the Narrung Narrows, including considering historic environmental conditions and present environmental conditions. Undertaking this review will help inform development of an Options Paper, and assist in determining what, if any, management action(s) should be implemented to assist with managing Lake Albert water quality.

1.2 Scope

This Literature Review will provide an overview of the CLLMM region, and a focused overview of Lake Albert and the Narrung Narrows. The overview of Lake Albert will include discussion of climate, geology, bathymetry, groundwater and resource and environmental values of Lake Albert and the Narrung Narrows.

The review will also include a summary of existing information regarding environmental conditions in Lake Albert, comparing historical conditions with current conditions. Environmental conditions considered in this review will include: water level and regime; water quality; salinity levels; habitat, including vegetation and wetlands; birds; and fish.

The review will provide a summary of the key issues affecting Lake Albert, particularly issues pertaining to managing water quality. The review will also identify and summarise reports and investigations which have previously considered management options to address water quality issues in Lake Albert. Management options previously investigated and raised by the community that will be discussed in this review include: removal of the Narrung causeway; dredging of the Narrung Narrows; construction of a channel or pipeline from the southern end of Lake Albert to the Coorong; installation of a permanent regulating structure across the Narrung Narrows; the construction of a groyne through the centre of Lake Albert; the construction of a central bund in Lake Albert; and variation of water levels in Lakes Albert and Alexandrina.

2 The Coorong, Lower Lakes and Murray Mouth Region

The River Murray exits in South Australia at the terminus of Australia's largest river system, the Murray-Darling; passing through Lake Alexandrina, past Lake Albert, and into the Coorong, the Murray Estuary, and, finally, through the Murray Mouth into the Southern Ocean. The CLLMM region is comprised of Lakes Alexandrina and Albert, and the Coorong Lagoon (**Figure 1**). The Coorong itself can be separated into three sub-regions: the Murray Mouth/Estuary, and the North and South Lagoons. The River Murray flows into the northern end of Lake Alexandrina. Unlike Lake Alexandrina, Lake Albert, which lies to the south east of Lake Alexandrina, is a terminal lake as it is not physically connected to the Coorong, and experiences no through flow of river water (Ebsary, 1983). Water passes between Lake Albert and Lake Alexandrina through a restriction called Albert Passage, but more commonly known as the Narrung Narrows.

The CLLMM region covers a total area of 140,500 Ha and encompassing 23 different wetland types (Phillips & Muller, 2006). The region is a complex ecosystem that encompasses riverine, lentic, wetland, terrestrial, littoral, estuarine, marine, and hypersaline habitats (DENR 2011). The CLLMM region also supports numerous threatened and migratory species protected under state and international agreements, and state and federal legislation.

The Lower Lakes cover approximately 650 square kilometres which make them the largest freshwater body in South Australia (DEH 2000). Lake Albert is the smaller of the two lakes (at +0.75 m AHD, volume 282.2 GL, surface area 177.1 km², mean depth 1.7 m) compared to Lake Alexandrina (at +0.75 m AHD, 1,629.4 GL, 662.3 km², and 2.8 m) (BMT WBM, 2013). The lakes receive freshwater inflows from the River Murray, the Eastern Mount Lofty Ranges tributaries, groundwater discharge, local run-off, and rainfall on the lakes surface.

Lakes Alexandrina and Albert (the Lower Lakes) are isolated from the Murray Mouth and Coorong by a system of barrages, with 593 independently operated gates across five structures (MDBC, 2006). The network of barrages were constructed between 1935 and 1940 to provide fresh water for irrigation, stock, and domestic purposes.

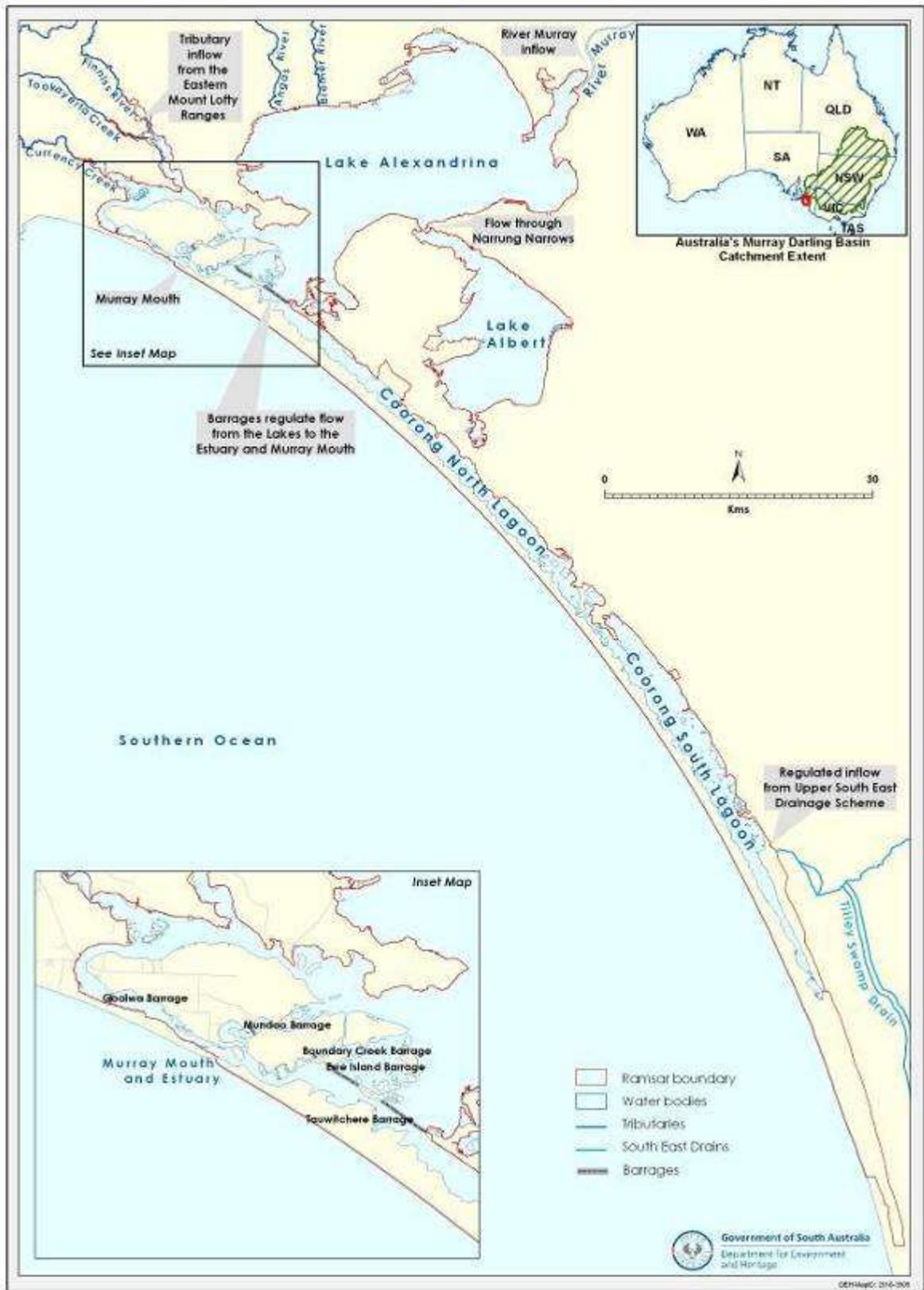


Figure 1: The Coorong, Lower Lakes and Murray Mouth site

In 1985, the CLLMM region was designated as a 'Wetland of International Importance' under the Ramsar Convention on Wetlands (the Coorong, and Lakes Alexandrina and Albert Wetland of International Importance). The region was listed for its physical and biological diversity and spectacular populations of migratory shorebirds, and satisfied at least eight of the nine criteria for listing when the site's Ecological Character Description (ECD) was completed in 2006. The ecological character of the site is protected under the national *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). The South Australian Government is responsible for providing primary legislation and policy for management of the wetland, and to report to the Australian Government on the status of the site, including any changes in ecological character.

3 Description of the CLLMM region

The following section provides a brief description of the CLLMM region, focussing on Lake Albert and the Narrung Narrows area. The description includes climate, topography, bathymetry, geology, hydrogeology, population, and resource use.

3.1 Climate

Ebsary (1983) identified the climate of the CLLMM region as typically Mediterranean, with mild, wet winters and hot, dry summers. Mean annual rainfall has been estimated as 463 mm for Lake Albert. Of this rainfall, 300 mm falls during the six months from May to October. Mean annual Class A pan evaporation has been estimated as 1660 mm. Using a pan factor of 0.69 to convert pan evaporation to lake evaporation shows that on average, rainfall exceeds lake evaporation only during the three months of winter.

The mean daily maximum temperature at Meningie for the winter months is around 15° Celsius, and rises to around 26° Celsius during the summer months. Daily summer temperatures can be as low as 10° Celsius, and as high as 40° Celsius. The range of temperatures encountered during winter months is 2° to 18° Celsius and frosts can be expected during cold nights.

3.2 Topography

Ebsary (1983) describes Lake Albert as a body of water formed in the depression between two sand ridges lying parallel to the coast. To the south, the lake is separated from the Coorong by a ridge of elevation between 10 and 20 metres. Recent topographic surveys indicate rises up to 30 m AHD between the Coorong and Lake Albert (DENR 2011). A larger sand dune forms the northern boundary of the lake. Elevations of 50 metres AHD within 1 kilometre of the lake are common.

The countryside surrounding Lake Albert is primarily low, flat grassland or swamp. The Narrung Peninsula is particularly low lying, with most of the area below 10 metres AHD elevation. Many areas are subject to inundation, and this has led to the formation of numerous salt pans. South and east of Meningie, the land is also low lying, but less flat than the Narrung Peninsula. Adjacent to the north east corner of Lake Albert is the large Waltowa Swamp.

Phillips and Muller (2006) note that the slow-moving Lake Albert waters allow for the deposition of silts and sediments, particularly at the southern end of the lake where extensive siltation reduces water depth and topographical diversity.

3.3 Bathymetry

Lake Albert is a broad and shallow waterbody. The lowest and deepest point in Lake Albert is at -1.75 m AHD (Phillips and Muller 2006). Below is a map illustrating the bathymetry of Lake Albert.

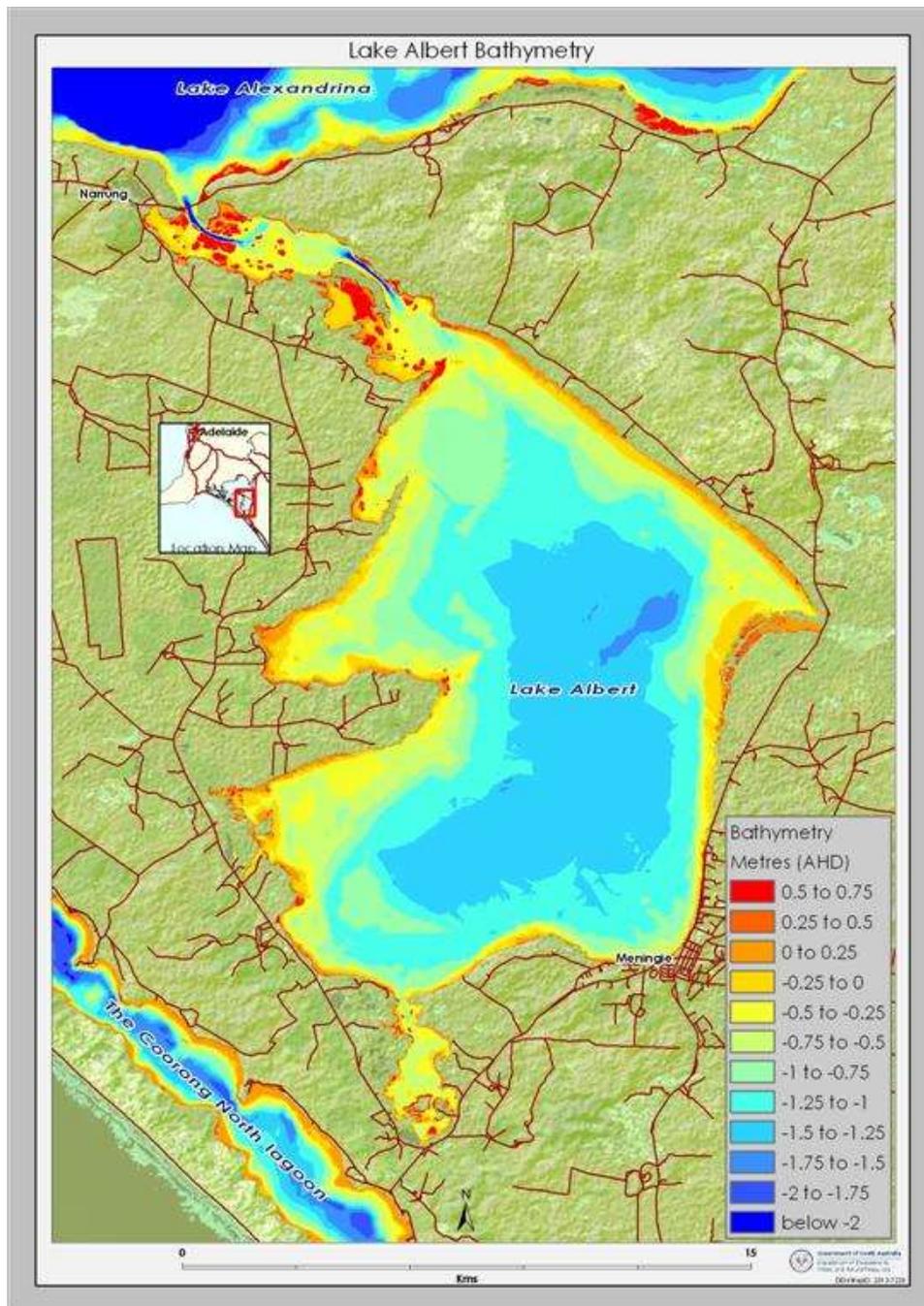


Figure 2: Lake Albert bathymetry

3.4 Geology

Lake Albert is underlain by tertiary sandy limestone marine sediments. Overlaying these sediments are stranded coastal dunes of the Pleistocene Bridgewater Formation, exposed to the east of Meningie and north of the lake. Rippon calcrete separates the upper member from the lower member of the Bridgewater Formation and is exposed on the Narrung Peninsula and to the south west of Meningie. Low lying swamp areas around the lake are recent alluvial flat deposits. Granites are exposed near the north east corner of Lake Albert and probably extend beneath the northern half of the lake as a basement high (Ebsary, 1983).

3.5 Hydrogeology

Ebsary (1983) notes that available groundwater data indicates a very gentle regional gradient toward the sea, resulting in a movement of groundwater toward Lake Albert from the north east. Regional groundwater flow is very slow and irrigation carried out near the lake produces a localised flow of groundwater toward the lake from all directions.

A considerable variation in groundwater salinity exists throughout the area, although generally the range is 10,000-20,000 EC units. Low salinities of a few thousand EC units may be found near the lake edge, while salinities in excess of 40,000 EC units are common near numerous salt pans on the Narrung Peninsula, probably caused by evaporation from the water table (Ebsary 1983).

SKM (2009) notes that groundwater flows through two major aquifer systems: a regionally confined aquifer, and an underlying confined aquifer with sand and bryozoal limestone (coral) layers. In the east of the investigation area the two aquifers are separated by a low permeability aquitard usually made up of dark-brown carbonaceous clay.

Rural Solutions (n.d.) prepared a brief summary of groundwater resources in the Lake Albert and Narrung Peninsula area. The report acknowledges that data relating to the quaternary limestone aquifer in the Lake Albert area is limited. Depth to groundwater varies across the existing bores from less than two metres to greater than 20 metres. Water level data indicates that water levels in the majority of monitored wells on the Narrung Peninsula had been dropping rapidly over recent years due to low rainfall conditions in the area limiting aquifer recharge.

Groundwater salinity typically ranges from 2,000 mg/L [3,000 EC] to over 100,000 mg/L [65,000 EC] and is alkaline. Water in the lower end of this salinity range can be suitable for stock watering, the primary use of this resource on the Narrung Peninsula. Significant groundwater extraction would likely lead to a rise in groundwater salinity.

Phillips & Muller (2006) explain that the groundwater table is shallow and saline under much of Lake Albert's floodplain and thus groundwater discharge creates seasonal and permanent salt-water marshes in depressions or swales around the lake edge.

In a report on element and nutrient balances in the Lower Lakes, Cook *et al.* (2008) conclude that the Lower Lakes are a substantial source of salts and that this is primarily due to saline groundwater entering the lakes – either directly or via the River Murray. They do, however, recommend further studies on the hydrology and geochemistry of the groundwater in the region are carried out in order that this hypothesis can be further explored.

The hydrogeology of the Coorong and Lower Lakes region is also discussed by Haese *et al.* (2008). The Coorong and Lower Lakes are located in the south-western edge of the Murray Geological Basin. The significant aquifers (geological formations which hold water) in this region are the Quaternary and Murray Group Limestone sequences, and the deeper Renmark

Group sands. The limestone sequences are in good hydraulic connection and form the shallow watertable aquifer. The Renmark and Murray Groups are separated by a series of confining clay aquitards.

Major processes such as groundwater discharge, dryland salinisation, irrigation, and groundwater/surface water interaction were identified within this region. Dryland salinity in the region is a major land degradation problem on the low-lying coastal plain, where clearing of native vegetation has led to a rising watertable. The risk of salinisation is most prevalent where depth to the watertable is less than two metres.

Groundwater flows radially from the zone of recharge at Dundas Plateau in the east, northward to the Murray River or westward, discharging to the Coorong, the Lower Lakes or low-lying salinised areas.

On the western side of Lake Alexandrina, the watertable is within a Quaternary clay which overlies and semi-confines the limestone aquifer. Elsewhere in low-lying areas around the Lower Lakes, the watertable occurs in organic-rich clays which were deposited when the Lower Lakes expanded in response to higher sea level about 6,000 years ago. These areas contain highly saline groundwater (>70,000 EC) due to strong evaporative discharge which has lowered the watertable below sea level. These areas are the focus for regional groundwater discharge in preference to the Lower Lakes which are at a higher level of ~0.75 m AHD.

3.6 Soil

The soils surrounding Lake Albert have formed from Quaternary Bridgewater and St Kilda Formations deposition. The soils within Lake Albert have also formed mostly as part of the St Kilda Formation under subaqueous conditions, but are distinguished from other soil material by having properties that can be affected by the oxidation of reduced inorganic sulfides (acid sulfate soil materials).

In 1931, Taylor published a report on the soils of the bed of Lake Albert. A survey of the bed of Lake Albert was undertaken to analyse its suitability for dry farming, or for production under irrigation. The report demonstrates that the bed of Lake Albert is not suitable for agricultural purposes.

The soils of the bed of Lake Albert were grouped into seven classes by Taylor (1931). **Table 1** below has been adapted from Taylor 1931.

Table 1: Description of Lake Albert soil classes adapted from Taylor 1931.

