Lake Albert Scoping Study Options Paper

Government of South Australia
Department of Environment, Water and Natural Resources

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1 Executive Summary

Lake Albert water quality has been very slow to recover from the high salinity levels reached during the peak of the drought between 2006 and 2010. During that time, inflows to Lake Albert and Lake Alexandrina (the Lower Lakes) dropped to historically low levels. Salinity peaked at more than 13 times the long term average in Lake Albert, threatening the ecology, local economy (particularly agriculture) and communities.

Lake Albert is a terminal lake with no direct connectivity to the sea, so the ability for salt to be naturally exported from the system is limited. The lake's main water inflow comes from Lake Alexandrina via the Narrung Narrows. Despite improvements in water levels and flows since the drought, salinity levels have declined but not returned to pre-drought levels.

The future is looking more promising. Under the Murray-Darling Basin Plan 2800 GL/year modelling scenario, Lake Albert is expected to experience salinity above 2000 electrical conductivity (EC) in only six periods in 114 years and these periods would be for a mean duration of 180 days. This is in contrast to 23 periods of 360 days (mean duration) under a baseline scenario with no Basin Plan (Heneker and Higham, 2012). Further, Lake Albert is not expected to fall below 0.0m Australian Height Datum (AHD) at any time under the Basin Plan.

Hence, the Basin Plan should greatly reduce the risk that Lake Albert will again experience the prolonged and extreme impacts of low water levels, low inflows and high salinity levels of 2006–2010, unless unprecedented low inflow conditions are experienced.

This Options Paper is based on the Lake Albert Scoping Study, which responds to concerns about the post-drought condition of Lake Albert and the wellbeing of its community, environment and industries. The Scoping Study was funded by the Australian and South Australian governments under the $137 million Coorong, Lower Lakes and Murray Mouth (CLLMM) Recovery Project and aimed to investigate options for the long-term management of Lake Albert water quality and the Narrung Narrows

This Options Paper is a summary of the:

- Main findings of the Scoping Study, including modelling and cost benefit analyses of lowering salinity levels to pre-drought levels.
- Management options that were identified and investigated in the Scoping Study to improve Lake Albert's water quality.

1.1 Potential management actions considered

Management actions to reduce Lake Albert salinity levels have been discussed in numerous studies since the early 1980s. Several of these were considered in the Scoping Study.

The following management options were shortlisted through a community engagement process and are now discussed in this Options Paper:

- **Base Case: Do Nothing Option** – Here, no further management actions would be undertaken. Lake Albert would continue to experience elevated salinity until normal lake operations achieve a salinity level within the historical range.
- **Option 1: Dredge the Narrung Narrows** - This would involve dredging sediment along the channel to remove flow restrictions through the Narrung Narrows. This option would aim to optimise the wind driven exchange of water between the two lakes.
- **Option 2: Remove, partially remove or modify the Narrung Causeway** - The Causeway was built in the early 1960s to allow the ferry to operate in adverse weather. This option would involve either (1) fully or partially removing the causeway to improve flows or (2)

installing infrastructure such as culverts within the causeway to improve flow, leaving the causeway in its current location.

- **Option 3: Construct a Coorong Connector (channel)** – This would involve constructing a regulated channel between Lake Albert and the Coorong North Lagoon to improve salt export from Lake Albert.
- **Option 4: Construct a Coorong Connector (pipe)** - This is similar to Option 3, however a pipeline would be installed instead of a channel.
- **Option 5: Construct a Permanent Regulating Structure in the Narrung Narrows** – This option involves the construction of a permanent structure in the Narrows channel to enable the independent manipulation of water levels between the two lakes. Water could be held in Lake Albert to surcharge the lake independently of Lake Alexandrina. Once Lake Alexandrina water levels are lower than Lake Albert, the structure could be opened, using the water level differences to export water and salt.
- **Option 6: Lakes Cycling** – This involves the use of existing barrages between the Coorong and Lake Alexandrina would be used to vary the level of the lakes. By raising the level of both lakes to put fresh water from Lake Alexandrina into Lake Albert, allowing time for mixing, water and salt would be drawn out of Lake Albert and discharged through the barrages. This option does not require additional structures within Lake Albert.
- **Emergency Drought Response: Temporary Reset pumping** - The concept of temporary reset pumping was identified as a possible emergency drought response during the final stages of this project. Temporary Reset Pumping would involve temporary pipes and pumps to transfer Lake Albert water into the Coorong following a drought sequence. The modelling results for the Coorong Connector would apply equally to Temporary Reset Pumping. This concept did not undergo engineering feasibility assessment or cost benefit analysis due to the timing of its identification.