Soil Type	Description	Area (acres)	Proportion of total area surveyed
A	Deep uniform clay, more than 13 feet deep	10,000	29.5
B	10-13 feet of uniform clay over hard sandy bottom	2,250	6.6
C	6-10 feet of uniform clay over hard sandy bottom	3,050	9.0
D	2-6 feet of uniform clay over hard sandy bottom	2,850	8.4
E	Less than 2 feet of clay over sandy bottom	10,200	30.0
F	Less than 2 feet of clay over limestone rock	3,250	9.5

G	2-6 feet of uniform clay over limestone rock	2,400	7.0
Total area surveyed		34,000	

In 2008, Fitzpatrick *et. al.* undertook a study which analysed soil profiles from Lake Albert, Lake Alexandrina and the River Murray system below Blanchetown (Lock 1) in South Australia in order to assess potential impacts of acid sulfate soils during the drought (2006-2010). The results of this study showed that acid sulfate soil materials were present in Lake Albert. "Sulfidic subaqueous soil and sulfuric soil marginally co-dominate in equal measures with sulfuric organic clayey soil, sulfidic subaqueous clayey soil, sulfidic soils and sulfidic cracking clay soil" (Fitzpatrick *et. al.* 2008, p 34).

Fitzpatrick *et. al.* used bathymetry, soil cores and vegetation mapping to predict the distribution of acid sulfate soil sub-types according to the following water-level scenarios: pre-drought water level (+0.5 m AHD); current water level as at February 2008 (-0.5 m AHD); and a further 1m drop in water levels (-1.5 m AHD). The report notes that as water levels drop, "aqueous soils become de-watered (dry, aerated) and thus potentially sulfuric (pH < 4) if sufficient sulfidic material is present in the drying layers" (Fitzpatrick *et. al.* 2008, p 59).

Figure 3 below depicts the predictive changes in acid sulfate soil material as water levels decline.

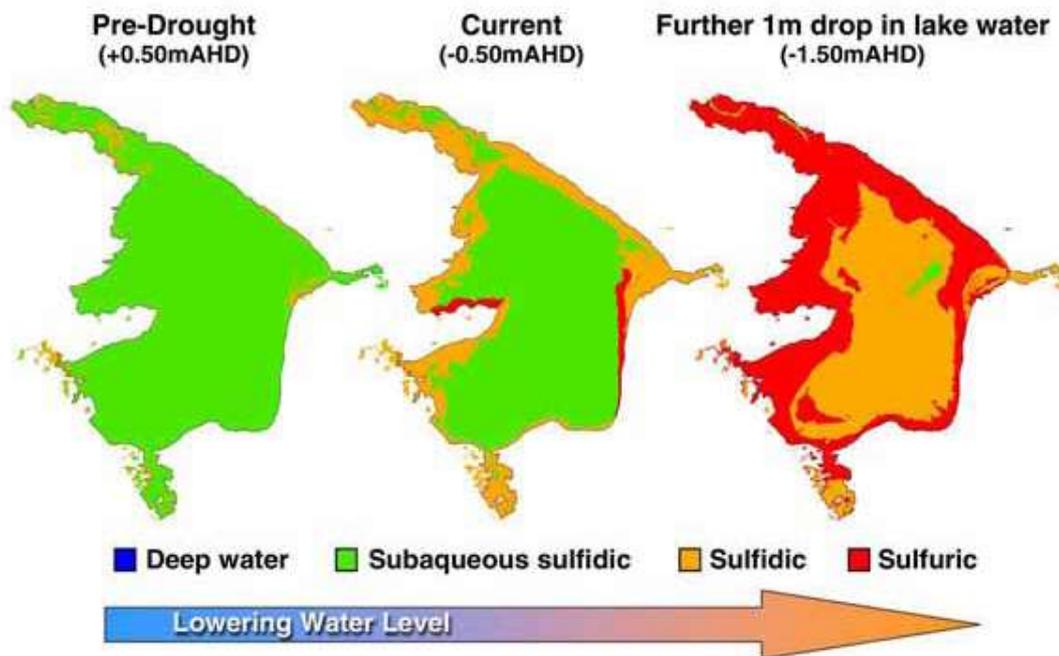


Figure 3: Predictive scenario maps depicting changes in ASS materials at different water levels in Lake Albert (+0.5 m AHD, -0.5 m AHD and -1.5 m AHD) as at 2008.

3.7 Population

The CLLMM region supports local communities which are dependant on an economy based on utilising the region through tourism, recreation, and primary industries. Surrounding towns include Goolwa, Clayton, Milang, Meningie, Wellington, Hindmarsh Island, Narrung, Langhorne Creek, Raukkan, and Salt Creek. The total population is approximately 30,000, of which more than 4,000 are Ngarrindjeri people who live and work on their traditional lands, primarily around Meningie, Raukkan, and Narrung (ABS, 2011).

The CLLMM region is a culturally and spiritually significant site for the Traditional Owners, the Ngarrindjeri. The CLLMM region is of central significance to the life and culture of the

Ngarrindjeri people – the land and waters of the CLLMM region must be healthy for the Ngarrindjeri to be healthy. The CLLMM region includes the “Meeting of the Waters” site, an area recognised as the place where the fresh and salt waters meet and mix and an important place for the reproduction of life.

3.8 Economic Values

3.8.1 Expansion of Economic Activity

Ebsary (1983) discussed the development of the Lake Albert region from the late 1800s to 1983. From the late 1800s until the construction of the barrages in 1940, the area consisted of large sheep and beef grazing estates. Small dryland dairy farms emerged in the years between the World Wars.

The large body of freshwater created by the construction of the barrages led to the introduction of flood irrigation in the late 1940s. By the early 1950s, there were sufficient dairies in the area to require the building of a small milk receiver factory at Meningie.

In 1954, Campbell Park Estate was purchased by the Government as a War Service Land Settlement Scheme and 14 dairy farmers were established in the area. Owners were discouraged from irrigating, but because farm sizes were inadequate to provide profitable enterprise without irrigation, sprinkler irrigation was established in 1958-59. In 1960, the area was restructured, and although only 11 farmers remained, irrigation had been introduced and the district began to grow.

Irrigation was limited to properties that bordered the lake initially, and therefore evolved in a fragmentary manner. A soil survey that was conducted identified the west and south east areas of Lake Albert as having the greatest potential for irrigation-based activities. However, the high costs of pumping water large distances precluded development in these areas.

During the 1960s, improved irrigation equipment became readily available, and this led to an expansion of irrigated areas. The issue of irrigation licences was frozen in 1968, but the amount of irrigation increased for a number of years after this due to the use of dormant licences. The area of irrigated land peaked in the early 1970s and remained relatively constant through to the mid-1980s because of the restrictions imposed by the irrigation licensing system.

In 1983, Ebsary noted that approximately 2,200 hectares were irrigated by Lake Albert water. This consisted mainly of Lucerne. The predominant form of agriculture in the area was self-contained dairying, with stud sheep, beef, and race horses. Several properties, at the time the report was prepared, provided feed to the sheep export trade, while some contributed to the dairy industry.

3.8.2 Present Economic Values

In 2006-2007 the Gross Regional Product (GRP) of the CLLMM region was \$686 million, including \$124 million from primary industries of which \$43 million was for irrigated agriculture. The GRP of the CLLMM region accounted for approximately 1 % of Gross State Product in 2006-07 (Econsearch, 2009). It is expected that the primary contributor to the primary industries GRP is the Lake Alexandrina region.

The CLLMM region contributes to tourism for the Fleurieu region, which generates approximately \$326 million and attracts around 652,000 overnight visitors per year (note that exact figures of the CLLMM region are not known). The services sector of the Fleurieu, supporting tourism and primary production, accounts for 8 % of GRP, and 15 % of all

employment (DEWNR, 2013b). Further information on the economic value of Lake Albert could not be easily identified at the time of writing.

3.9 Resource Use

The River Murray is a critical source of water and, combined with the Lower Lakes area, provides water for agriculture and town drinking supplies for approximately 27,000 people, although the recent [January 2009] installation of potable and irrigation pipelines has reduced the reliance of communities on water from the Lower Lakes (DEH 2010b).

Importantly, the region supplies 80 per cent of the total Mulloway catch for South Australia (Pierce, 1995), as well as significant quantities of Callop, European Carp, Bony Bream, Black Bream, Coorong Mullet and Goolwa Cockles. The fishery works within its own management plan which includes the deliberate over-harvesting of European Carp in order to enhance aquatic environmental benefits. There is also a significant recreational fishery; however, its value has not been estimated.

“Commercial fishing families work hard to produce high quality product for their regional, state and interstate customers, the most popular being the iconic Coorong Mullet. Since 2008 four key species, Mullet, Mulloway, Pipis and Golden Perch have been certified as sustainable by the Marine Stewardship Council, the world’s highest environmental standard for fisheries.

The rotational harvest strategy of the fishery also allows us to target Black Bream, Flounder and Redfin as well as Bony Bream and Carp. The bait harvest supports the state’s valuable Rock Lobster industry.

Coorong fishermen are saying that they have never seen conditions as good as this, since natural flows have returned to the estuary.

Gross Value of Production figures for all Lakes and Coorong Commercial Fishery species are published annually by Econsearch (Economic Indicators for the Lakes & Coorong Fishery)”.
(Glen Hill, 2013, pers com)

3.9.1 Land Use

The CLLMM region has a mix of primary industries that is predominantly irrigated and dryland agriculture, manufacturing industries related to wine, machinery and equipment, boat building and maintenance, and recreation and tourism activity and historically irrigated agriculture (DEH 2010a). Sheep, beef and dairy cattle farming; grain, vegetable, fruit and nut growing; viticulture and fishing are the main primary industries in the area. There is also a significant urban population with associated housing and service sectors.

There has been a notable shift away from irrigated crops during the recent drought. Phillips and Miles (2009) undertook an analysis of the Coorong, and Lakes Alexandrina and Albert Ramsar site and its surrounds to determine the extent of wetland ecosystems and change, to monitor revegetation efforts, and to potentially assess the socio-economic impact on the region.

“A Normalised Difference Vegetation Index (NDVI) analysis was used at two dates to investigate Photosynthetic Activity (PA) activity in seven land use classes, including economic cultural and ecological land use areas as Lake Albert water levels receded between March 2005 and March 2008”.

Referring to **Figure 4**,

“The March 2005 NDVI shows medium PA evenly spread throughout the scene, with higher activity along channel borders and waters edge (water levels at approximately +0.65 m AHD). Very high PA signals were noted in the irrigated pivot circles throughout the area of interest. The March 2008 NDVI shows generally lower levels of PA throughout (water levels at -0.48 m AHD). The medium and high PA signal is most noticeably absent throughout the scene. In the Narrung channel, wetlands have a smaller area of high PA, while the extent of wetlands is decreasing. The intensity of the signal around the lake edge wetlands has diminished markedly, and irrigated crop pivot circles are greatly reduced in number”.

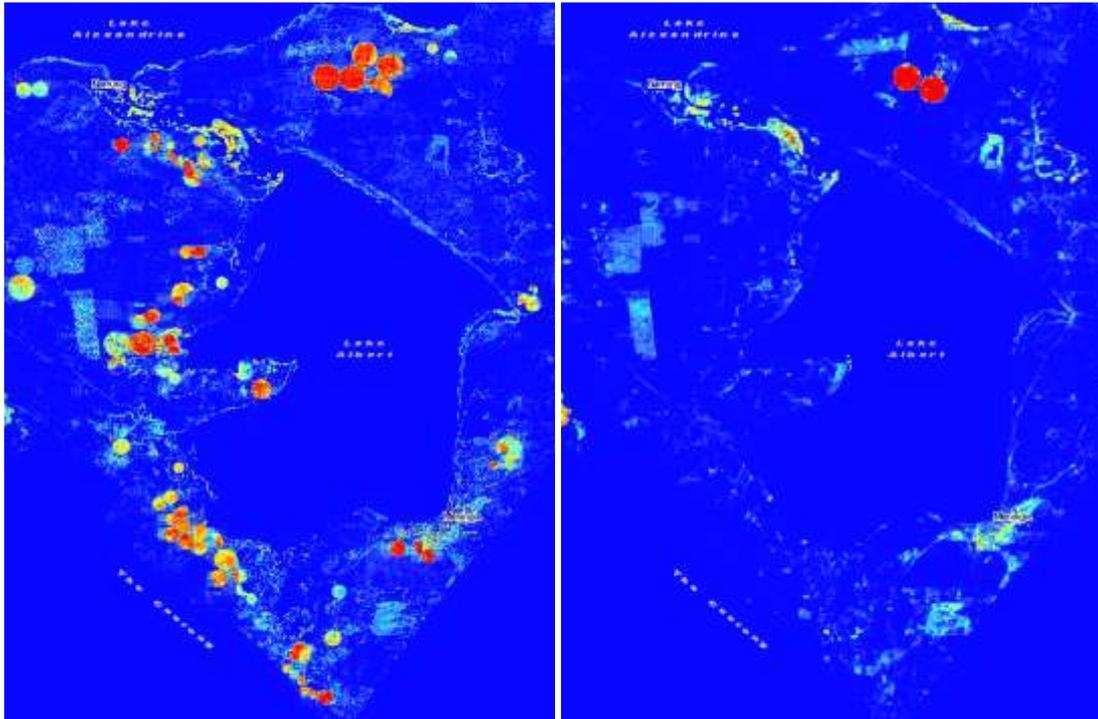


Figure 4: A comparison of March 2005 (left image) and March 2008 (right image) Normalised Difference Vegetation Index (Phillips and Miles, 2009)

Sobels (2011) notes in a study of impacts to the communities of the Lower Lakes from loss of access to irrigation water since 2006, that:

“...on the Narrung Peninsula there are 76 centre pivots most of which had been idle for three to four years. Conservatively they would each cost \$250,000 to replace and around \$40,000 each to refurbish. Most of them will not be used again for a variety of reasons to do with the individual farmer’s situation including a lack of certainty about access and supply. The number of irrigated dairy farms had reduced from 17 to three in the same period.

A crucial, key outcome of this situation is changed land use on the Narrung Peninsula. By January 2011 an estimated 3,500 acres (1,400 hectares) of irrigated dairy and beef farms had been converted to cropping, much of which had been purchased by a single farmer from the Mid-North of SA.”

These changes had effects on employment, on the land, and also indirect employment ramifications for local communities (Sobels, 2011).

In response to the severe region-wide drought, the \$35 million Taillem Bend to Narrung pipeline project was brought forward to meet the needs of farmers who would have had to begin culling stock on or about the middle of December 2008 because they had almost no water and salinity was increasing rapidly. At the time Sobels prepared the study in mid-2011, irrigators with a licence around Lake Albert were still unable to use the lake water due to salinity of around 7,000 EC units. The pipeline to the Narrung Peninsula delivers stock and domestic water as distinct from the Creeks Pipeline which is primarily for irrigation purposes.

The rapid change of land use from irrigation-reliant industries to dry land agriculture use over a very short period of time, combined with the uncertainty caused by the lack of water/irrigation access within Meningie and the Narrung Peninsula resulted in General Valuation changes (Sobels, 2011). A letter documenting the changes in General Valuation from 2005/6 to 2010/11 from the Deputy Valuer-General to the President, Lower Lakes and Coorong Infrastructure Committee dated 16 March 2012 is provided as **Attachment A**.

4 Environmental Conditions

The following section provides a summary of existing information regarding environmental conditions in Lake Albert, comparing historical conditions with current conditions. The terms 'historical' and 'current' are used loosely in their definitions but generally 'historic' is pre the 2006 -2010 drought and 'current' refers to during and post drought. Environmental conditions considered in this section include: water level and water regime; water quality; salinity; habitat, including vegetation and wetlands; birds; and fish. For the purposes of this section current conditions is proposed to include conditions post-drought. Where information is available, historic conditions includes pre and post-European settlement.

4.1 Water level and water regime

4.1.1 Historic Conditions

Phillips and Muller (2006) note of water levels prior to European settlement:

“lake levels started to rise from groundwater inputs entering the lakes prior to the first rains in late autumn (presumably driven by decreasing atmospheric pressure). Lake levels would steadily rise through winter, driven by EMLR (Eastern Mount Lofty Ranges) tributary inflows, rainfall on the lakes and groundwater inputs, with levels peaking in late spring-early summer when River Murray flows came from the headwaters. Over summer, water levels would slowly drop when evaporation exceeded trickling inputs from draining groundwater and the tributaries of Lake Alexandrina.” (Phillips and Muller 2006, p 190)

4.1.2 Current Conditions

Lake Alexandrina receives freshwater from rainfall, runoff from the local floodplain, and from inflows from the River Murray, the tributaries and from discharging groundwater. The land-locked Lake Albert receives some of these waters through the Narrung Narrows, and is supplemented by inputs from rainfall, local runoff and groundwater flows. Wind patterns (speed and direction) greatly influence flow patterns and water levels by 'tilting' the lake surface, or by creating waves that generate head differences between the lakes themselves, and between connected water bodies. (Phillips and Muller 2006, p 201)

Since the construction of the barrages in the 1930s/40s, the water levels of Lake Alexandrina and Lake Albert have been regulated by inflows from the River Murray and outflows through

the opening of the barrage gates. Initially built to provide fresh water for the local community and for river transportation, the barrages, and therefore lake levels, in recent times have been managed primarily to ensure irrigation supply through summer when River Murray and tributary inflows, and rainfall are lowest, and evapo-transpiration is greatest. (Phillips and Muller 2006, p 190)

At the height of the recent drought (2006-2010), Lake Albert water levels dropped to -0.5 m AHD. Following improved River Murray inflows to the region in 2010/11 and the breaching and subsequent removal of Narrung Bund, Lake Albert water levels returned to pre-drought levels. As at 25 August 2013, Lake Albert water levels were recorded at approximately 0.85 metres AHD. **Figure 5** below shows the Lake Albert mean lake levels from July 2012 to July 2013.

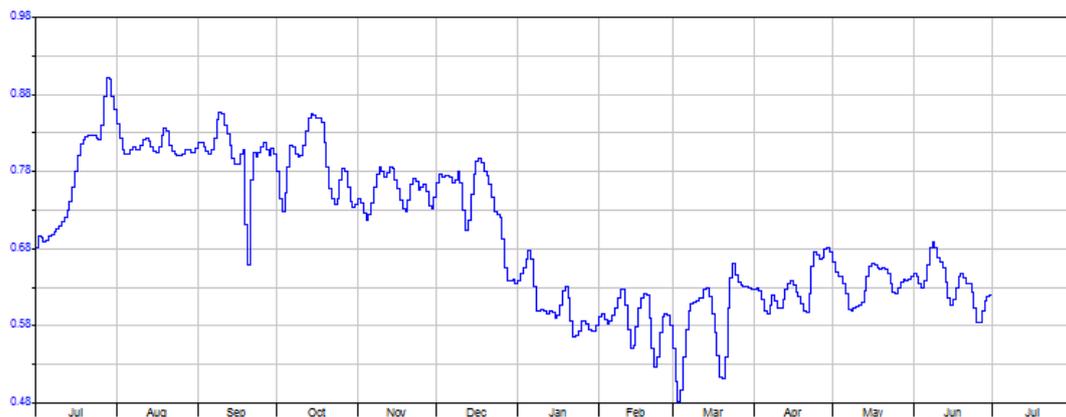


Figure 5: Yearly Lake Albert water level in metres (calculated mean lake level) from 1 July 2012 to 1 July 2013.

http://riverdata.mdba.gov.au/sitereports/lkalbert/mdba_lkalbert_site_report.html. Accessed 1 July 2013

The *Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Water Management Plan* (in draft) proposes a lake operating regime which fluctuates lake levels for ecological outcomes. The proposed regime and lake levels are shown in **Figure 6** below.

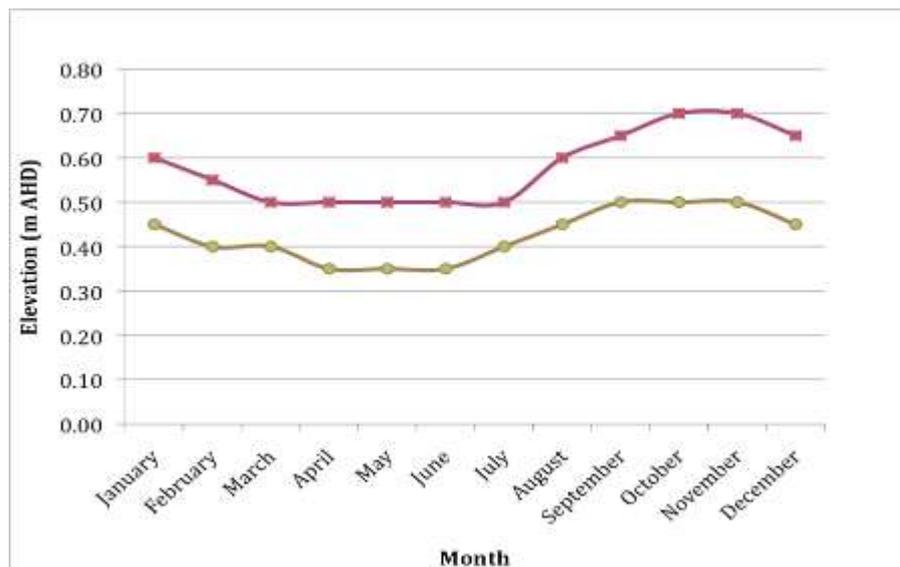


Figure 6: Proposed ideal annual operating envelope for Lakes Alexandrina and Albert showing upper and lower water level limits (*Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Water Management Plan* (draft), 2013)

4.2 Water quality

4.2.1 Historic Conditions

In 1998, the South Australian Environment Protection Authority (EPA) released a water quality monitoring report discussing the results of its ambient water quality monitoring program (October 1995 - December 1997). According to the findings, water quality of Lakes Alexandrina and Albert was poor.

Monthly samples from five sites on Lake Alexandrina and three sites on Lakes Albert were analysed for nutrients, heavy metals, and major ions, and for water clarity and salinity. The results of the analyses were then compared against Australian and New Zealand guidelines for fresh and marine water quality guidelines for each variable measured to designate if the water quality was good, moderate or poor. The water quality of the Lower Lakes was described as poor because of:

- high turbidity in Lake Alexandrina
- moderate nitrogen and phosphorus concentrations
- concentrations of heavy metals exceeding national guidelines for the protection of aquatic ecosystems at some sites
- salinity exceeding the guidelines for good quality drinking water at some sites.

Lake Albert was more saline but less turbid than Lake Alexandrina, and had higher concentrations of some dissolved salts. Lake Alexandrina had higher concentrations of some heavy metals and of total phosphorus.

4.2.2 Current Conditions

A report from the South Australian Environment Protection Authority (2013) which investigated water quality in the CLLMM region during the recent drought, data collected between August 2008 and July 2010 was examined. The report concluded that:

“water quality in the Lower Lakes at the end of the Murray-Darling Basin deteriorated substantially during the hydrological drought from 2007-09... A marked shift to a more saline, turbid and eutrophic system occurred during the drought. These water quality changes were attributed to a lack of flushing, which coupled with lake volume reductions, resulted in concentration of dissolved and suspended material and increased wind-driven re-suspension of sediments as the lakes became much shallower.

Cyanobacterial species became more dominant with one large toxic bloom recorded. Rewetting of exposed acid sulfate soils on the lake margins also resulted in severe surface water acidification and very high soluble metal levels in over 2,000 ha of surface water.” (EPA, 2013, p 77)

Ecological monitoring of the CLLMM region is currently being undertaken as part of the CLLMM Recovery Project. Abiotic monitoring includes surface and shallow groundwater quality (salinity, pH, dissolved oxygen, temperature, metals, alkalinity/acidity, turbidity and nutrients) and acid sulfate soils.

Overall, surface water quality in the Lower Lakes has been shown to have improved as a result of the continued high water levels and inflows from the River in 2011-12. All water quality parameters are back within the Australia and New Zealand Environment Conservation Council (ANZECC) water quality guidelines.

For up to date water quality information, see the EPA's website at http://www.epa.sa.gov.au/environmental_info/water_quality/lower_lakes_monitoring/lake_albert_monitoring

The high flows and cooler water temperatures kept blue green algae under control, although in Lake Albert blue green algae densities were higher than those seen in Lake Alexandrina and the tributaries.

Acid sulfate soil monitoring showed that the neutralisation (to pH >4) rate of acidic soil is highly variable. In some areas, sulfuric (pH <4) conditions continue to persist and the acidification hazard remains high in many parts of the lakes. Consequently, if water levels were to decline below 0 m AHD for a length of time, this could again pose a serious risk to the water quality of the Lower Lakes.

4.3 Salinity

4.3.1 Historic Conditions

Pre-European Settlement

A palaeoecological investigation (Barnett, 1994), concluded that the results of the investigation suggested conditions have been mostly oligosaline-freshwater since the formation of Lake Alexandrina, with an overall increase in freshwater conditions. An investigation by Fluin (2007), which did not include Lake Albert, suggested that Lake Alexandrina was predominantly fresh throughout its history, with marine water indicators never dominant; thereby suggesting that Lake Alexandrina was only moderately influenced by tidal inflow. Major inputs from the River Murray were evident in the diatom assemblages, particularly in the past 2,000 years. As Lake Albert receives its inflows from Lake Alexandrina, this is useful to note.

A palaeoecological investigation of the Lower Lakes including Lake Albert is currently being undertaken (2012-13) by Haynes *et al* (unpublished), will provide information about water quality conditions during the past ~7,000 years. Fossilised diatoms are examined from sediment cores: diatoms (unicellular algae) are excellent indicators of water quality as they are very sensitive to any changes in water quality, such as salinity, and preserve very well in sediments.

In a report by the Murray-Darling Basin Commission (MDBC) in 2001, it is noted that under natural flows conditions, prior to the implementation of regulation and diversions through the Murray-Darling Basin, Lakes Alexandrina and Albert were predominantly fresh water lakes, only becoming brackish or saline at times of low river flow. This is supported by Phillips and Muller (2006) who note that "at the time of European settlement, the lakes were fresh and reliable water sources as evidenced by the importance of townships such as Clayton, Milang and Meningie, and the original intention to locate Adelaide at Currency Creek in the early years." (Phillips and Muller, 2006, p 168)

Post-European Settlement

Phillips and Muller (2006) note that salinity levels in Lakes Alexandrina and Albert have steadily risen as a result of system levers (such as River Murray regulation, extraction, and barrage operation) and anthropogenic impacts. The authors further note that "by the late-1800s, alternative freshwater supplies to the lakes had to be sources from underground supplies for town, stock domestic and industrial supplies." (Phillips and Muller, 2006, p 168)

Lake Albert is naturally more saline than Lake Alexandrina and exhibits more of the original character of the Lower Lakes before their impoundment in 1940. Lake Albert salinity has been measured at Meningie since 1969 (Ebsary, 1983). Since Lake Albert is a terminal lake which experiences high evaporation rates, a salinity gradient exists from north to south. The periodic wind driven inflow of fresher Lake Alexandrina water reduces the salinity of Lake Albert's northern waters thereby increasing the salinity gradient. As the water in the Narrung Narrows is typically fresh, winds from the north west cause a significant freshening of the north east corner of Lake Albert, which is more than 10 kilometres from the end of the Narrows.

As the edges of the lake have gentle slopes, water depths are commonly less than 0.5 metres up to 100 metres from the shore. Evaporation from these shallow areas is expected to result in lake edge salinities being higher than the body of the lake. Backwaters in the south west corner of the lake, and the appendage to the south, consistently record higher than average salinities because their isolation prevents an adequate flushing effect (Ebsary, 1983).

Ebsary (1983) notes that peaks in salinity occur during summer due to low lakes levels, peak groundwater return flows, and high evaporation rates. Meningie salinity is usually at its highest toward the end of the irrigation season (end of summer) because of the additive effects of concentration due to evaporation and highly saline return flows due to heavy irrigation. Low lake levels compound the salinity problem because they cause a greater inflow of saline groundwater. The head forcing groundwater to flow into the lake is the difference between the groundwater and lake levels. Under normal lake conditions, this driving head is only a few metres, thus lake levels have only to fall a small amount to increase the head by a relatively large amount. As groundwater inflow is proportional to the driving head, decreases in lake level can cause significant increases in the quantity of salt returned to the lake by irrigation.

Salt water intrusions into the lake environment were not common until after 1900 when significant water resource development had occurred in the River Murray system (Sim & Muller, 2004). Short-lived intrusions would occur during periods of low flow down river, resulting in a lower lake level. However, it appears that only small areas of the lakes, around the mouth and channels, were affected (Sim & Muller, 2004).

Taylor (1931) notes that in 1930, when the report was prepared, "the water of the lake [were] slightly saline, [with] the salinity vary[ing] with seasonal conditions..." The author further notes that in March-April 1930, Lake Albert water was "affected by incoming sea water from Lake Alexandrina, which had become very saline as a further consequence of the low river level, so that Lake Albert was not potable for humans and taken unwillingly by stock until accustomed to it".

Phillips and Muller (2006) indicate that Lake Albert salinities typically reach conductivities of up to 3,000 EC at the end of periods of low River Murray inflows. The authors further note that the lakes were fresher prior to the closure of the Murray Mouth in 1981; for example, Lake Albert regularly recorded salinities of between 600 EC (at the end of winter) and 900 EC (at the end of summer). Since 2000, salinity levels in Lake Albert have ranged between approximately 1,300 EC and 2,300 EC (Phillips and Muller, 2006).

4.3.2 Current conditions

As water levels in CLLMM region dropped during the recent drought (2006-2010), salinity levels increased. Evapo-concentration and the influx of marine water through the barrages into Lake Alexandrina (facilitated by head difference between the higher seas and the lower water level in the lakes) and the reduction in salt export from the River Murray waters (**Figure**

7) led to salinity levels in both lakes increasing beyond values normally associated with freshwater environments (the normal value is generally less than 1000 EC).

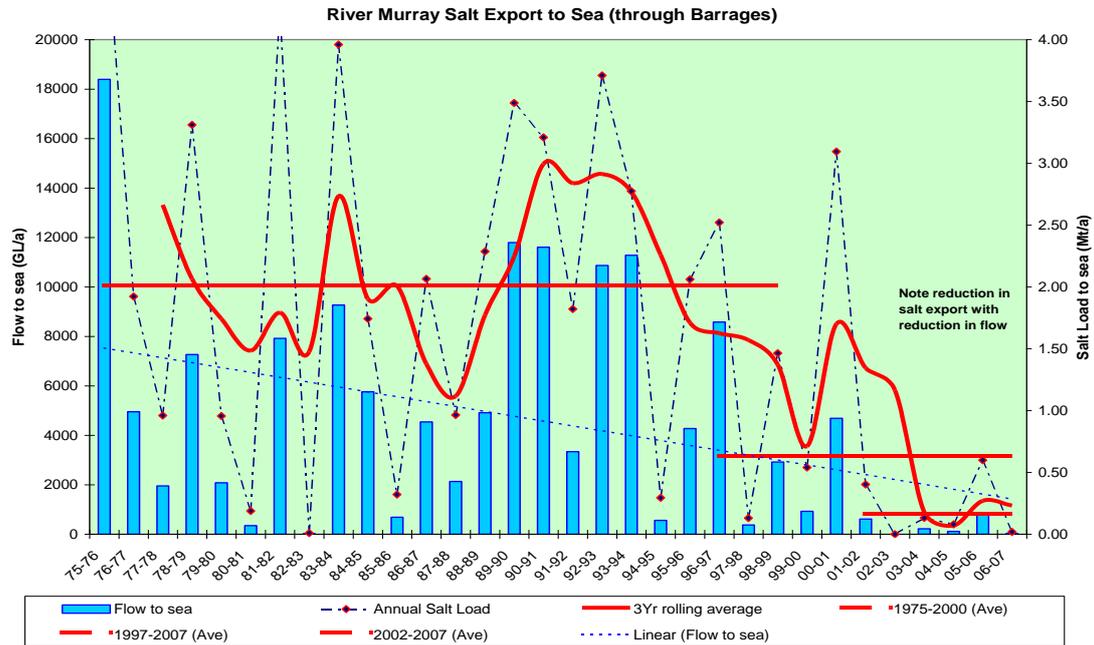


Figure 7: River Murray Salt Export to Sea (through Barrages)

In early 2010, salinity levels in Lake Albert peaked at around 22,000 EC (EPA, 2013). During the drought, when the Narrung Bund was constructed and water was pumped to Lake Albert from Lake Alexandrina, a distinct spatial variation in salinity was observed, with lower salinity levels observed near the Narrung Narrows, grading to higher levels in the southwest region of the lake. Following the breaching of the bund this spatial variation was accentuated. (EPA, 2013)

As seen in **Figure 8**, following significant rainfall and flooding in the Murray-Darling Basin throughout winter and spring 2010, the Lower Lakes refilled quickly. Salinity levels in Lakes Albert quickly dropped to approximately 10,000 EC shortly after the Narrung Bund was breached in September, predominantly as a result of dilution on refilling. While this was a dramatic decrease at this time, further salinity reduction has been a slow process. By June 2012, salinity had still only declined to between 3,400 EC and 4,300 EC. As of early October 2013, the 7-day rolling average salinity in Lake Albert was approximately 2,500-2,600 EC.

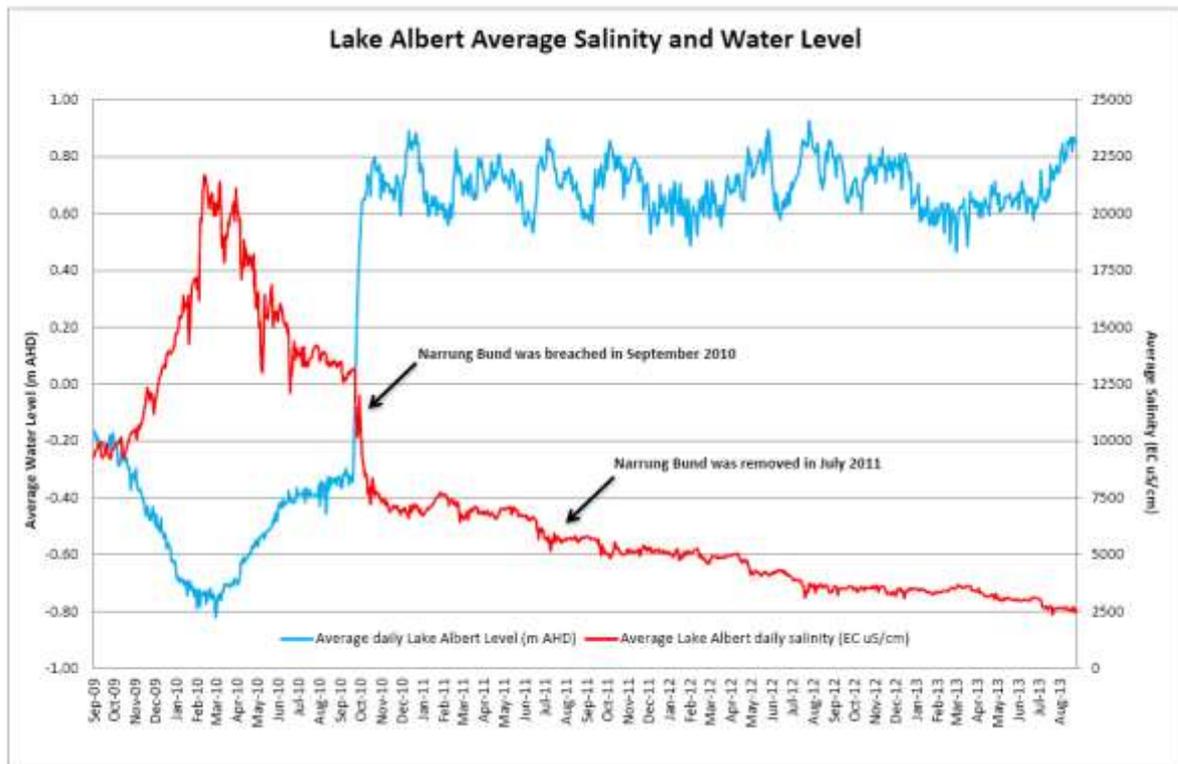


Figure 8: Lake Albert and Lake Alexandrina salinity September 2009 to August 2013

The Coorong, and Lakes Alexandrina and Albert ECD (Phillips and Muller, 2006) recommends that salinity in Lake Albert is maintained below 1,500 EC, based on a five year average. This allows for periods of higher salinity during low inflows, and for the fact that Lake Albert is always more saline than Lake Alexandrina because of its terminal nature.

4.4 Habitat

4.4.1 Historic Conditions

Phillips and Muller (2006) note that prior to European settlement, the significantly fresher waters of Lake Albert supported “extensive submerged aquatic plant beds and diverse emergent macrophyte communities that fringed the lakeshore” (Phillips and Muller, 2006, p 38). The authors further note that submerged aquatic plants are now restricted to sheltered, littoral habitats.

Prior to 2007, when water levels in the CLLMM region declined significantly, fringing wetlands in the Lower Lakes region contained diverse communities of emergent, amphibious and submergent taxa (Gehrig *et al.*, 2012). Fresh water impounded in Lakes Alexandrina and Albert by the barrages maintains a variety of permanent and ephemeral wetlands (DEH, 2000). The Lower Lakes are fringed with tall reeds, *Phragmites* sp., and bulrush or cumbungi, *Typha* sp., and there are sheltered flats and lagoons in places. Many wetlands also support lignum and samphire at the high water mark (behind the reeds) where evaporation provides saline conditions suitable for samphire growth. The lakeshore vegetation forms an almost unbroken habitat corridor around the lakes which has a critical role in allowing birds, fish, frogs and other animals. The Lower Lakes provide habitat for a number of nationally and internationally significant species (Phillips & Muller, 2006).

The *Wetlands Atlas of the South Australian Murray Valley* (Jensen *et al.*, 1996) provides a compilation of relevant information for wetlands in the South Australian Murray Valley,

including in the CLLMM region. Conservation values from two separate assessments are included in the wetland summaries: Thompson (1988) and Lloyd and Balla (1988). Thompson's criterion for conservation evaluation included the following: the area of wetland remaining in the region; diversity of habitat; permanence of the wetland; use by waterbirds; diversity and abundance of aquatic fauna; and regeneration of fringing vegetation. Lloyd and Balla used a point system to assess conservation value, looking at the diversity and status of aquatic fauna and aquatic vegetation; the condition and cover of marginal (fringing vegetation); the condition of the wetland; and the presence of special features. The conservation values are as follows:

- low (0-10)
- moderate (10-20)
- high (20-30)
- exceptional (30+)

Six wetlands (as seen below in **Figure 9**) were identified as wetlands fringing Lake Albert, including: Narrung; Narrung Narrows; Belcanoe; West Kilbride; Marnoo Complex; and Waltowa Swamp.



Figure 9: Lake Albert's Fringing Wetlands

Table 2 below provides a summary of the information relating to Lake Albert fringing wetlands presented in the Jensen *et. al*, 1996. The table lists the species present, as summarised by the authors, and the conservation valuations of Thompson and Lloyd and Balla.

Table 2: Summary of information relating to Lake Albert fringing wetlands as detailed in Jensen *et. al.*, 1996.