1.2 Investigation and assessment methodology

The Scoping Study involved a detailed assessment of past studies to come up with the six main management options above. It also incorporated community inputs from formal consultation documents, including a Community Requirements Study and a Ngarrindjeri Position Paper.

Throughout the Study, community engagement took place via a Community Reference Group (CRG), a sub-group of the CLLMM Community Advisory Panel that includes representatives from the Coorong District Council, Meningie Narrung Lakes Irrigators Association and Ngarrindjeri Regional Authority. The CRG is a conduit between the broader community and government. As at March 2014, this group had met on 10 occasions.

1.3 Salinity Modelling Investigation

The effectiveness of each management option in reducing salinity was tested using:

- **Preliminary modelling (BMT WBM, 2013)** - a desktop investigation to provide an initial assessment of potential management options
- **MSM Bigmod Modelling (MDBA 2013) -** a long-term modelling suite that models potential change in water management and salinity levels within the Lower Lakes
- **TUFLOW FV Modelling (BMT WBM, 2014)** - the salinity dynamics of the Lower Lakes and Coorong were modelled to evaluate the effectiveness of the six management options.

Twelve scenarios were tested to assess the impact of varying wind conditions, inflow and evaporation, and initial salinity (at 400/5000 EC and 700/2000 EC[1]).

1.4 Salinity Modelling Results

The preliminary modelling investigations, MSM Bigmod, and TUFLOW FV modelling considered all potential management actions with the exception of the Permanent Regulating Structure that was not considered using MSM Bigmod due to the technical nature of its operational rules.

The Coorong Connector delivered substantial improvement in Lake Albert salinity relative to the Base Case in all modelled scenarios. It could reduce salinity to historic levels (~ 1500 EC) within the three years modelled in TUFLOW FV. Lake Cycling was the only other option that resulted in salinity improvement, but less so than the Connector over the same time period. Whilst the Connector provides for the shortest term salinity reduction, the approvals and construction period required to put this measure in place means that a similar outcome could be achieved through Lakes Cycling over the same period.

Other management options tested delivered marginal benefits relative to the Base Case and only under some scenarios. In certain scenarios, the other management options actually delivered worse salinity outcomes than the Base Case, namely the Permanent Water Regulating Structure and Dredging Narrung Narrows / Removal of Narrung Causeway.

1.5 Coorong Connector Design Considerations

The Department of Environment, Water and Natural Resources (DEWNR) engaged Sinclair Knight Merz (SKM) to undertake a two part engineering feasibility study of the potential management actions. The study comprised:

- Part 1: Engineering Feasibility Review using a Multi-Criteria Analysis Framework
- Part 2: Concept Design and Cost Estimate.

Three alignments were considered for the Coorong Connector (**Figure 1**). The Meningie Lakes Narrung Irrigators Association (MNLIA) proposed Alignments 1 and 2 while Alignment 3 was defined by URS (2006). The current concept design, however, only considered Alignment 2 as it is one of the two shorter alignments and offers the best access to deeper bathymetry, therefore requiring the least dredging. Alignment 2 is also the most cost effective.

Analysis by SKM revealed that a 'channel' Connector is preferred to a 'pipeline'. To achieve the volume transfer required (1GL/day), a pipeline would require three or more large (2400 mm diameter) pipes and would deliver similar benefits to that of a channel for a higher comparative cost. SKM indicated that a pipeline would be more complex and expensive to construct, operate and maintain than a channel system for a range of reasons, including piping footprint requirements, ongoing cleaning of the inside of the pipeline, operations and maintenance.

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[1] 400/5000 EC refers to 400 EC in Lake Alexandrina and 5000 EC in Lake Albert. 700/2000 EC refers to 700 EC in Lake Alexandrina and 2000 EC in Lake Albert. The 400/5000EC scenario was chosen to represent a 'recovery from drought' situation while the 700/2000EC scenario was chosen to represent approximate current conditions.

Figure 1: Possible alignments or the Coorong Connector between Lake Albert and the Coorong.

The key design features of the Coorong Connector (channel) based on Alignment 2 are as follows:

- The channel would be operated to maintain target salinity levels in Lake Albert and manage infrequent high Coorong water levels versus Lake Albert levels
- The alignment length is 1825 m and the excavation volume for disposal is 244,000 m^3
- Dredging into the Coorong and Lake Albert (700 m and 200 m respectively) is required to achieve the necessary invert levels
- The estimated cost is approximately $18.97 million (+/-30 %, 2014 dollars) including design and construction contingencies.

1.6 Shortlisting of Options

The six management options were assessed against four 'viability' criteria: effectiveness, project feasibility, community support and acceptable delivery period. These criteria reflected 'mandatory requirements'; if an option scored a 'no' against any criterion, it was assessed 'not viable' and was not considered further in the Scoping Study. The following two options are considered viable for further assessment:

- **Option 3** Construct a Coorong Connector (channel)
- **Option 6** Lakes Cycling

1.7 Cost Benefit Analysis

Having met the criteria in the shortlisting process, options 3 and 6 underwent a cost benefit analysis (CBA) to determine value for money. Here is a summary of the analysis.

- Quantitative assessment of the Coorong Connector channel (Option 3). The focus here was on whether the Connector – an expensive option – would deliver net benefits.
  - The CBA estimated Net Present Value (NPV) and Benefit Cost Ratio (BCR) over a 25 year period. The estimated benefit cost ranged between 0.30 and 0.41. Under all the scenarios tested, the costs are greater than the associated benefits.

- A breakeven assessment estimated that the project would require a total irrigated area of between 5179 Ha and 5607 Ha for the benefits to equal the costs. This level of development exceeds the historic peak of 2800 Ha in 2005. To return to historical levels of irrigated land area, significant investment would be needed in farm infrastructure and equipment, which must be paid off over a longer time horizon. Based on consultations through the CRG with landholders, this step change in investment is unlikely.
  - The threshold approach was taken to calculate the dollar value required for qualitatively assessed benefits, namely social and environmental benefits, for the project to break even. For this project to break even, the Net Present Value of all environmental and social benefits would need to be at least $13.12 million (under the higher estimate of production benefits) or $15.12 million (lower estimate).
- Qualitative assessment of Lake Cycling (Option 6). The existing lakes cycling approach could be refined to achieve a greater salinity benefit for Lake Albert without additional infrastructure. Or it may be able to be augmented by some automation of gates at Goolwa Barrage. The latter may be able to be managed by an operator safely regardless of weather or light, and quickly enough to respond to high tides causing reverse flows into the lake or to opportunities to discharge larger volumes of water during low tides.
  - The CBA only considered the costs and benefits of this option – a cheaper option than the Coorong Connector – qualitatively as the costs are difficult to quantify; the majority of costs are borne by SA Water as part of barrage operations (Brenton Erdmann, SA Water pers. comm. 2014). Note that Lake Cycling would be more expensive if barrage gates were upgraded.
  - The CBA identified that proactive Lake Cycling would:
    - provide more flexibility to cycle the lakes according to the optimal environmental timing and conditions
    - enable more frequent lake cycling and at shorter intervals
    - reduce labour cost relating to operations
    - enable a medium-term planned environmental outlook of cycling, rather than the current opportunistic approach.
  - The CBA suggested that the limited installation of automatic close gates should be pursued if the economic, environmental and social benefits are greater than the incremental costs.

1.8 Conclusion

As a result of the modelling investigation, dredging Narrung Narrows, removal or modification of Narrung Causeway and the Permanent Regulating Structure were discounted. Lakes Cycling and the Coorong Connector were progressed and the concept of ‘Temporary Reset Pumping’ arose as a variation of the Coorong Connector.

The Scoping Study identified two potential options to provide further improvement for Lake Albert salinity. These are:

1. Optimise the Lakes Cycling management action to maximise salt export from Lake Albert. Upgrading a limited number of gates at Goolwa Barrage to allow for automated closure could also be investigated.

2. The pre-feasibility cost estimate for the Coorong Connector is $19m +/-30% and Benefit Cost Ratio is marginal at 0.30 to 0.41. For the project to break even, an irrigated area of between 5179 Ha and 5607 Ha is required. The current irrigated area is 400 Ha, and the historic peak was in 2005 at 2800 Ha. A Threshold Approach was taken to calculate the dollar value required for qualitatively assessed benefits, namely social and environmental benefits, for the project to break even. Using the figures fromTable **16** the Net Present Value of all the other benefits (environmental and social) would need to be at least $13.12 million (under the higher estimate of production benefits) or $15.12 million (under the lower estimate of production benefits).

The Coorong Connector was the only infrastructure-based option that delivered substantial improvement in Lake Albert salinity relative to the Base Case in all modelled scenarios. It could reduce salinity to historic levels (~ 1500 EC) within three years. Lake Cycling was the only other option that resulted in salinity improvement, but less so than the Connector over the same time period.

Considering the timeframes for implementation depend on climatic conditions and the efficiency of Lakes Cycling, historical salinity levels may be achieved before it is possible to build and operate a Coorong Connector.