Wetland	Species present	Thompson Valuation	Lloyd and Balla Valuation
Narrung	Samphire, abundant aquatic plants, many hundreds of waterbirds of many species and an abundance, but only a moderate diversity of aquatic invertebrates. (Thompson Survey, 1983-85)	High	21-30 (High)
Narrung Narrows	Extensive areas of bulrush and reeds. These wetlands provide important habitat for waterfowl and probably aquatic fauna. (Thompson Survey, 1983-85) Extensive areas of aquatic and large areas of open water, with small patches of lignum and a few willows. (RMWMC Comments, 1994)	High	21-30 (High)
Belancoe	Sedges, dense bulrush, dense aquatic plants, a few species of waterbirds, Mitchellian freshwater hardyheads, big-headed gudgeons and an abundance of aquatic invertebrates. (Thompson Survey, 1983-85)	High	21-30 (High)
West Kilbride	Sedges, reeds, several species of waterbirds, Mitchellian freshwater hardyheads, Australian smelt, blue-spotted goby and aquatic invertebrates. Black swans and purple swamphens bred on this wetland. European carp were present. (Thompson Survey, 1983-85)	High	21-30 (High)
Marnoo Complex	Sedges, reeds, aquatic plants, hundreds of waterbirds of many species, Mitchellian freshwater hardyheads, Australian smelt, redfin perch and a diversity of aquatic invertebrates. Fringing this wetland is a remnant stand of the formerly more widespread salt paperbark (<i>Melaleuca halmaturosum</i>). Black swans bred on this wetland. (Thompson Survey, 1983-85)	High	21-30 (High)
Waltowa Swamp	Reeds, samphire, sparse aquatic plants, hundred of waterbirds of several species, Mitchellian freshwater hardyheads and a diversity and abundance of aquatic invertebrates. (Thompson Survey, 1983-85)	High	21-30 (High)

A habitat assessment of the Coorong, and Lakes Alexandrina and Albert Ramsar site by Seaman in 2003 identified and mapped the types of habitats and the condition of them. The assessment considered ecological values such as connectivity, pest plants, human impacts, integrity of vegetation associations, and condition of core habitat areas. Habitat descriptions given included: pristine (no obvious signs of disturbance); excellent (vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species limited to 5-20% coverage); very good (vegetation structure altered, obvious signs of disturbance and 20-50% weed invasion); good (vegetation structure significantly altered by very obvious signs

of multiple disturbances); degraded (basic vegetation structure severely impacted by disturbance, intensive management required to return to a “good” condition); and completely degraded (vegetation structure no longer intact and area completely/near completely devoid of native species).

Habitat condition around Lake Albert was shown to range from Excellent to Degraded (Seaman, 2003). Most of the Narrung Narrows area was given a rating of excellent, although areas such as this were “quite isolated on a regional scale” (Seaman, 2003, p 41). The Lake Albert shoreline areas assessed were given ratings of Degraded, Very Good, and Excellent, with Excellent and Degraded being the dominant ratings. The Narrung Narrows stood out as an ecological hot spot when compared across Lakes Alexandrina and Albert; there were very few areas that were classified as Excellent habitat. **Figure 10** below depicts the habitats mapped in the Ramsar site, and indicates their condition.

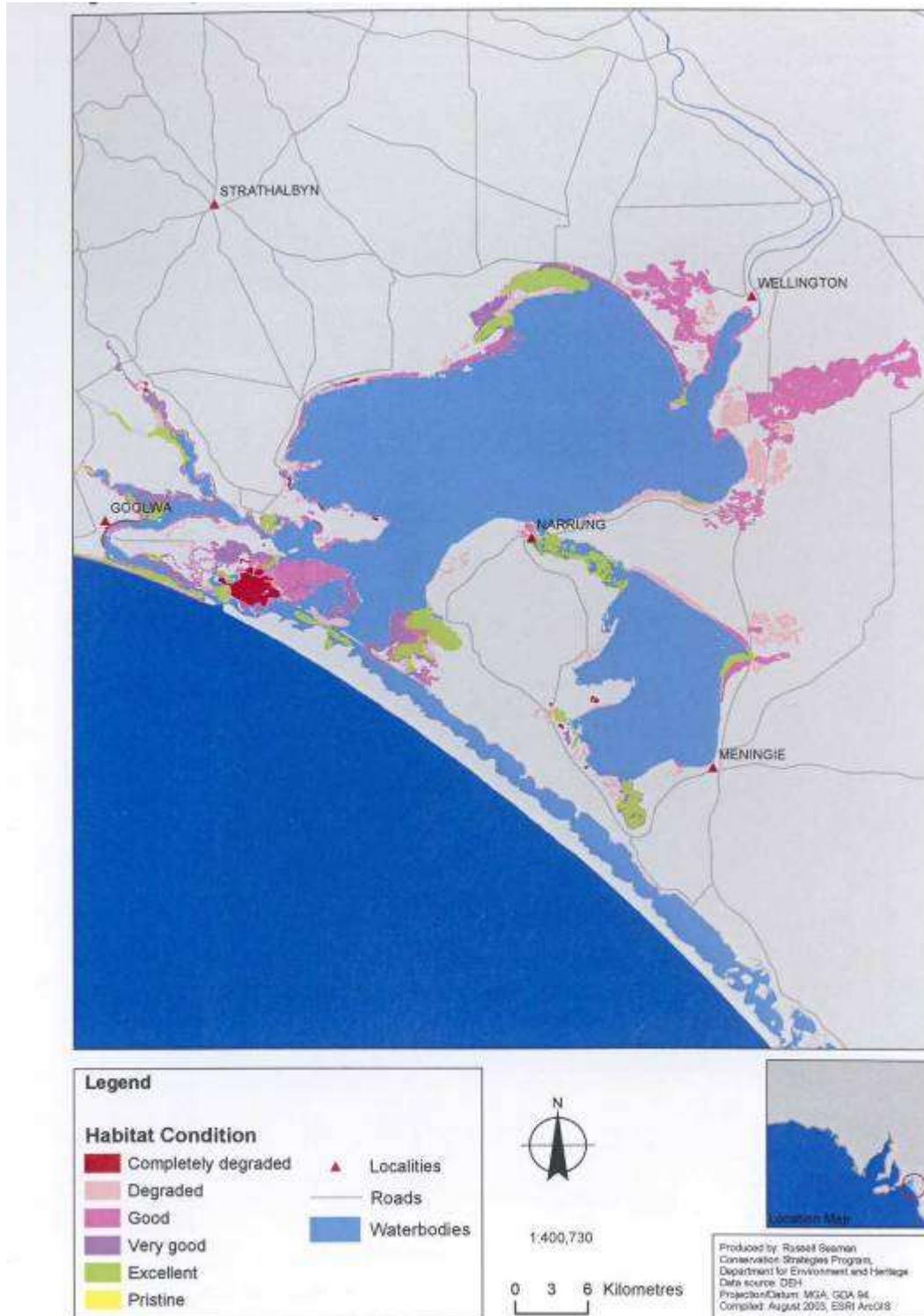


Figure 10: Habitat condition in the CLMM region

The Coorong, and Lakes Alexandrina and Albert ECD (Phillips and Muller, 2006) provides a qualitative description of Lake Albert, including a summary description of its ecological value. The authors noted that Lake Albert supported remnant patches of *Gahnia filum* and extensive, highly significant *Phragmites australis* and *Typha domingensis* reedbeds, which provide excellent sheltered habitat for a range of fish and other vertebrate species, as well as long-term rookery sites for ibis, spoonbill and cormorants. The authors also noted that, in

addition to species present in Waltowa Swamp listed in **Table 2** above, the wetland complex also supported significant orchid species and freshwater marshes.

4.4.2 Current Conditions

Thiessen (2010) conducted a habitat assessment of Ramsar wetland types in the CLLMM region to assess the impact of the drought. The assessment was undertaken based on the methods adopted by Seaman (2003) in order that conditions in 2010 could be compared to those assessed by Seaman in 2003 (pre-drought). Only 13 of the of the 19 Ramsar wetland types were re-sampled due to low representation of the remaining six wetland types. The same value system was used for each site surveyed: excellent, very good, degraded, and completely degraded (see earlier descriptions for each value). However, due to many sites having changed in habitat community so significantly as a result of the drought, it was not possible to compare values to those given by Seaman (2003) as it was no longer a comparison of the same wetland types.

The wetland types listed in the ECD that include the Lake Albert and Narrung Narrows areas are included in those types that underwent significant change in habitat community. Most changed from reedbeds, sedge lands and/or open water habitats to introduced grassland or samphire communities; indicative of drought conditions. An example provided was Waltowa Swamp, which was a healthy reedbed and open water association in 2003 and had lost water and seen a decline in reedbed condition in 2010. The loss of water flow changed the water regime and consequently the structure of the habitat, making it impossible to continue to provide critical habitat for waterfowl, waterbirds, waders, and Murray hardyhead.

Narrung wetland was one of the few sites that experienced an improvement in condition since 2003. Thiessen (2010) notes that:

“The condition of the Narrung wetland was enhanced due to management actions that were implemented [by the Coorong District Local Action Plan (CDLAP) and the South Australian Murray Darling Basin Natural Resource Management (SA MDB NRM) Board through the Narrung Wetland Management Plan (Bjornsson, 2006)]... The strategy they applied included fencing the wetland, obtaining water licenses and approval for artificial watering of the area, and a revegetation program.” (Thiessen, 2010, p 37)

Thiessen (2010) concluded that the wetland habitat condition of the majority of wetlands surveyed declined as a result of the drought, and that “water regimes changed across the entire Lower Lakes system, and vegetation associations were altered favouring the proliferation of weed communities” (Thiessen, 2010, p 39).

Vegetation surveys conducted during a four-year period (spring 2008 to autumn 2012) as part of *The Living Murray* program (Gehrig *et. al.*, 2012) demonstrate the changes in vegetation types observed at varying water levels. Gehrig *et. al.* noted that:

“the plant community around the edge of Lake Albert was generally dominated by terrestrial taxa between spring 2008 and autumn 2010, with some floodplain and amphibious taxa also present. From spring 2010, amphibious and emergent taxa replaced the terrestrial taxa, particularly between elevations +0.4 m AHD and +0.6 m AHD. At elevation +0.2 m AHD, there was a marked increase in emergent taxa. The lower elevations (0 and -0.5 m AHD) remained bare following inundation in winter 2010. Apart from significant increases in the abundance of *Aster subulatus* and *Cotula coronopifolia* in autumn 2012, there were no significant indicators for all remaining elevations, suggesting that the plant communities remained unchanged for the latest surveys (spring 2011 to autumn 2012).” (Gehrig *et. al.*, 2012, p 26)

Lake Albert had the highest proportion of exotics compared to other lakeshore survey sites (Lake Alexandrina and Goolwa Channel).

Gehrig *et al.* (2012) included vegetation surveys of wetlands in the CLLMM region, including Narrung and Waltowa wetlands. The plant community at the Narrung wetland was found to be unchanged during the survey period, with a mixture of terrestrial, amphibious and emergent taxa present, particularly a native salt marsh comprised of *Sarcornia quinqueflora*, *Suaeda australis*, and *Frankenia pauciflora*. In autumn 2012, submergent, emergent and amphibious taxa were present, with *Ruppia tuberosa* a significant indicator. Results indicated that the plant community in Waltowa wetlands remained largely unchanged during the survey period.

4.5 Birds

4.5.1 Historic Conditions

Limited historical information is available for bird species specifically using Lake Albert. In a literature review of bird species dependant on the habitat provided by wetlands within the Coorong, and Lakes Alexandrina and Albert Wetland of International Importance (Ecological Associates, 2009), the authors note that waterbirds constitute a fundamental component of the system, and that terrestrial bird species are reliant on wetland productivity.

4.5.2 Current Conditions

Rogers (2012) collated results from monthly waterbird surveys conducted across the Lower Lakes, Coorong and Murray Mouth Icon Site between 2001 and 2012 as part of *The Living Murray* program. The summarised findings are as follows:

- The drop in water level in the Lower Lakes during the period of low flows associated with the recent drought (2006-2010) resulted in sharp increases in the abundance of shorebirds in this region, including migratory shorebirds. However, this increase in habitat availability within the lakes was at least partly offset by a decline in habitat availability in the southern Coorong.
- Immediately following the return of significant River Murray inflows in 2010/2011, habitat availability for shorebirds in both the Coorong and Lower Lakes reduced to near zero, and very few shorebirds were recorded anywhere in the Icon Site. The number of shorebirds recorded in the site 12 months after the return of flows had increased from this historic low, but was still low compared to earlier survey periods.
- While increases in the abundance of a number of selected species was recorded with the return of flow, some species with quite different ecological requirements continued to decline, suggesting some ongoing issues with ecosystem function of the site.

O'Conner *et al.* (2012) undertook a detailed and quantitative review of the Coorong, and Lakes Alexandrina and Albert Wetland of International Importance status using bird data. An assessment was made as to whether changes in bird communities using the site have affected the site's Ramsar status across the years. This study did not single out Lake Albert, rather examined the Ramsar Site as a whole. The findings of the report are summarised as follows:

- Ten bird monitoring datasets were available for analysis in this project, nine of which were used to justify Ramsar criteria. Annual waterbird census data were the most useful for providing total numbers of individuals across the site. Smaller, species-specific surveys within the CLLMM region provided valuable breeding records and population counts for rarer species.

- The CLLMM region meets all five Ramsar criteria that are relevant to birds (Criteria 2-6). In particular, the CLLMM region supports 15 threatened species, 15-27 species that regularly breed at the site, 57 species that are listed under migratory bird agreements, 56 species that use the site for moulting, >20,000 waterbirds every year, and >1% of the Flyway population size for 10 waterbird species.
- While Criteria 5 and 6 were regularly met by up to 16 waterbird species, six of these species (curlew sandpiper, grey teal, hoary-headed grebe, red-capped plover, and fairy tern) had higher populations in 1985 (South Lagoon only) compared to recent annual population sizes across the entire CLLMM site (2000-2012). This highlights the limitations of whether the Ramsar criteria is still relevant as a measure for detecting potentially critical bird declines within the CLLMM.

Paton and Bailey (2012) counted waterbirds at Lakes Alexandrina and Albert between 9 and 21 January 2012. During this time, more than 74,000 waterbirds were counted as using the Lower Lakes (60 waterbird species), with more than 30,000 using both Lake Albert and Lake Alexandrina (excluding the Goolwa Channel). Lake Albert supported comparable numbers of waterbirds to Lake Alexandrina (34,905 and 30,708 respectively). These abundances were approximately double those of the previous year, with many species having increased in both abundance and distribution. These increases in abundance appear to be driven by influxes of birds from other wetlands rather than breeding activity within the Lower Lakes.

4.6 Fish

4.6.1 Historic Conditions

Bice (2010b) prepared a report collating existing knowledge on the ecology of fish in the CLLMM region in order to develop an understanding of factors and/or drivers important to maintaining sustainable populations of fish species. The report was prepared during the recent drought (2006-2010) to inform decision-making, in particular to predict impacts to fish communities caused by the implementation of potential management options being considered at the time to address the environmental problems facing the region.

The report included a summary of the traditional distribution and abundance of selected species. Species were selected based on the following criteria:

- Whether the species had been collected in the region in the preceding 20 years; and
- Possesses national or state conservation significance; or
- Is commercially important; or
- Is considered an indicator of environmental damage.

Table 3 below has been adapted from the discussion of occurrence of selected species in the CLLMM region (in the last 20 years) in Bice (2010b). Only selected species identified as occurring in Lake Albert have been included in the table. Notes on the specific distribution of selected species within the CLLMM region has been included.

Table 3: Summary of selected species identified as occurring in the Lower Lakes (adapted from Bice, 2010b)

Species	Scientific Name	Specific Distribution within the CLLMM region
Large-bodied native freshwater species		
Silver perch	<i>Bidyanus bidyanus</i>	Rare in the Lower Lakes. Species was once widespread. (Records from commercial fishery in

		Lake Alexandrina and Albert; little recent data from the Lakes).
Golden perch	<i>Macquaria ambigua</i>	Widespread in Lake Alexandrina, also found in Lake Albert.
Murray cod	<i>Maccullochella peelii peelii</i>	Likely rare in Lake Alexandrina. Once widespread. (Records from commercial fishery in Lake Alexandrina and Albert; little recent data from the Lakes).
Bony herring	<i>Nematalosa erebi</i>	Very common and widespread in the Lower Lakes.
Eel-tailed catfish	<i>Tandanus tandanus</i>	Likely rare in the Lower Lakes. (Records from commercial fishery in Lake Alexandrina and Albert. Last collected near Pomanda point).
Common small-bodied native freshwater species		
Carp gudgeon complex	<i>Hyoseleotris</i> spp.	Common and widespread in the Lower Lakes.
Flat-head gudgeon	<i>Philpnodon grandiceps</i>	Very common and widespread in the Lower Lakes.
Dwarf flat-headed gudgeon	<i>Philypnodon macrostomus</i>	Moderately common and widespread in the Lower Lakes.
Australian smelt	<i>Retropinna semoni</i>	Very common and widespread in the Lower Lakes.
Unspecked hardyhead	<i>Craterocephalus stercusmuscarum fulvus</i>	Moderately common and widespread in the Lower Lakes.
Rare and endangered small-bodied native freshwater species		
Murray hardyhead	<i>Craterocephalus fluviatilis</i>	Declining. Traditionally present in several off-channel wetlands in the Lower Murray. In the Lower Lakes, the species is primarily distributed around Hindmarsh Island, the Goolwa Channel and Clayton and Milang bays. Also some areas of sheltered lake edge in Lake Albert. Formerly locally abundant.
Diadramous species		
Common galaxias	<i>Galaxia maculates</i>	Common and widespread in the Lower Lakes
Short-finned eel	<i>Anguilla australis</i>	Rare. Recent (2008) record in Goolwa Channel, Lower Lakes.
Congolli	<i>Pseudaphritis urvillii</i>	Moderately common and widespread (in the Lower Murray and Lower Lakes). However, abundance and distribution have declined since the construction of the barrages. Thousands of juveniles were observed migrating into the lakes in 2006/07, but severe declines were observed in 2007/08 and 2008/09.
Estuarine Species		
Yellow-eyed mullet	<i>Aldrichetta forsteri</i>	Rare in the Lower Lakes. Records from commercial fishery in Lake Alexandrina and Albert (most recent in 2005). Other recent records in the Lower Lakes are from around Tauwitchere, Goolwa and Hunters Creek.
Black bream	<i>Acanthopagrus butcheri</i>	Some records of this species in the Lower Lakes (most recent 2009). Has been recorded moving into the barrage fishways and a recent record for upstream of Goolwa Barrage. Likely rare in the Lower Lakes.
Tamar goby	<i>Afurcagobius tamarensis</i>	Moderately common and patchily distributed in the Lower Lakes.
Bluespot goby	<i>Pseudogobius</i>	Common in the Coorong (Murray Estuary) and the

	<i>olorum</i>	Lower Lakes. Widely distributed.
Lagoon goby	<i>Tasmanobius lasti</i>	Common in the Coorong (mostly Murray Estuary, but also North Lagoon) and the Lower Lakes. Widely distributed.
Small-mouthed hardyhead	<i>Atherinosoma microstoma</i>	Very common in the Coorong and Lower Lakes. Widely distributed in the Lower Lakes.
Marine Species		
Mulloway	<i>Argyrosomus japonicus</i>	Some commercial catches of this species in the Lower Lakes (most recent 2005). Has also been recorded moving into the barrage fishways. Likely very rare in the Lower Lakes.

The following alien freshwater species were also identified as common and very common and widespread in the Lower Lakes: Goldfish (*Carassius auratus*), Common carp (*Cyprinus carpio*), Eastern Gambusia (*Gambusia holbrooki*), and Redfin perch (*Perca fluviatilis*).

Bice (2010a) gives an indication of the commercial fishery species present in Lake Albert in a report collating information from a trial fish-down (targeted exotic fish species reduction through netting) undertaken in October 2009. Due to low water levels and increasing salinities in Lake Albert during the recent drought (2006-2010), the threat of a large-scale fish kill in the lake emerged. The trial fish-down aimed to remove as much of the fish biomass as possible (through commercial fishing) in order to prevent potential negative impacts to Lake Albert water quality. Fishing efforts focused on the Narrung Narrows. A total of 98 tonnes of fish were removed from Lake Albert, comprising of: 74 tonnes of common carp, 23 tonnes of bony herring, and ~1 tonne of golden perch and redfin perch.

Bice (2010a) concluded that the catches indicated that common carp and bony herring were abundant in Lake Albert, dominating the large-bodied fish biomass, while golden perch and redfin perch were less abundant. Three other large-bodied freshwater fish species previously recorded in Lake Albert (silver perch, eel-tailed catfish, and Murray cod) were not recorded during the fish-down. Although fishing methods used, specifically net mesh sizing, may not have been ideal to catch these species, the authors concluded that silver perch and eel-tailed catfish are likely rare in Lake Albert. The authors note that further investigations would be required to determine the status of Murray cod in Lake Albert.

4.6.2 Current Conditions

Wedderburn and Barnes (2012) undertook threatened fish species monitoring in the Lower Lakes during 2011/2012 as part of *The Living Murray* program with the specific aim of locating remaining populations of three threatened fish species (Yarra pygmy perch, Southern pygmy perch, and Murray hardyhead) and establishing if they successfully recruited over the 2011/2012 season. The authors note that the recent Basin-wide drought (2001-2010) had “deleterious Basin-wide effects on fish communities, which were most pronounced near the Murray Mouth”. A substantial decline in the proportion of specialist fish, particularly diadromous and threatened species, and an emerging dominance of generalist freshwater and estuarine species was also noted.

Wedderburn and Barnes (2012) note that over three quarters of the 18 freshwater, estuarine and diadromous native fish species regularly recorded in the Lower Lakes are small-bodied (<200 mm maximum total length), including three threatened taxa. The genetically distinct population of Yarra pygmy perch (*Nannoperca obscura*) does not occur anywhere else in the Murray-Darling Basin. The species had not been recorded in the Lower Lakes since February

2008, and is critically endangered in South Australia, and listed as vulnerable under the EPBC Act. Southern pygmy perch (*Nannoperca australis*), is endangered in South Australia. Murray hardyhead (*Craterocephalus fluviatilis*), is endemic to the Basin, is listed as critically endangered in South Australia, and was recently elevated to endangered status under the EPBC Act.

The authors found that the restoration of freshwater habitat was required to improve the chances of threatened fish species recovery. A notable increase in freshwater macrophytes during the 2010/2011 season at sites formerly inhabited by the three threatened fish species, which continued into the 2011/2012 season, was also noted. One monitoring site, located in the south west corner of Lake Albert (adjacent to an artificial channel that formerly fed an irrigation pump at Campbell House) is considered a significant site due to previous threatened fish populations being recorded. The authors note of their findings in this location that:

“...in an earlier The Living Murray condition monitoring event there was evidence of recruitment in the Murray hardyhead population... However, Murray hardyhead was not captured at this site during the 2009-10 and 2010-11 seasons. Indeed, no fish were captured at this site in March 2010, which might relate to high salinity and other habitat or food web factors at the time. For example, salinity was very high [20,000 EC] in March 2010, and might have contributed towards failed recruitment. Since the high freshwater inflows to Lake Albert in 2010, salinities at this site have been relatively low, and correspond to an increase in aquatic plant cover.

The fish community at this site was predominated by the estuarine blue-spot goby in November 2009 and November 2010, and included low numbers of Murray hardyhead. The fish community was more diverse in November 2010 following the freshwater inflows, and included estuarine (eg lagoon goby) and freshwater (eg Australian smelt) species. In November 2011, common galaxias and carp each constituted a third of the fish community, and blue-spot goby was notable. The overall number of fish captured in November 2011 was substantially lower than during the same time in the previous two seasons. There were no threatened fish captured at this site in the 2011-12 *The Living Murray* condition monitoring.” (Wedderburn and Barnes, 2012, p 49)

5 Issues Affecting Lake Albert

5.1 Pre-drought

Early accounts of Lake Albert and the CLLMM region generally post-European settlement (summarised in Sim and Muller, 2004) suggest that rising salinity levels have been a primary concern post-European settlement. **Table 4** below is adapted from Sim and Muller’s report ‘A Freshwater History of the Lakes: Wellington to the Murray Mouth, 1800s to 1935’ and provides a summary of events and historical observations relating to Lake Albert from the 1820s (when the first Europeans visited the region) until construction of the barrages in the 1930s. Other significant occurrences since construction of the barrages have been added (and are referenced accordingly and identified in italics) up to 2012 when removal of the Narrung Bund was completed.

Table 4: Summary of events and historical observations relating to Lake Albert (adapted from Sim and Muller 2004, additional information from DPTI, 2013)

Year	Observation
1820s	Sealers and whalers from Kangaroo Island became aware of the Lower Lakes
1839	Overlanders bringing stock from New South Wales noted of Lake Alexandrina that the water was fresh, sweet and was not salty.
Early 1840s	Settlers allowed stock (sheep and cattle) to graze along the shores of Lakes Alexandrina and Albert, allowing stock free access to the fresh water.
1840	Various accounts of Lake Albert note that reeds encircled the lake shore in a continuous belt, and that the waters were fresh in some parts, and brackish in others.
1853	First paddle steamers commence on the Lakes and River
1878	Green water in Lake Alexandrina kills horses, cattle and sheep
1887	During a debate in the South Australian Parliament regarding the River Murray “Many people imagined that there would be nothing to fear from only flood waters being taken, but this was a great mistake. All the floodwaters were required to drive out the salt water.” There was a fear that extraction of water for irrigation would cause the lower Murray to become impregnated with salt to a considerable distance above Wellington.
1889	South Australia complains of water extraction by New South Wales and Victoria. Local Member, Mr AH Landseer said the lower River and lakes country was being destroyed “by the encroaching of seawater for want of sufficient fresh water down the river to keep it back during low water”. During a Parliamentary debate on locking the Murray, Mr Caldwell told the House that when it was found that “the salt water was gradually encroaching upon the fresh water in the stream there was real cause for apprehension”.
1901	Because of low river flows, seawater was observed coming into the river at Goolwa
Early 1900s	Salinity recognised as major issue The Southern Argus explained the salt water problem as being caused “through the joint influences of long continued drought and an increasing diversion of waters”
1902	“Mr Hacket, chairman of the Meningie District Council, said that it was only too plain that the land was decreasing in value owing to the growing saltiness of the water”
1902	Hon G. Brookman said, “Lakes Alexandrina and Albert were almost salt. The reeds that used to grow around them had practically died.”
1902-04	Many observations of reeds and water plants dying due to the high salinity

1904	Discussions commenced regarding option of building barrages in the vicinity of the Murray Mouth
1905-06	Proposal to drain Lake Albert and reclaim the land
1922	<i>May: DC Meningie wrote to Local Govt dept “the Government be asked to place a barrage at North Western end of the Albert Passage to prevent the influx of salt water into Lake Albert, the said barrage to be so constructed as to allow of the crossing of Stock, etc, From the District of Narrung to the nearest market Taillem Bend.” (DPTI, 2013).</i> <i>September: Based on advice received from Director of Irrigation, the department advised DC Meningie that barrage is not recommended. (DPTI, 2013).</i>
June 1923	<i>DC Meningie wrote to Local Govt dept again “to take immediate steps to prevent the influx of sea water into Lakes Albert & Alexandrina” (DPTI, 2013).</i>
August 1923	<i>Briefing to Commissioner of Public Works “erection of a series of barrages between Lake Alexandrina and the Coorong has been the subject of several requests and reports, and in 1905 an Act was passed authorising a portion of the work to be carried out. Objection to the proposed works had been made by land owners on the lower river.” (DPTI, 2013)</i>
1923	Suggestion that both Lake Alexandrina and Lake Albert be drained, but later found that the government had never contemplated the draining of the lakes.
1930	Salinity still a major issue with many reeds and aquatic plants dying
1935	Building of the barrages commences
1940	Barrage construction completed

The existence of salinity as an issue in Lake Albert prior to the recent drought (2006-2010) is also evident through investigations undertaken to address Lake Albert salinity, extending as far back as 1983 (Ebsary). These investigations are discussed in detail in Section 6. For instance, Ebsary (1983) notes of Lake Albert salinities that:

“Since the last major flows down the River Murray in 1975/76, when the entire system was flushed of its poor quality water, salinity in Lake Albert [had] risen to levels which [were] thought to be causing reductions in yield of crops irrigated with lake water. [Further] salinity has increased over this period because Lake Albert does not experience a through flow of water and river conditions since 1975 have been such that there has not been sufficient natural flushing of salts from the lake to prevent salinity rising to high levels”. (Ebsary, 1983, p 4)

5.2 Drought – Acidification Threat

Between 2006 and 2010, the River Murray flows were at historically low levels due to over-allocation and drought across the Murray-Darling Basin. As a result, inflows into the Lower Lakes were not able to replenish evaporative losses, and average lake levels dropped to

unprecedented lows. In April 2009, average water levels were at their lowest in Lake Alexandrina: one metre below sea level (-1.0m AHD) (DENR, 2011).

Low lake levels led to the exposure of previously submerged sulfidic sediments known as acid sulfate soils. Acid sulfate soils are pyrite rich sediments that are benign while inundated. Acid sulfate soils are found through the CLLMM region. When exposed to oxygen, the soils quickly oxidise to form sulphuric acid. This posed a number of negative consequences for water quality and ecological health. At -0.75 m AHD (Australian Height Datum), approximately 61.0 km² of sediments are exposed in Lake Albert. At -0.5 m AHD, 41.93 km² of sediments are exposed to oxygen (DENR, 2011).

The Lower Lakes Acid Sulfate Soils Scientific Research, formed to investigate key knowledge gaps and assist with management decisions, indicated that a broad-scale acidification trigger point for Lake Albert was -0.75 m AHD, and the preferred water level management was a level above -0.5 m AHD. For Lake Alexandrina, the acidification trigger point was -1.75 m AHD, and the preferred water level management level was -1.5 m AHD. The preferred water level management level relates to the water level above which the risk of acidification of the lakes' main water bodies is significantly reduced (DENR 2010c).

By March 2008, the water level in Lake Albert was approaching the then projected critical acidification water level trigger of -0.5 m AHD. The bathymetry of Narrung Narrows shows there is a natural disconnection between the two lakes at -0.3 m AHD.

5.2.1 Construction of the Narrung Bund and Pumping

In April 2008, a bund was built across the Narrung Narrows to enable water levels in Lake Albert to be managed independently of those in Lake Alexandrina. This management action was implemented in response to concerns regarding the acidification of the Lake Albert waterbody. The objective of the bund was to allow water to be pumped from Lake Alexandrina into Lake Albert to maintain the water level in Lake Albert above its acidification trigger of -0.5 m AHD. This was based on advice at the time that the best method of managing acid sulfate soils is prevention by keeping the sediments inundated.

The Narrung Bund was built from imported earthen material sources from two local 'borrow pits', steel sheet piles, concrete blocks (forming a stable base for larger water pumps), and iron rods and ties.

On 2 May 2008, pumping of water from Lake Alexandrina to Lake Albert commenced at the rate of 170 GL per annum, and continued until 30 June 2009. Initially pumping was to be undertaken until September 2008. This timeframe was then extended to September 2009. Pumping of water from Lake Alexandrina into Lake Albert maintained Lake Albert water levels above -0.5 m AHD from April 2008 to June 2009.

By 30 June 2009, it was apparent that there was insufficient fresh water available to sustain water levels in both lakes to prevent acidification. As a result, a decision was made to discontinue pumping. The fixed infrastructure was left in place to enable rapid recommencement of pumping in the event that more water became available.

Lake Albert's water level was forecast to drop below -0.5 m AHD before the end of 2009. However, inflows from the eastern Mount Lofty Ranges tributaries during winter and spring 2009 resulted in higher than expected water levels in Lake Alexandrina. This provided an opportunity for water to be pumped into Lake Albert again to help prevent acidification. Consequently, in September 2009, the South Australian State Cabinet approved the proposal

to pump up to 35 GL of water from Lake Alexandrina to Lake Albert between January and June 2010.

Subsequently, on 14 December 2009, the South Australian Government approved the pumping of 56 GL of water to maintain Lake Albert at -0.75 m AHD until at least July 2010. The South Australian Government undertook investigations into the costs and benefits of pumping additional water into Lake Albert to achieve a higher target water level, quantifying the additional gains in acid sulfate soil risk management of maintaining Lake Albert's water level at or above -0.75 m AHD. The additional 56 GL of water was sourced from the 170 GL of state water resource availability or purchase for the Lower Lakes during 2009. Pumping from Lake Alexandrina to Lake Albert recommenced on 5 January 2010.

On January 2010, the Murray-Darling Basin Officials Committee agreed to 100 GL of Darling River flood waters being delivered to the River Murray for allocation to the Lower Lakes. It was also agreed that 48.3 GL of the Living Murray water be allocated to Lake Albert. On 20 January 2010, 20 GL from the Commonwealth Environmental Water Holder was allocated exclusively for delivery to Lake Albert.

In total, 90 GL of water was pumped into Lake Albert from Lake Alexandrina between 5 January 2010 and 5 June 2010.

5.2.2 Removal of the Narrung Bund

During July and August 2010, the water level in Lake Alexandrina rose rapidly with increased inflows due to rainfall in the north of the Murray-Darling Basin and the subsequent unregulated flows. Plans for pumping were superseded, and an investigation into options to passively transfer water across the bund through the use of siphons or a spillway was undertaken. As part of this investigation, geotechnical advice was sought on the stability of the bund. Advice was received that the bund was likely to fail and would not be able to support modifications.

On 19 September 2010, a section of the structure was breached and the lakes reconnected with 100 m of the 300 m bund removed. The emergency controlled breach was required as the head difference between the lakes compromised structural stability.

Following the partial remove, plans were undertaken for the complete removal of the structure. Removal options included various combinations of dredging and excavating. Options explored considered environmental and social implications, site logistics, technical and engineering feasibility and safety. Removal of the bund was undertaken in two phases. Phase 1 involved removal of as much introduced material as possible. Practical completion of Phase 1 works was achieved on 19 July 2011. Phase 2 involved a relatively minor amount of works to remove high areas in the Narrung Narrows identified as navigational hazards by the South Australian Department for Planning Transport and Infrastructure (DPTI).

5.3 Post-drought - Salinity

As previously mentioned in Section 4.3.2, salinity levels rose dramatically during the recent drought (2006-2010). The additional inflows and higher water levels since 2010/11 diminished the immediate threat of acid sulfate soils causing acidification of the Lake Albert water body; however, salinity remains an ongoing issue.

While Lake Albert is naturally saltier than Lake Alexandrina due to its shallower form and terminal nature, the prolonged drought, installation of Narrung Bund and pumping from Lake Alexandrina to Lake Albert, coupled with evapo-concentration has elevated the salt load in the

lake. The lake levels are presently being cycled up and down between +0.55 m AHD and +0.83 m AHD to assist water exchange between Lake Alexandrina and Lake Albert.

The persisting salinity levels in Lake Albert have been identified by community members as an issue which needs to be addressed. High salinity is particularly problematic for irrigators who require water below certain salinity levels depending on their agricultural activity. PIRSA (2008) discusses water quality requirements for livestock (see **Table 5**). Sheep can tolerate higher salt concentrations than cattle, but sudden changes to more saline water may cause lowered production because sheep may not drink the more saline water immediately, but may become used to it gradually through mixing it with fresh water for a few days. As the salt concentration increases, stock drink more water compared with drinking fresh water. At higher salinities food intake will decrease.

Stock grazing green feed can tolerate higher salt concentrations than the same stock on dry feed. Stock grazing saltbush or salty feeds are less tolerant to saline water than stock grazing other types of pasture. Pregnant, lactating, and young stock have lower salt tolerances than older dry stock. Pigs and poultry have the lowest tolerance to salt than all other types of livestock. The salinity of water must be taken into account before feeding these stock prepared rations that may contain salt.

Table 5: Salinity tolerances of livestock and poultry (PIRSA, 2008)

Animal	Maximum concentration for healthy growth (EC)	Maximum concentration to maintain condition (EC)	Maximum concentration tolerated (EC)
Sheep	6,000	13,000	*
Beef cattle	4,000	5,000	10,000
Dairy cattle	3,000	4,000	6,000
Horses	4,000	6,000	7,000
Pigs	2,000	3,000	4,000
Poultry	2,000	3,000	3,500

*Maximum level depends on type of feed available, e.g. saltbush vs. greenfeed

6 Management options considered

In response to the water quality issues, primarily salinity, identified in Section 5, numerous studies and investigations have been undertaken to examine potential management options to address these issues. The following section collates existing information and reports relating to Lake Albert, focusing on reports and investigations associated with the management of Lake Albert water quality. The existing information has been grouped based on the management option considered by the report or investigation. Section 6.1 briefly discusses reports and studies relating to management of acid sulfate soils in Lake Albert, while Section 6.2 focuses on management of Lake Albert water quality, in particular salinity.

6.1 Acid Sulfate Soil Management Options

In 2008-2009, a number of investigations were carried out to assess and review management options for acid sulfate soils in the Lower Lakes. At the time, water levels were declining as a result of unprecedented drought and over-allocation of flows in the Murray-Darling river system. The lowering of water levels increases the volume of sulfidic material in acid sulfate soils that is exposed to atmospheric oxygen. On exposure it generates acid and metalliferous drainage (AMD) which has the potential to result in ecological, health and water quality

issues. The generation of acid and metalliferous water had the potential to be a significant environmental issue in the Lower Lakes.

It is important to recognise that the increased inflows into the CLLMM region in 2010-2011 inundated areas of acid sulfate soils exposed during the drought, reducing the threat of large-scale acidification of the CLLMM region. The environmental and health risks associated with acid sulfate soils are not an issue while the soils remain submerged, as is currently the case. In addition, under the Basin Plan, Lake Albert water levels dropping below 0m AHD will be significantly reduced. Under the Basin Plan development scenario, the lakes drop below 0m AHD 2.8% of the time (3.1 years in 114 year period). It is preferable to prevent acidification by ensuring sediments remain saturated, thus removing the risk of acid sulfate soil exposure and acidification. As such, the management options included in Section 6.1 are for discussion purposes only, and do not form part of the wider Lake Albert Scoping Study.

A summary of the reports/studies into the acid sulfate soil management options considered in relation to Lake Albert are provided in **Table 6**.

Table 6: Summary of reports/studies considering management of acid sulfate soils in Lake Albert.