Under the Basin Plan 2800 GL/year scenario, there would only be six periods in a 114 year span where Lake Albert experiences salinity over 2000 EC and these periods would be for a mean duration of 180 days. This is in contrast to 23 periods of 360 days (mean duration) under a baseline scenario with no Basin Plan (Heneker and Higham, 2012).

Should a severe drought occur in the future, a possible emergency action would be to implement Temporary Reset Pumping to speed up the recovery of Lake Albert. This temporary option would cost less than a permanent Coorong Connector, both in terms of capital expenditure and operations and maintenance and would be quicker to implement due to its temporary nature. Such a proposal would need cross-jurisdictional support and would be consistent with the MDBA Drought Emergency Operating Framework.

The outcomes of the Scoping Study will be considered by the South Australian Government and relevant parties to determine the most appropriate next steps. Should a decision be made to progress with an outcome or option, a Business Case may be developed to support the preferred option.

2 Introduction

This Options Paper is a summary of work completed under the Lake Albert Scoping Study.

The Scoping Study, announced in December 2012 and completed in early 2014, is an investigation into the future management of water quality in Lake Albert and the Narrung Narrows. It was funded by the Australian and South Australian governments, and is one of 20 management actions under the $137 million Coorong, Lower Lakes and Murray Mouth (CLLMM) Recovery Project.

The Scoping Study was informed by a community-based reference group and an extensive range of investigations, culminating in the development of an Options Paper. If required, a Business Case may also be prepared that will discuss the preferred management option/s as developed by the South Australian Government and the community.

The Scoping Study reflects many of the objectives of the CLLMM Long-Term Plan (June 2010), with particular focus on the following:

- 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 water quality to maintain Ngarrindjeri cultural life
- Tourism and recreation businesses can utilise the lake
- Productive and profitable primary industries continue.

2.1 Purpose

The Scoping Study was carried out in response to unprecedented drought conditions in the Lower Lakes region between 2006 and 2010 and to community concerns about the subsequent economic, social and environmental impacts on the Lake Albert region.

Due to historically low River Murray flows, water levels in the Lower Lakes reached a record low of one metre below sea level. This led to an increase in salinity, which threatened the ecology of Lake Albert, the local economy (particularly the agricultural sector) and dependent communities. Furthermore, potential acid sulfate soil (PASS) became exposed to oxygen resulting in changes to the ecological characteristics of the region. A number of government investigations, interventions and on-ground works and measures were initiated in response.

This Options Paper outlines the works undertaken to date to identify and investigate potential management options for improving Lake Albert's water quality. This includes a summary of:

- background issues relating to the region's environmental, social and economic profile
- the issues driving the need for the study
- all investigations undertaken as part of the Scoping Study to inform the development and assessment of management actions
- the options considered and the analysis undertaken for management actions to assess their feasibility as part of the Scoping Study.

Note that the Lake Albert Scoping Study was designed to achieve the following outcomes:

1) Identify water quality and flow requirements for managing salinity in Lake Albert and the Narrung Narrows
2) Identify community requirements regarding Lake Albert and Narrung Narrows
3) Identify potential management actions to achieve the environmental and social goals for Lake Albert and Narrung Narrows
4) Complete feasibility assessments on the potential management action(s)
5) Complete a cost benefit analysis on the feasible management action(s)
6) Where appropriate, producing a Business Case to seek funding for the implementation of the preferred management action(s).

2.2 Potential management actions considered

The following management options to reduce salinity in Lake Albert are considered in this Options Paper:

- Base Case: Do Nothing Option under Basin Plan 2800GL/year flows
- Option 1: Dredging of the Narrung Narrows
- Option 2: Removal, Partial Removal or Modification of the Narrung Causeway
- Option 3: Construction of a Coorong Connector (channel)
- Option 4: Construction of a Coorong Connector (pipe)
- Option 5: Construction of a Permanent Regulating Structure in the Narrung Narrows
- Option 6: Lake Cycling

Management actions to reduce Lake Albert salinity levels have been considered across numerous studies since the early 1980s. Prior to the Scoping Study, the most comprehensive study was completed by Ebsary in 1983 on behalf of the then South Australian Department for Engineering and Water Supply. URS also completed a large investigation into the Coorong Connector in 2006. More recently (February 2012), the Meningie Narrung Lakes Irrigators Association proposed a Five Point Plan to manage Lake Albert and the Coorong water quality, particularly salinity. These prior investigations were considered in detail during the Scoping Study.

Figure 2 summarises how the six management options listed above were identified and shortlisted from previous studies and reports[2]. New management options identified throughout the Scoping Study are also listed in **Figure 2**.