Report/study	Summary of findings
Earth Systems Pty Ltd (2008)	<p>The report identified and broadly categorised acid sulfate soil management approaches for the Lower Lakes as follows:</p> <ul style="list-style-type: none"> - prevent acid mineral drainage (AMD) by managing lake water levels to ensure that acid sulfate soils are permanently submerged and sulphide oxidation is therefore minimised; - control AMD in-situ via neutralisation (addition of organic matter to acid sulfate soils) - treat AMD within the lake water bodies, either passively or actively, via neutralisation (alkalinity addition) and/or reduction (organic matter addition). <p>The report led to the development of a preliminary management plan which provided an initial assessment of potential acid sulfate soil management strategies for Lake Albert (Earth Systems, 2009). Four key management strategies were identified at the time:</p> <ol style="list-style-type: none"> 1. Continue pumping water from Lake Alexandrina to Lake Albert 2. Flood Lake Albert with saline water (either from the Coorong or the Southern Ocean) 3. Use local groundwater resources to maintain at least partially saturated conditions, but not necessarily inundate acid sulfate soils 4. Terminate refilling of Lake Albert from Lake Alexandrina and either use Lake Alexandrina to saturate, but not necessarily inundate acid sulfate soils; or create a dry lake bed or ephemeral wetland. <p>Significant limitations were associated with Strategies 1 and 2. Strategy 4 was determined as the preferred approach as limitations on suitable groundwater resources were identified for Strategy 3.</p>
Maunsell Australia Pty Ltd (2008b)	<p>The study conducted a literature review of acid sulfate soils mitigation using bioremediation techniques. This included organic mulch - prevention of exposure to the atmosphere and oxidation of sulfidic material by covering areas of expose lakebed with organic mulch, and to promote bioremediation. Potential benefits included</p>

Report/study	Summary of findings
	increasing the buffering capacity of the soil; promotion of microbial reduction of sulfate to sulphide; and immobilisation of metals. Potential negatives included the possible increase of nutrients into the lake; mobilisation of metals in the initial reducing conditions; and logistical problems.
Maunsell Australia Pty Ltd (2008a)	The study conducted a literature review on the potential to allow seawater incursions into Lake Alexandrina in order to treat the impacts of acid sulfate soils. The rationale for this management option was that lake water levels would be increased, thereby reducing the area of exposed lakebed, while also allowing naturally occurring salts (carbonates) in the seawater to neutralise any acidity already found in the waterbody as a result of low water levels and exposed sediments. The study notes negative impacts including the transformation of the freshwater ecosystem to a marine ecosystem; and the possibility that the introduced seawater could travel up the River Murray channel, threatening South Australia's water supply,
Tonkin Engineering Science (2008)	The study investigated the potential for offsetting Lake Albert evaporation, and thus acid sulfate soil exposure, through the construction of a pipeline to supply water to Lake Albert from either the Coorong or the Southern Ocean. Pumping from the Coorong rather than the Southern Ocean was considered more advantageous (lower capital costs, reduced construction footprint, shorter pipelines and reduces installation times), although disadvantages were noted (source water could be more saline, pumping would cause flushing of the Coorong with sea water through the mouth, potential scouring of the Coorong at the inlet if not appropriately designed). Cost estimates for construction of a pipeline from the Coorong to Lake Albert were \$20,910,000.
Tonkin Consulting (2009)	<p>In 2009, Tonkin Consulting was engaged by the then Department of Environment and Heritage to undertake a review of the available options to transfer water from the Coorong to Lake Albert to mitigate the impacts of acid sulfate soils. The objective of this study was to identify potential construction methodologies, project costs, and timeframes associated with the provision of temporary infrastructure to maintain the minimum desired water levels in Lake Albert. The overall management option requirement was to transfer 170 GL per annum from the Coorong to Lake Albert. Options had to be capable of being constructed and commissioned within an eight to twelve week timeframe.</p> <p>Tonkin Consulting (2009) reviewed two potential alignments for the transfer facility (following Seven Mile road from Kennedy Bay to the Coorong, and following Long Point Road from the main body of Lake Albert to the</p>

Report/study	Summary of findings
	<p>Coorong), and three potential construction methodologies along each alignment (open channel flow under gravity, pump and pipes, and pump and pipe to an open channel). All options were found to be technically feasible. Open channel construction estimates for the two alignments were calculated as being \$21,325,000 (Seven Mile Road alignment), and \$63,672,000 (Long Point Road alignment). Required land corridors for the open channel options were calculated to be 150 metres wide and 160 metres wide, respectively.</p> <p>*Note: While the option for construction of an open channel is similar to the salinity management option (discussed in Section 6.2.3) it should be noted that the usefulness of this study for comparison purposes is limited as the options proposed in the study are aimed to deliver different environmental outcomes than the rest of the studies and reports relating to the construction of a channel between Lake Albert and the Coorong (ie, aimed to assist in acid sulfate soil management within Lake Albert rather than reduction in Lake Albert salinities). Furthermore, the options considered by the report were designed to be temporary in nature, unlike other studies and reports considering the construction of a channel detailed in Section 6.2.3.</p>
Sinclair Knight Merz Pty Ltd (SKM) (2010)	<p>SKM were engaged by SA Water to undertake a technical feasibility and practicality assessment of options to manage acid sulfate soils derived acidification of the CLLMM system. The general methodology of the assessment was based on a Multi Criteria Analysis to provide a robust evaluation of multiple options against common criteria. The assessment indicated that the option to provide freshwater through environmental allocations was generally ranked number one across the majority of technical versus costs contribution ratios. The provision of freshwater (buy-backs) also shares the number 1 ranking when costs contribution was minimised. The re-vegetation option ranked at number 2 for certain contribution ratios. However, further analysis of the scores indicated that the re-vegetation option scored poorly on a technical basis (ie in terms of acidification management), but retained a high ranking due to high scores awarded on the costs contribution, coupled to a high multiplier for the perceived low environmental risks.</p> <p>The ranking of the seawater inundation (via barrages) option increased when the cost contribution was increased, as it is a low cost option. It did not score significantly well on the technical contribution as a treatment measure, as it was downgraded by its potentially high environmental risk, associated with inundating oxidised sediments.</p>

Report/study	Summary of findings
	<p>However, as the option scored a technical ranking of 4 (of 8), it was considered that there was merit in using this option as a preventative measure under certain conditions, (ie to safeguard certain areas of Lake Albert).</p>
<p>Department of Environment and Natural Resources (2010c)</p>	<p>The main management implications of the report's findings are:</p> <ul style="list-style-type: none"> - Some exposed sulfuric (pH<4) materials from acid sulfate soil "hotspots" can be managed or treated locally. Various factors (with respect to acidity generation, neutralisation and transport processes) will determine the type and appropriateness of management actions required. - The risk of broad-scale lake acidification is reduced if water levels are stabilised at or above minus 1.5 m AHD in Lake Alexandrina and minus 0.5 m AHD in Lake Albert. The risk profile substantially increases past these water levels and/or with prolonged time near these levels. - While seawater addition is a valid option to prevent drying out and acidification of currently submerged sediments, it is a higher risk management option compared to freshwater as enhanced contaminant (acid and metals) mobilisation will occur over oxidised lake marginal sediments. - Recovery of water quality following lake acidification could take months-years, whereas recovery from soil acidification will take much longer and achieving previous conditions may not be possible.
<p>Muller (2011)</p>	<p>The then Department of Environment and Natural Resources commissioned an Ecological Consequences Assessment to determine the relative ecological outcomes of several regional water management options, with the introduction of seawater being the primary focus. The assessment was undertaken by Muller in 2011, considering the following three management options:</p> <ul style="list-style-type: none"> - Do nothing scenario - Introduction of seawater - Delivery of freshwater <p>The assessment found that under the 'do nothing' scenario salinity levels would increase, resulting in serial losses of all freshwater plants and animals, with all but the salt-sensitive species perishing within 18 months; the severe limitation of colonisation of estuarine species; and the eventual disappearance of even estuarine species as salinities reach hypersaline concentrations. The result would be an extremely simplified ecosystem. The</p>

Report/study	Summary of findings
	introduction of seawater would eventually result in ecological collapse as a result of rapidly increasing salinity levels. The delivery of freshwater would maintain water levels in Lake Albert above the acidification management level; however, a progressive increase in salinity would lead to serial loss of all but ten of the most salt-tolerant taxa within the first year. Remaining biota would become increasingly stressed by habitat loss and resource limitations over time, indicating severe ecological damage.

6.2 Water Quality Management Options

Studies investigating options to manage Lake Albert water quality have been undertaken for a number of decades, with perhaps the most comprehensive completed in 1983 when Ebsary undertook a study on behalf of the then South Australian Department for Engineering and Water Supply. Among the most recent suggestions to managing Lake Albert and the Coorong water quality, particularly salinity, is the 'Five Point Plan' proposed by the Meningie Narrung Lakes Irrigators Association in February 2012. The proposed management actions include:

1. Remove the [Narrung] causeway;
2. Remove the [Narrung] Bund in its entirety;
3. Dredge the whole of the Narrung Narrows;
4. Install a pipeline at the southern end of Lake Albert to the Coorong; and
5. Return natural flows to the southern end of the Coorong.

The Five Point Plan was addressed by the Australian Conservation Foundation (ACF) and Environment Victoria in a submission to an inquiry by the House of Representatives Regional Australia Committee into 'the potential role that new environmental works and measures projects could play in partially offsetting SDL [sustainable diversion limits] reductions under the Basin Plan, focussing particularly on prospective project proposals identified by state governments and community interests'. The discussions of elements of the Five Point Plan from the submission are discussed further in this section.

Element two of the Five Point Plan is not considered as part of the Study as it was completed in October 2012. Element Five is also not considered as part of the Study as it is being considered through the South East Flows Restoration Project (also part of the CLLMM Recovery Project).

Table 7 provides a summary of the water quality management options considered in various reports/studies, detailing when the study was undertaken, by whom, the concept of the management option, and the purpose of the study (to provide context).

Table 7: Summary of Lake Albert water quality management options considered in various reports/studies.

Management Option Considered	Date of study	Who undertook the study	Concept of management option (as detailed in the study/report)	Purpose of study (for context)
Removal of the Narrung Causeway	2012	ACF and Environment Victoria	Proposed as part of the Meningie Narrung Lakes Irrigators Association 5-point plan to reduce salinities in Lake Albert. Purpose of the management option is to improve water changeover into Lake Albert.	Submission to an inquiry by the House of Representatives Regional Australia Committee into new environmental works and measures projects that could potentially partially offset sustainable diversion limits reductions under the Basin Plan.
Dredging of the Narrung Narrows	1983	Ebsary	Purpose of the management option is to reduce salinities by improving flow between Lake Alexandrina and Lake Albert to help flush out the build up of salt in Lake Albert.	Study undertaken on behalf of the then South Australian Engineering and Water Supply Department to investigate the potential to construct a channel between Lake Albert and the Coorong in order to reduce Lake Albert salinities. In addition to this management option, the report also considered five additional salinity mitigation options, including dredging the Narrung Narrows
	2005	McInerney	Purpose of the management option is to improve flows between the lakes and ultimately reduce salinities in Lake Albert.	PhD titled, 'A triangular grid finite-difference model for wind-induced circulation in shallow lakes' centred around testing techniques for the finite-difference model. The effect that dredging the Narrung Narrows to increase depth would have on inflows into Lake Albert was considered as an example.
	2012	ACF and Environment Victoria	Proposed as part of the Meningie Narrung Lakes Irrigators Association 5-point plan to reduce salinities in Lake Albert. Purpose of the management option is to increase flows and turnover.	Submission to an inquiry by the House of Representatives Regional Australia Committee into new environmental works and measures projects that could potentially partially offset sustainable diversion limits

Management Option Considered	Date of study	Who undertook the study	Concept of management option (as detailed in the study/report)	Purpose of study (for context)
				reductions under the Basin Plan.
Construction of a channel and/or pipeline at the southern end of Lake Albert to the Coorong	1983	Ebsary	Purpose of the management option is to reduce salinities in Lake Albert by allowing flushing of poor quality water and replacement by fresher water from Lake Alexandrina.	Study undertaken on behalf of the then Engineering and Water Supply Department to investigate the potential to construct a channel between Lake Albert and the Coorong in order to reduce Lake Albert salinities. In addition to this management option, the report also considered five additional salinity mitigation options.
	1988	Burton	As suggested by Ebsary (1983), the purpose of the management option is to reduce salinities in Lake Albert by allowing flushing of poor quality water and replacement by fresher water from Lake Alexandrina.	Investigation into the effectiveness of a channel between Lake Albert and the Coorong as recommended by the South Australian Water Resources Council in response to the experiences associated with management of the Lower Lakes, particularly control water level fluctuation to reduce Lake Albert salinities.
	2006	URS	Unclear from the report the purpose of the management option, although related reports (WBM Oceanics, 2006; Walters and Souter, 2006; and PIRSA, 2006) indicate that it is to reduce Lake Albert salinities.	Report containing pre-feasibility and design costs estimate undertaken on behalf of the South Australian Department of Water, Land and Biodiversity Conservation. Design and cost estimate focussed, no analysis of the ecological impacts to either the Coorong or Lake Albert.
	2006	WBM Oceanics Australia	Purpose of the management option is to reduce salinities in Lake Albert.	Modelling assessment of the potential benefits for improvement of salinity levels in Lake Albert that might be obtained by connecting Lake Albert to the Coorong prepared for the South Australian Department of Water, Land and Biodiversity Conservation.

Management Option Considered	Date of study	Who undertook the study	Concept of management option (as detailed in the study/report)	Purpose of study (for context)
	2006	Walters and Souter	Purpose of the management option is to reduce salinities in Lake Albert, and to deliver environmental water to the Coorong for environmental benefit.	Study undertaken on behalf of the South Australian Department of Water, Land and Biodiversity Conservation to assess the ecological benefits and losses that may result from the construction of the Lake Albert channel. The study draws on the hydrological assessment of the channel undertaken by WBM Oceanics Australia (2006).
	2006	PIRSA	Purpose of the management option is to reduce Lake Albert salinities by flushing flows from the less saline Lake Alexandrina when surplus water is available.	Economic analysis to investigate the cost effectiveness of constructing a channel between Lake Albert and the Coorong with respect to agricultural and fisheries production. The analysis used input data from the hydrological assessment undertaken by WBM Oceanics Australia (2006).
	2012	ACF and Environment Victoria	Proposed as part of the Meningie Narrung Lakes Irrigators Association 5-point plan to reduce salinities in Lake Albert. Purpose of the management option is to reduce salinities in Lake Albert.	Submission to an inquiry by the House of Representatives Regional Australia Committee into new environmental works and measures projects that could potentially partially offset sustainable diversion limits reductions under the Basin Plan.
Permanent regulating structure across Narrung Narrows	1983	Ebsary	Purpose of the management option is to permit a more selective flow of water into Lake Albert to control the quality of water entering Lake Albert.	Study undertaken on behalf of the then Engineering and Water Supply Department to investigate the potential to construct a channel between Lake Albert and the Coorong in order to reduce Lake Albert salinities. In addition to this management option, the report also considered five additional salinity mitigation options, including a permanent regulating structure across the

Management Option Considered	Date of study	Who undertook the study	Concept of management option (as detailed in the study/report)	Purpose of study (for context)
				Narrung Narrows.
Groyne* through the centre of Lake Albert *A groyne is a rigid hydraulic structure built from a bank that interrupts water flow and limits the movement of sediment.. All of a groyne may be under water. Groynes are generally made of wood, concrete, or rock pile	1983	Ebsary	Purpose of the management option is to improve mixing of Lake Albert and Alexandrina waters and therefore reduce the salinity of Lake Albert.	In 1982, Ebsary commenced a study on behalf of the then Engineering and Water Supply Department to investigate the potential to construct a channel between Lake Albert and the Coorong in order to reduce Lake Albert salinities. In addition to this management option, the report also considered five additional salinity mitigation options, including a groyne through the centre of Lake Albert.
	2005	McInerney	Purpose of the management option is to improve mixing of Lake Alexandrina water in Lake Albert, thereby reducing salinity in the Lower reaches of Lake Albert rather than just the upper.	PhD titled, 'A triangular grid finite-difference model for wind-induced circulation in shallow lakes' centred around testing techniques for the finite-difference model. The effect that a groyne through the centre of Lake Albert would have on flow was considered as an example.
Variation of water levels in Lakes Albert and Alexandrina	1983	Ebsary	Purpose of the management option is to reduce Lake Albert salinity levels by removing salt from Lake Albert.	Study undertaken on behalf of the then Engineering and Water Supply Department to investigate the potential to construct a channel between Lake Albert and the Coorong in order to reduce Lake Albert salinities. In addition to this management option, the report also considered five additional salinity mitigation options, including varying water levels in Lakes Albert and Alexandrina.
	2012a	BMT WBM	Purpose of the management option is to use water level management to reduce Lake Albert salinities.	Commissioned by the Department of Environment and Natural Resources to undertake a range of studies to

Management Option Considered	Date of study	Who undertook the study	Concept of management option (as detailed in the study/report)	Purpose of study (for context)
				improve understanding of key environmental hydraulic process in the CLLMM system, particularly the terminal Lake Albert and Coorong waterbodies.
	2012b	BMT WBM	Purpose of the management it to reduce Lake Albert salinities by improving flushing of salt from Lake Albert as a result of fluctuating lake levels.	To predict whether fluctuating lake levels could improve flushing of salt from Lake Albert.
Central Bund in Lake Albert	1983	Ebsary	Purpose of the management option is to lower Lake Albert salinity levels by reducing the surface area in Lake Albert in order to reduce evaporative losses and consequently reduce the build up of salt.	Study undertaken on behalf of the then Engineering and Water Supply Department to investigate the potential to construct a channel between Lake Albert and the Coorong in order to reduce Lake Albert salinities. In addition to this management option, the report also considered five additional salinity mitigation options, including constructing a central bund in Lake Albert.

6.2.1 Removal of the Narrung Causeway

Australian Conservation Foundation (ACF) and Environment Victoria - 2012

Concept and detail of management option considered:

Removal of the Narrung causeway that is “restricting water flows through the Narrung Narrows” (ACF and Environment Victoria, 2012) as a management option to improving water changeover into Lake Albert.

Findings:

The submission briefly discusses the option to remove the Narrung causeway, noting that the management option (among other infrastructure and proposed improvements) should only be undertaken if detailed environmental impact assessment confirms that the management option will not result in further significant environmental harm. The submission suggests investigating removal of the Narrung Causeway to determine if removal can be achieved in a manner which prevents further environmental harm from mobilising silt. The submission also notes as a response to the Meningie Narrung Lakes Irrigators Association ‘Five Point Plan’ for Lake Albert and the Coorong that removal of the Narrung ferry causeway (Point One) is supported by the Conservation Council of South Australia. No further discussion is provided in response to Point One of the ‘Five Point Plan’.

6.2.2 Dredging the Narrung Narrows

Ebsary – 1983

Concept and detail of management option considered:

Ebsary (1983) explored whether dredging and widening of the Narrung Narrows to improve hydraulic efficiency would allow a greater mix of water between the lakes and would and consequently enhance the freshening effect. The author notes that the winds in the vicinity of Lake Albert induce a fluctuating flow of water between Lakes Albert and Alexandrina. As the water in Lake Alexandrina is almost always less saline than that in Lake Albert, these wind driven flows cause an appreciable freshening of the northern waters of Lake Albert. Ebsary observes that where the reeds reduce the effective width of the Narrows, the depth of the channel is between 4 and 5 metres, and where reeds are absent and the entire width of the Narrows is effective, the depth is about 1 metre at full supply level. Ebsary surmises that this is likely the result of increased water velocity and therefore scouring in areas where the channel width is narrower. The smallest sections of the Narrung Narrows (450 - 500 m²) were those where reeds have reduced the effective width to a few hundred metres. The causeway section (560 m²) was marginally greater than the smallest sections.

Findings:

Ebsary (1983) used a salinity model (calibrated using a mean monthly volume of wind induced flows through the Narrung Narrows of 9,930 ML) to calculate a flow versus head relationship for the following channel improvements:

- All sections smaller than the causeway section dredged to the same areas the causeway section;
- All sections (except the causeway section) smaller than 1,000 m² dredged to area of 1,000 m²; and

- All sections, including the causeway section, smaller than 1,000 m² dredged to area of 1,000 m².

Ebsary's findings indicate that the first two options for dredging the Narrung Narrows would result in increased in channel flow. The results from the modelling excluded the option of dredging all sections (including the causeway section) smaller than 1,000 m² to an area of 1,000 m² and indicated that the option would not increase in channel flows. As such, this option was excluded from further consideration. The percentage increases in channel flow and volume of material required to be dredged for each of the three options listed above are represented in **Table 8**. **Table 8** also summarises the cost and benefit/cost ratios for each option, as provided in Ebsary (1983). Cost was determined assuming a unit cost of \$2 per cubic metre for dredging, plus \$0.5 million for hire of equipment, design, survey, and supervision. Cost/benefit ratios were determined based on estimated salinity benefits (115 EC units and 330 EC units), calculated as value benefits of \$0.74 million and \$2.11 million respectively.

Table 8: Summary of findings relating to options to dredge the Narrung Narrows from Ebsary (1983)

Dredging option	Volume of material to be dredged	Percentage increase in channel flow	Cost	Benefit/Cost ratio
All sections smaller than the causeway section dredged to the same areas as the causeway section	300,000 m ³	15% increase in channel flow	\$1.1 million	0.67 (115 EC units salinity benefit, \$0.74 million value benefit)
All sections (except the causeway section) smaller than 1,000 m ² dredged to area of 1,000 m ²	1.8 million m ³	60% increase in channel flow	\$4.1 million	0.52 (330 EC units salinity benefit, \$2.11 million value benefit)
All sections, including the causeway section, smaller than 1,000 m ² dredged to area of 1,000 m ²	Not provided	Reduction in velocities across the section, but no increase in channel flow.	Not considered	Not considered

Ebsary notes of the two options considered further that much of the additional water forced into Lake Albert could potentially flow back out into Lake Alexandrina prior to mixing sufficiently to dilute salinities in Lake Albert.

Environmental effects identified by Ebsary included: reducing salinity in Lake Albert, particularly the northern waters (the magnitude of which would not exceed the yearly fluctuations in salinity experienced at the time); removal of some of the reeds growing in the shallow water of the Narrung Narrows; removal of quantities of earth from the bottom of the

Narrung Narrows; and disposing of dredged material either in the lakes or adjacent to the Narrows.

McInerney – 2005

Concept and detail of management option considered:

Where Ebsary (1983) examined the influence of dredging to increase the width of the Narrung Narrows, McInerney (2005) examined the effect that increasing the depth of the Narrung Narrows to three metres would have on flow into Lake Albert. The author notes that the depth of the Narrung Narrows at the time was approximately two metres. McInerney hypothesised that dredging the Narrung Narrows would allow more water to flow between Lakes Albert and Alexandrina, potentially decreasing salinity in the upper regions of Lake Albert.

Findings:

McInerney (2005) compared the Narrung Narrows at a baseline depth of two metres with a dredged three metre depth scenario. A 48 day period between 13 October and 30 November 1967 was considered only. The results showed that increasing the depth of Narrung Narrows to three metres increases the exchange of water between the lakes on some days.

Considering the 48 day period, when the Narrows is three metres deep, a volume of $7.47 \times 10^8 \text{ m}^3$ enters Lake Albert. This is compared with the two metre scenario when $5.62 \times 10^8 \text{ m}^3$ enters Lake Albert. Under a three metre scenario, $8.14 \times 10^8 \text{ m}^3$ exits Lake Albert and when the Narrung Narrows is two metres deep, $6.29 \times 10^8 \text{ m}^3$ exits the lake. The model run was undertaken with outflows through Tauwichee Barrage, which explains the greater volume exiting Lake Albert than entering Lake Albert. McInerney suggests dredging the Narrung Narrows to increase the exchange of water between the lakes, and that there would potentially be salinity reduction in the upper regions of Lake Albert as a result of the management option.

6.2.3 Construction of a channel and/or pipeline at the southern end of Lake Albert to the Coorong

Ebsary – 1983

Concept and detail of management option considered:

In 1982, Ebsary undertook a study on behalf of the South Australian Engineering and Water Supply Department to investigate the effectiveness of constructing a channel between Lake Albert and the Coorong. The concept of the management option was that the construction of the channel would enable flushing of poor quality water from Lake Albert and replacement with fresher water from Lake Alexandrina, thus helping to reduce Lake Albert salinity levels. Ebsary assumed that the channel would only operate on when the barrages were open, and that it would not operate if Lake Albert salinities were below Lake Alexandrina's.

The envisaged channel design was a 1.6 kilometre long channel and regulator at the southern end of Lake Albert. Due to the topography of the area, Ebsary determined that the channel would need to be wide and shallow, with an expected width of 20 to 100 metres, and a depth of two to three metres. A channel capacity of 500 to 3,000 ML/day was calculated to produce velocities of 0.03 m/s through the narrowest sections of the Coorong, less than the tidal and wind induced flows in the area (Ebsary, 1983).

Findings:

Ebsary (1983) used a salinity model to calculate the mean improvement in salinity levels from channels varying in capacity from 0 to 150 GL/month (0 GL/month, 15 GL/month, 90 GL/month, and 150 GL/month). The salinity improvements, capital costs, annual operation costs, total present value costs, total present value benefit, and benefit cost ratio determined by Ebsary (1983) for each of the channel capacities are shown in **Table 9**.

Table 9: Summary of channel capacity calculations from Ebsary (1983)

Channel capacity	Capital cost (\$M)	Annual Cost (\$M)	Total present value cost (\$M)	Salinity improvement (EC units)	Total present value benefit (\$M)	Benefit/cost ratio
15 GL/month	1.5	0.032	2.11	660	4.22	2.00
90 GL/month	4.6	0.099	6.47	960	6.14	0.95
150 GL/month	7.1	0.153	10.00	980	6.27	0.63

Ebsary (1983) determined that a maximum net benefit of \$2.4 million would be achieved when the channel capacity is 25 GL/month, with associated costs totalling \$2.7 million, a total benefit of \$5.1 million, and a Benefit/Cost ratio of 1.9.

Although Ebsary acknowledges the salinity benefit that could be gained through the management action (Lake Albert salinities being reduced to a level similar to Lake Alexandrina, expected to be about 1,700 EC units), the report concludes that unless irrigators in the area were prepared to meet the costs associated with construction of the channel, the additional benefit to be gained by constructing the channel (when compared to the management option of fluctuating lake levels) would be difficult to justify when the high associated costs are taken into consideration (Ebsary, 1983). As such, the preferred management option recommended by Ebsary is fluctuation of lake levels rather than construction of the channel.

It is also worth noting that Ebsary (1983) highlights the potential for a major impact to the Coorong ecosystem and, consequently, suggests the need for a rigorous environmental impact statement.

Burton – 1988**Concept and detail of management option considered:**

In 1988, Burton considered a Lake Albert channel to reduce salinity in Lake Albert. Burton undertook the investigation in response to a recommendation by the South Australian Water Resources Council given the experiences in the operation of varying lake levels as adopted per the recommendations of Ebsary (1983).

Findings:

Burton (1988) found that the maximum viable width of the channel would be 55 metres, and identified that the volume release through such a channel in a six week period would be

84 GL. Disadvantages noted by Burton included the possible accumulation of the Lake Albert colloidal load at the interface with the salty Coorong water.

Burton (1988) concluded that information obtained from water level recorder at the time indicated that the period over which the channel would pass adequate flows was significantly less than anticipated by Ebsary (1983), and that the reduction in salinity and thus benefit was also significantly less than estimated by Ebsary (1983).

URS – 2006

Concept and detail of management option considered:

In 2006, URS prepared a report on behalf of the Department of Water, Land and Biodiversity Conservation containing a pre-feasibility concept design and cost estimate for a channel connecting Lake Albert to the Coorong. The report does not make it clear what the purpose of the channel was, although other related reports (WBM Oceanics Australia, 2006; Walters and Souter, 2006; and PIRSA, 2006) suggest that the aim of the management option was to reduce Lake Albert salinities. The report did not include an analysis of the ecological or water quality benefit or otherwise of this management option.

Findings:

URS (2006) determined that the pre-feasibility design for the excavated channel would be 3.5 kilometres long, 50 metres wide at the base, and have side batter slopes of 1V:3H. A pre-feasibility concept design drawing (**Figure 11**) was developed through an assessment against topography, geotechnical and geological factors, existing roads and farm tracks, access to and past the channel, and land usage.

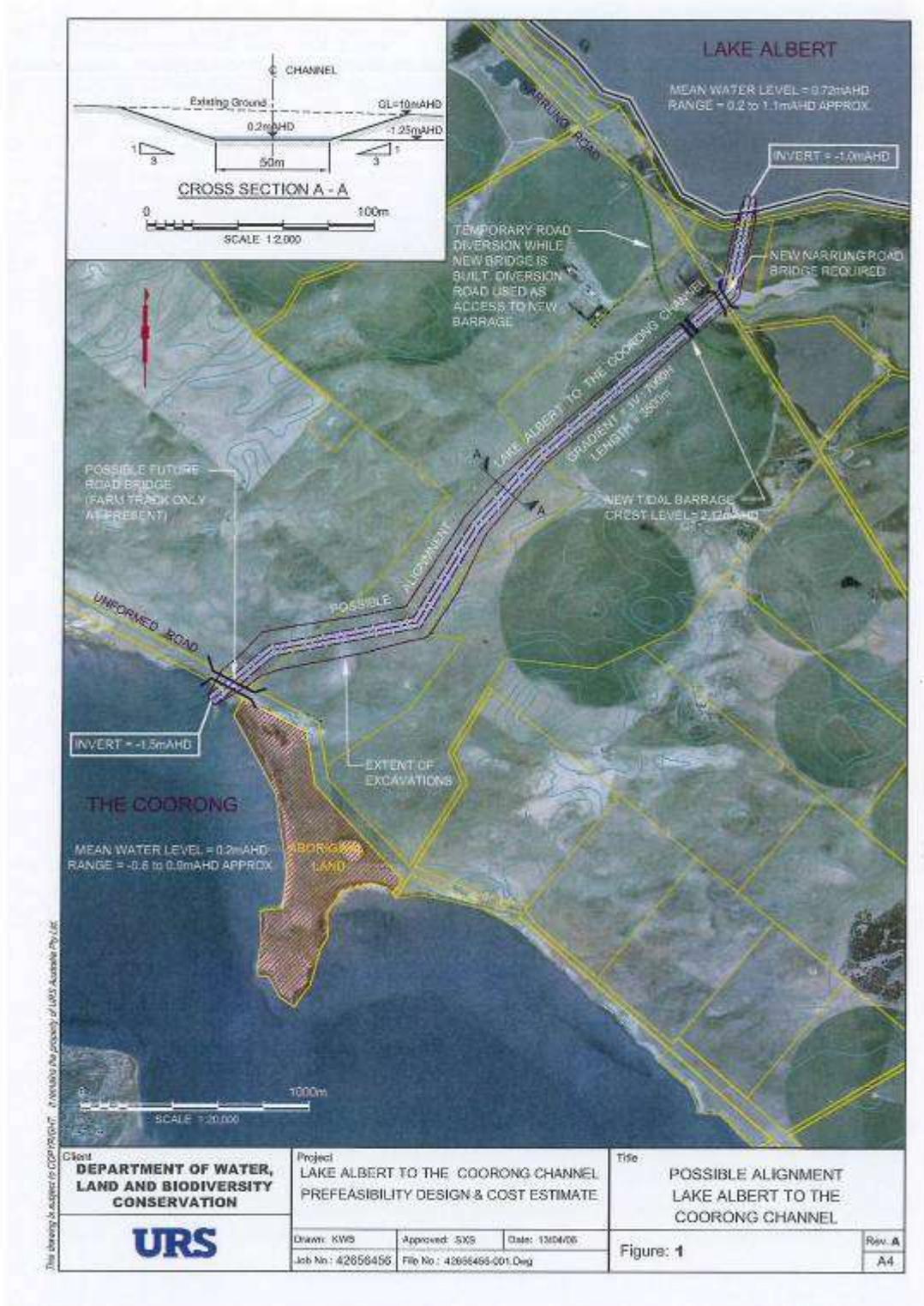


Figure 11: URS (2006) pre-feasibility concept design drawing

The report notes that the proposed alignment was selected to avoid areas of Aboriginal land identified on the northern shores of the Coorong, near the outlet of the proposed channel, and to minimise potential impacts to land usage. However, the report acknowledges that farm areas which the channel traverses would be effectively cut-off from north-west to south-east. The geological and geotechnical considerations highlighted some geotechnical issues,

including: the excavatability of the geological strata (ranging from easy sand to hard sheet calcrete, impacting on excavation equipment and methodology; groundwater levels with respect to the drain invert, influencing whether excavation should be undertaken in the wet or dry; and the erodibility of the sides and base of the channel.

The channel gradient was assumed to be 1V:7000H with a depth of 1.72 metres, based on the channel bed entrance level (Lake Albert) being assumed as -1.0 m AHD, and the channel bed exit level (the Coorong) being assumed as -1.5 m AHD. Calculations showed that for average water levels (0.72 m AHD for Lake Albert and 1.0 m AHD for the Coorong) the channel would have a flow rate of 45 m³/second, or 3,850 ML/day, with an average velocity of 0.5 m/second.

Based on the pre-feasibility channel design, the estimated quantity of excavated earthworks was 3.5 million m³. The report also notes that dredging of both Lake Albert and the Coorong would be required, although the extent of this dredging was not known at the time as detailed bathymetric information was not available.

The report includes a rough order cost estimate (+/- 20%) for the construction of the channel of \$126,000,000 + GST, with most costs noted as being associated with excavation and disposal of the spoil (URS, 2006). The cost estimate assumes an excavation rate of \$12/m³ for excavation with a 30 tonne excavator, and an earthworks haulage rate of \$12/m³, assuming that there are suitable sites for a spoil disposal area within 30 kilometres of the site (not including at a dump site).

WBM Oceanics Australia - 2006

Concept and detail of management option considered:

WBM Oceanics Australia (2006) conducted a modelling assessment of connecting Lake Albert and the Coorong in order to reduce Lake Albert salinities. The assessment considered that the Lake Albert connection would be a channel and barrage of 50 metre base-width and base level of -1 m AHD, with side slopes at 1:3. The barrage was assumed to be located at the northern end of the channel, would be a type equivalent to the Tauwitche barrage, and would have a total capacity of approximately 3,500 ML/day.

Findings:

WBM Oceanics Australia (2006) compared salinities in both Lake Albert and the Coorong to the existing base case (no connecting channel) and the connected case. The authors of the modelling assessment established flow and barrage release scenarios based on typical operating procedures in order to conduct the modelling assessment, as follows:

- a. Short scenarios: Two short scenarios (six weeks) tested to assess the immediate short term relative influence of different release flow rates on Lake Albert and Coorong salinities. The flows were 2,000 ML/day and 7,500 ML/day.
- b. Long scenarios: Two long scenarios (five years) to assess longer term responses to long term variability of river flow, incorporating the effects of evaporation.

Two models were run for each of the four scenarios: the RMA model and the Delft3D model. The results of the modelling indicated that under all scenarios the construction of a channel between Lake Albert and the Coorong would have a significantly beneficial effect in reducing salinities in both Lake Albert and the Coorong. For the short scenarios the models confirmed, as predicted in the assessment, that Lake Albert salinities are reduced as a result of lower

salinity water being drawn in from Lake Alexandrina. However, the two models differed in the spatial distribution of the salinity reductions, with the Delft3D model showing marked salinity reduction around the lake margins and less in the centre of the lake, while the RMA model showed a more uniform distribution. The salinity benefits for the long scenarios are considered clear by the authors, although it is noted that the results are contingent on sufficient river flow being available to overcome lake evaporation and allow water to discharge through the channel (WBM Oceanics, 2006).

Walters and Souter - 2006

Concept and detail of management option considered:

Walters and Souter (2006) considered the same channel design as assessed in WBM Oceanics Australia (2006).

Findings:

Walters and Souter (2006) examined the potential impact on the Coorong of the Lake Albert channel. Walters and Souter (2006) note that the modelling undertaken in WBM Oceanics Australia (2006) showed that releasing water from the Lake Albert channel into the Coorong would move the area of estuarine influence away from the Murray Mouth. The authors note of the impacts to the Coorong, that unless sufficient water were released this would likely move the boundary of marine influence further down the Coorong and dilute the salinity gradient rather than create significant extra estuarine habitat. Input of freshwater to the Coorong would be moved away from an area of high ecological value (mudflats around Tauwitchere) to an area of lower habitat quality. This would reduce the impact of freshwater releases on these mudflats and be detrimental to this critical habitat.

Walters and Souter (2006) concluded that there is no compelling environmental reason, from the perspective of the Coorong, for construction of a channel between Lake Albert and the Coorong, noting that rather than improving the health of the Coorong, the channel would supply the Coorong with poor quality, turbid water.

Walters and Souter (2006) also note of the WBM Oceanics Australia (2006) modelling assessment that the short scenario modelling results discussed do not consider the effects of wind on mixing and circulation, or of the effects of evaporation in Lake Albert; and that the long scenario modelling would have benefited from considering a wide range of flow scenarios, potentially a longer time frame than between 1993 and 1999.

Primary Industries and Resources South Australia (PIRSA) – 2006

Concept and detail of management option considered:

PIRSA (2006) conducted an economic analysis of a channel between Lake Albert and the Coorong to reduce Lake Albert salinities. The analysis re-investigated the cost effectiveness of constructing the channel with regards to agricultural and fisheries production, using the salinity and water flow modelling undertaken by WBM Oceanics Australia (2006) to update cost benefit analyses undertaken by previous studies such as Ebsary (1983).

Findings:

PIRSA (2006) used the construction costs estimated by URS (2006), \$89.5 million, as the basis for the cost benefit analysis. A Benefit-Cost Analysis (BCA) was used for the economic

evaluation to estimate the size of the net social benefits of the management option, and to determine whether the management option was a sound investment of public funds. In order for the management option to be considered a good investment, the analysis notes that the sum of the benefits to irrigated agriculture, fisheries, and the environment need to exceed the \$89.5 million construction costs.

The economic analysis determined that the total value of benefits to irrigated agriculture in the CLLMM region as a result of the construction of a channel between Lake Albert and the Coorong would be in the order of \$1.9 million to \$3.2 million, depending whether local irrigators are aware of potential salinity damage. The BCA determined that this resulted in a Benefit Cost Ratio of between 0.02 and 0.04.

The analysis concludes that given that “the costs of construction and ongoing operations and maintenance of the channel [would be] in the order of \$90 million, there would need to be very significant net benefits, in the order of \$87 million, to the fisheries sector, environment or other factors for the channel to be economically viable and therefore justifiable expenditure of public funds” (PIRSA, 2006, p 14).

Potential benefits to the irrigated agricultural sector identified through the analysis included increased yields due to salinity damage being avoided, or reduced water purchase costs. Identified potential benefits to the fisheries sector included increased numbers of some commercial species weighed against potential costs including increased carp numbers and potentially reduced catch quantities due to fish migration (PIRSA, 2006).

Australian Conservation Foundation (ACF) and Environment Victoria - 2012

Concept and detail of management option considered:

The ACF and Environment Victoria (2012) briefly discussed opening Lake Albert to the Coorong, and Point 4 of the Meningie Narrung Lakes Irrigators Association ‘Five Point Plan’ for Lake Albert and the Coorong, which proposed installation of a pipeline between the southern end of Lake Albert and the Coorong.

Findings:

The submission briefly discussed the proposal to open Lake Albert to the Coorong, noting that the proposal was not supported due to significant environmental issues. In response to the Meningie Narrung Lakes Irrigators Association ‘Five Point Plan’ for Lake Albert and the Coorong, the submission identified that the Conservation Council of South Australia does not support Point 4 as it would not improve water quality in the Coorong, would damage an already fragile ecosystem, would not compensate or replace inadequate natural flows into the Coorong, Lower Lakes and Murray Mouth, and would provide no real benefit to the Coorong or Lower Lakes.

6.2.4 Permanent regulating structure across Narrung Narrows

Ebsary – 1983

Concept and detail of management option considered:

Ebsary (1983) considered the potential for a barrage across the Narrung Narrows as a Lake Albert salinity mitigation option. The management option involved the construction of a lock and barrage across the Narrung Narrows in order to permit a more selective flow of water into

Lake Albert. The management option was believed to allow the lake to be isolated at times when poor quality River Murray water is passing, which would be particularly useful in preventing the poor quality entering the lake as flood waters rise. After allowing the poor quality water to pass, the lake could be filled with better quality water, thus reducing the overall lake salinity.

Findings:

Ebsary (1983) noted that the control works would also permit a number of other operational procedures, such as filling Lake Albert to above full supply level, lowering the level in Lake Alexandrina and then allowing Lake Albert level to fall below full supply level after mixing of Lake Albert waters due to wind, thereby replacing poor quality lake water with good quality river water. However, Ebsary notes that this would be a very cumbersome method of operation.

Ebsary concluded that the greatest benefit of a control structure across the Narrows would be in preventing the inflow of poor quality water as flood waters rise, which would only be of benefit during times of flood and at these times the barrages can be opened to permit the poor quality water to flow out to sea rather than into Lake Albert. Furthermore, Ebsary notes that a structure across the Narrung Narrows would also seriously inhibit the wind induced mixing between Lakes Albert and Alexandrina, resulting in the overall management option being of little benefit.

In addition, Ebsary found that most of the operating strategies for which this option would be used could be achieved by utilising the existing river regulating structures and concluded that the management option was not attractive given the associated capital cost (\$3.05 million) and annual costs (\$66,000).

Environmental effects identified by Ebsary included: reducing salinity in Lake Albert, (no more than the yearly fluctuations in salinity experienced at the time); changing water level in Lake Albert by up to 0.1 metres and 0.3 metres below existing full supply (lake level not expected to differ from normal pool level for any great length of time); to create a physical barrier between Lake Alexandrina and Lake Albert.

6.2.5 Groyne through the centre of Lake Albert

Ebsary – 1983

Concept and detail of management option considered:

Ebsary (1983) investigated the potential for a groyne through Lake Albert to improve mixing of Lake Albert and Alexandrina waters, thereby reducing Lake Albert salinity. Ebsary notes that mixing of better quality Lake Alexandrina is largely confined to the northern section of Lake Albert where wind activity is present. The management option considered by Ebsary involved the construction of a north-south groyne-like structure through the centre of Lake Albert. Ebsary describes the structure as being either a flexible membrane with floats at the top and weights at the bottom, or be a fixed sheet pile wall. Ebsary hypothesised that the structure could operate by having a moveable section of wall at the northern end which would utilise wind induced surges to deflect water down one side of Lake Albert, forcing the lake water to circulate around the structure and into Lake Alexandrina. This circulation would prevent fresh water inflows into Lake Albert from being confined to the northern end of the lake, thereby helping to reduce salinities in the southern end of the lake, and would keep Lake Albert

salinities lower during prolonged periods of barrage closure because the circulating process is wind driven rather than flow-influenced.

Findings:

Ebsary concluded that the management option had many drawbacks, including operational issues and cost. In particular, Ebsary notes that the structure would reduce the volume of water exchanged between lakes Alexandrina and Albert by inhibiting the formation of a head across the Narrung Narrows due to wind effects. In addition, the stability of a flexible membrane structure would likely be compromised by the strong winds experienced in the area, and the operation and timing of the movement of the moveable section of wall would likely be impractical. Ebsary finishes by highlighting that the costs associated with the construction of a structure of adequate length to improve mixing would be upwards of \$22 million, which the author considers to be prohibitive.

Environmental effects identified by Ebsary included a reduction in Lake Albert salinities similar to Lake Alexandrina salinities, and the creation of a physical obstruction to recreation activities and fauna in the lake.

McInerney – 2005

Concept and detail of management option considered:

In addition to investigating the effect that increasing the depth of the Narrung Narrows has on the inflow of water into Lake Albert, McInerney (2005) also used the finite-difference model technique to examine the influence that the groyne-like structure (impermeable barrier) suggested by Ebsary (1983) would have on flow patterns.

Findings:

McInerney's thesis examined the influence that the impermeable barrier would have on flow patterns within Lake Albert with the moveable section of the barrier in positioned in two different ways (see **Figure 12**), as compared against the results when there is no barrier in Lake Albert.

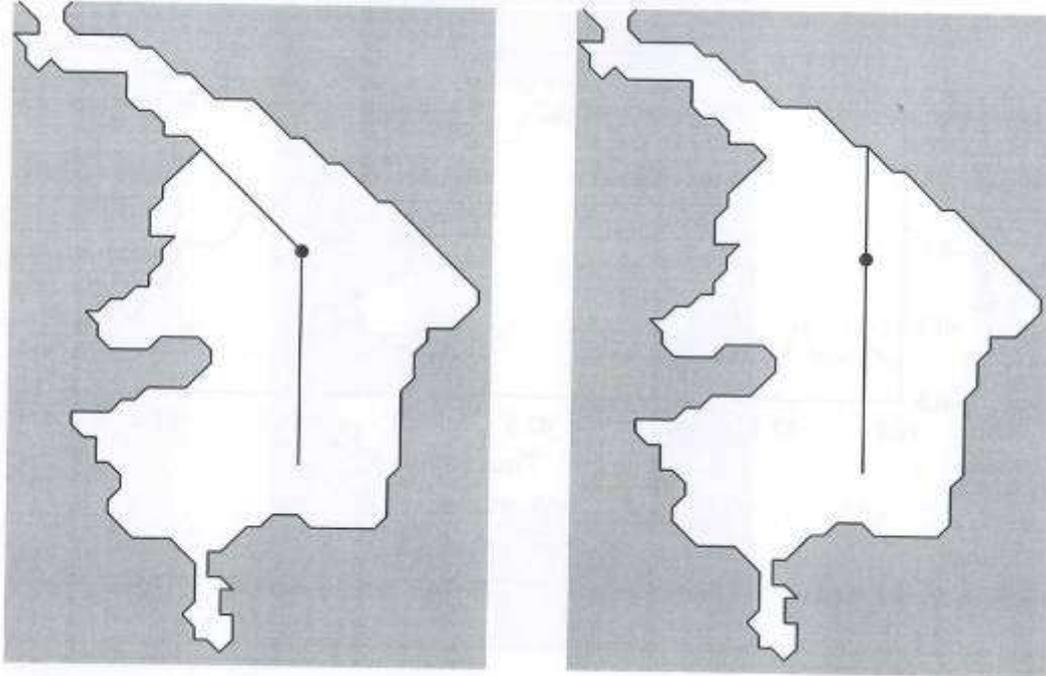


Figure 12: Diagram of barrier positions examined by McInerney (2005). The left diagram is Barrier Position 1, the right Barrier Position 2.

McInerney used the same 48 day period between 13 October and 30 November 1967 to examine the impact to flow patterns. McInerney's results confirmed Ebsary's assertion that mixing of fresh water inflows from Lake Alexandrina are confined the northern section of Lake Albert when there is no barrier, although it is noted that this could be confirmed with a salinity transport model.

McInerney concluded that the results of the modelling suggest that the construction of an impermeable barrier in Lake Albert would result in a more complete mixing of waters in the upper and lower regions of Lake Albert, provided that the regular switching between the two barrier positions occurred. Furthermore, McInerney noted that salinity levels would increase on one side of Lake Albert if the impermeable barrier remained in Barrier Position 1 for too long.

McInerney also used the same methodology to test Ebsary's suggestion that the impermeable barrier would most likely inhibit the formation of a head across the Narrung Narrows and thereby reduced the exchange of water between lakes Alexandrina and Albert. McInerney's findings suggest that the exchange of water between the two lakes is only marginally reduced when the impermeable barrier is introduced in either position 1 or 2.

6.2.6 Variation of water levels in Lakes Albert and Alexandrina

Ebsary – 1983

Concept and detail of management option considered:

Ebsary (1983) examined the possibility of varying water levels in lakes Alexandrina and Albert, through barrage operations, to allow water to flow out of Lake Albert and prevent a build-up of salt. Ebsary hypothesised that, if it was known that fresh water was going to be

flowing down the River Murray, then the barrages could be opened prior to the arrival of the fresh water to remove a significant quantity of salt, allowing Lake Albert to be filled with fresher water, thus reducing salinity.

Findings:

Ebsary (1983) used a salinity model to examine the following two scenarios:

- i. Lower the lake level to EL 0.5 prior to the arrival of a flow greater than 15,000 ML/day. Also lower level to EL 0.5 every other month if flow is greater than 15,000 ML/day for more than two consecutive months.
- ii. Fluctuate lake level between EL 0.64 and 0.84 if flow at Lock 1 is greater than 15,000 ML/day for a month.

A threshold flow of 15,000 ML/day was chosen to allow for losses downstream of Lock 1, and to give a sufficient margin of safety in the event that the predicted flow was overestimated. Of the 912 months analysed, 196 (21 per cent) had a mean daily flow in excess of the threshold.

Results of the modelling suggested that from EL 0.64 to 0.84, Lake Albert volume was 36 GL, and the volume of the entire lakes system was 180 GL. For scenario i., if the level of the lakes is fluctuated between EL 0.64 and 0.84 once a month during periods of surplus flow, then 36 GL of water will be removed from Lake Albert and replaced by an equal quantity of fresher water. Fluctuating lake levels once a month was shown to allow the inflowing water ample time to mix within Lake Albert before flowing out again.

Ebsary (1983) calculated that the mean salinity improvement for scenario i. was 300 EC units, and 340 EC units for scenario ii.

Environmental effects identified by Ebsary (1983) included a reduction in Lake Albert salinity (no greater than the yearly salinity fluctuations experienced at the time the study was undertaken), potential change in Lake Albert water level by up to 0.1 m above and 0.3 m below the existing full supply.

Ebsary (1983) identifies fluctuation in lake levels as part of the preferred engineering option, noting that it showed substantial benefits in reducing salinity levels, at a very low cost.

BMT WBM – 2012a

Concept and detail of management option considered:

BMT WBM (2012a) considered how water level management within the Lower Lakes could enhance salinity reduction within Lake Albert, and provided a forecast of Lower Lake water levels and salinity for given inflow and water level management objective.

Findings:

The aim of BMT WBM's investigations was to provide an estimate of predicted salinity and water levels. Modelled predictions were based on a range of forecast lake inflows, target lake levels, and historically observed wind and tides. Given that catchments rainfall could generate significant differences in actual lake inflow, a number of additional flow scenarios were also simulated. The additional flow scenarios also investigated the release of stored water termed environmental flow (e-flow) as it was above the required minimum flows dictated by existing river regulations.

The report describes a baseline model forecast for the 12 month period 18 April 2012 – 18 April 2013. The model is defined as a forecast simulation, because it used a range of predicted and previously observed data to define model boundary conditions. The use of a forecast model simulation was used to determine the likely water levels and salinities within the Lower Lakes and the Coorong in the future. A number of additional scenarios that investigated different lake inflows, evaporation, wind and tide conditions, target lake levels, and changes to barrage release distribution were also simulated.

Model results indicated that a single water level fluctuation event could increase salt export from Lake Albert by nearly 50 per cent.

The unavailability of long term forecast rainfall and evaporation conditions meant that a design or historic net evaporation boundary conditions needed to be used in the forecast simulations. To determine the influence of net evaporation data on predictions of future salinity levels in the Coorong and Lower Lakes, three different evaporation boundary conditions were simulated: 975 mm/y, 834 mm/y, and 605 mm/y. The model results indicate that salt transport and salinity level predictions in Lake Albert and the Coorong are highly dependent on the selected evaporation boundary condition.

The study also showed that the selection of climatic data to run forecast models could result in significant changes to the predicted salinity levels and salt fluxes in the Lower Lakes and Coorong. By running scenarios with a range of historic or design conditions, an indication of the range of likely forecast predictions can be established.

While giving due consideration to the range of future predictions (due to the difference in actual and forecast conditions) that may have been likely over the 12 month study period, the model investigations revealed that the deliberate raising and lowering of lake levels can cause a significant increase in flushing of salt from Lake Albert. Using the standard series of target lake levels the model predicted that during the simulated period 92,277 tonnes of salt would be exported from Lake Albert (12.2% reduction from the initial salt mass of the lake). However, using the manipulated target lake level series, 142,000 tonnes would be exported (18.7% reduction). This is a near 50% increase in salt mass removal compared to the non-manipulated scenario.

BMT WBM – 2012b

Concept and detail of management option considered:

BMT WBM (2012b) used ten hydrodynamic model simulations of the Lower Lakes, Coorong and Murray Mouth to predict if changes to lake water levels may improve the flushing of salt from Lake Albert. The study modelled five different water level management options and two different wind and tide conditions. Model simulations covered the approximate three month period from early June to early September.

The five different lake water level management options were:

- 0.7 m AHD
- 0.8 m AHD
- 0.9 m AHD
- 0.1 m cycled
- 0.2 m cycled

The two different wind and tide data sets used in the scenario simulations were:

- 1/6/2008 – 7/9/2008
- 1/6/2010 – 7/9/2010

Findings:

The results of BMT WBM's investigations indicated that during winter, wind mixing alone is able to cause significant salt export from Lake Albert. The model simulations indicated that during the simulation period, the use of 2010 wind conditions resulted in an increase in salt export of 20 per cent when compared to the equivalent 2008 simulation.

The model scenarios also indicated that by deliberately raising and lowering lake levels, up to 35 per cent more salt could be exported from Lake Albert than if a static 0.7 m AHD level was adopted. The results also suggest that the timing of lake level fluctuations significantly influence the magnitude of salt export.

The model results also indicated that no increases to salt export are likely to occur if lake water levels were deliberately raised above typical operating levels. The increases to salt export that occur in 0.8 and 0.9 m AHD scenarios occur due to the bulk transport that happens during actual water level changes and not during the static period of increased water levels.

While the model results show that large lake level fluctuations are likely to enhance salt export from Lake Albert, adaptive management should be used to ensure that targeted water level changes do not reduce the impact of wind driven salt export events.

The impacts of water level targets and hence barrage discharges on the salt dynamics of the Coorong should also be considered.

6.2.7 Central Bund in Lake Albert

Ebsary – 1983

Concept and detail of management option considered:

Ebsary (1983) also considered the construction of a bund within Lake Albert to reduce the surface area of the lake, thereby reducing evaporative water losses. At the time Ebsary's report was prepared, the mean annual evaporative loss from Lake Albert had been estimated at 122 GL, representing 42 percent of Lake Albert's volume at full supply. The management option considered involved a closed bund shape (which could contain sea water or be allowed to dry completely) leaving an annulus of fresh water around the perimeter of the lake.

Findings:

Ebsary found that the bund would inhibit wind induced mixing of waters between Lake Albert and Lake Alexandrina as a result of decreased fetch winds from the east and south-east. Ebsary noted that although a greater quantity of flushing water would be made available by the reduction in the Lake Albert volume, the bund could make Lake Albert more susceptible to high salinities when lake levels are low. Further, the reduction in Lake Albert volumes would also prevent the dilution of inflowing highly saline groundwater when the lake was below full supply.

Environmental effects identified by Ebsary included: the creation of an obstruction to recreational activities on the lake; a change in the environment to a large section of Lake

Albert from fresh water to salt water; the possibility that the ecology within the bunded area could be destroyed; and an increase in the quantities of water available for diversion within South Australia.

Ebsary concludes that the overall effectiveness of a central bund in Lake Albert would be much less than constructing a channel between the Lake Albert and the Coorong, particularly considering the estimated cost of in excess of \$10 million to construct a bund which encloses an area of approximately 2,000 hectares.

7 Conclusion

This Literature Review has identified and summarised key existing information and reports relating to Lake Albert, focusing on comparing historic and current environmental conditions, identifying the key issues affecting Lake Albert, and management options previously considered to address Lake Albert water quality issues. A comparison between historic and current environmental conditions highlights that European settlement has significantly impacted on the CLLMM region environment, and that the recent drought of 2006 to 2010 had a dramatic effect on the ecology of the site. The Literature Review notes that the target salinity level for Lake Albert is 1,500 EC (Phillips and Muller, 2006), and that water levels should be maintained above -0.75 m AHD in order to prevent large-scale acidification events.

The Literature Review also highlights that Lake Albert water quality management has been an ongoing issue since European settlement, particularly management of salinity levels. Existing reports and studies have highlighted that the following management options provide little benefit in reducing Lake Albert salinities, particularly when associated costs are considered:

- permanent regulating structure across the Narrung Narrows;
- groyne through the centre of Lake Albert; and
- central bund in Lake Albert.

Existing reports and studies have also suggested that some salinity improvement may be made by dredging the Narrung Narrows, but that the greatest improvements to reducing salinity are to be made through construction of a channel/pipeline between Lake Albert and the Coorong, and variation of water levels in Lakes Alexandrina and Albert. However, it should be noted that several studies and reports investigating the channel/pipeline between Lake Albert and the Coorong questioned the cost effectiveness of this management option when the high associated costs are weighed against the potential benefits (Ebsary, 1983; Burton, 1988; PIRSA, 2006).

The information presented in this Literature Review will be used to inform the Lake Albert Scoping Study, including guiding what management actions are investigated, and development of the Future Directions paper and Business Case.

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Attachment A



Government of South Australia

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16 March 2012

Mr Neil Shillabeer

President

Lower Lakes and Coorong Infrastructure Committee

Dear Neil

In response to your email dated 7th March 2012 asking for verification of value movements between 2005/2006 and 2010/2011 financial years within the immediate areas around Meningie and Narrung Peninsula, I provide the General Valuation (GV) decisions made for each year as outlined in the table below;

Financial Year	Dry Land	Irrigated Land
2005/2006	Increased 35%	No Change
2006/2007	Increased 25% (Meningie) Increased 15% (Narrung)	No Change
2007/2008	Increased 5%	Reduced 25-30%
2008/2009	Reduced 10-15%	Reduced 20% (Meningie) Reduced 40% (Narrung)
2009/2010	No change (Meningie) Reduced 11% (Narrung)	Reduced 11%
2010/2011	No Change	No Change

I advise that the GV value movements made for each financial year apply to the region as a whole, however individual property value movements may vary. The GV value movements reflect the uncertainty caused by the lack of water/irrigation access within Meningie and the Narrung Peninsula, and is further emphasised by the rapid change of land use from irrigation reliant industries to dry land agricultural use over a very short period of time.

In addition, regular monitoring of irrigated land has occurred with further reductions being made to land when water licenses have been reduced or sold. In instances where the irrigation licenses were reduced or sold values would have dropped from \$4,800 to \$9,700 per hectare (irrigated) in 2006/2007 to between \$1,000 to \$2,000 per hectare as dry land use by 2009/2010. Irrigated values in the main are now \$3,750 per hectare.

The Valuer-General is continuing to monitor the region for any further changes to land use and affect to value levels as water restrictions have been eased, although few irrigated properties remain.

Regards



Andrew Weinmann

Per
Steve O'Loughlin
DEPUTY VALUER-GENERAL