Each of the six management options looked at in this Options Paper has been considered to varying extents across the range of studies and investigations undertaken to date. These include: Literature Review, Community Requirements Study, Legislative Review, Water Quality Modelling, Qualitative Engineering Analysis, Geotechnical, Acid Sulfate Soil and Ecological Investigations, Ngarrindjeri Position Paper, MSM BigMod Modelling, TUFLOW FV Modelling, Engineering Feasibility and Preliminary Option Design, and Cost Benefit Analysis.

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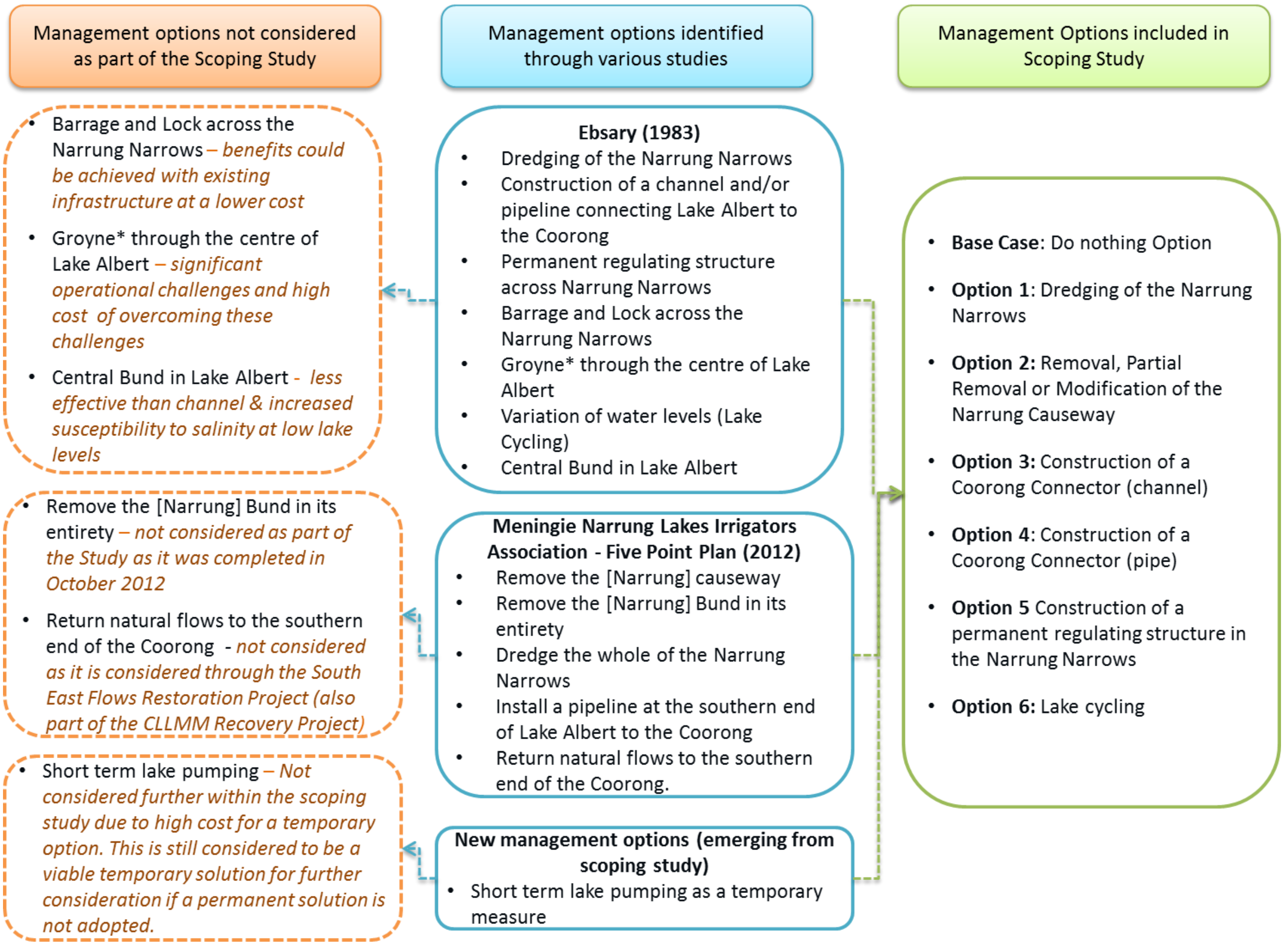
[2] Whilst there have been many studies undertaken; for simplicity, only the most comprehensive study (Ebsary) and the most recent report (Five Point Plan) have been presented in the diagram.

Figure 2: Identification of management options for consideration in the Scoping Study



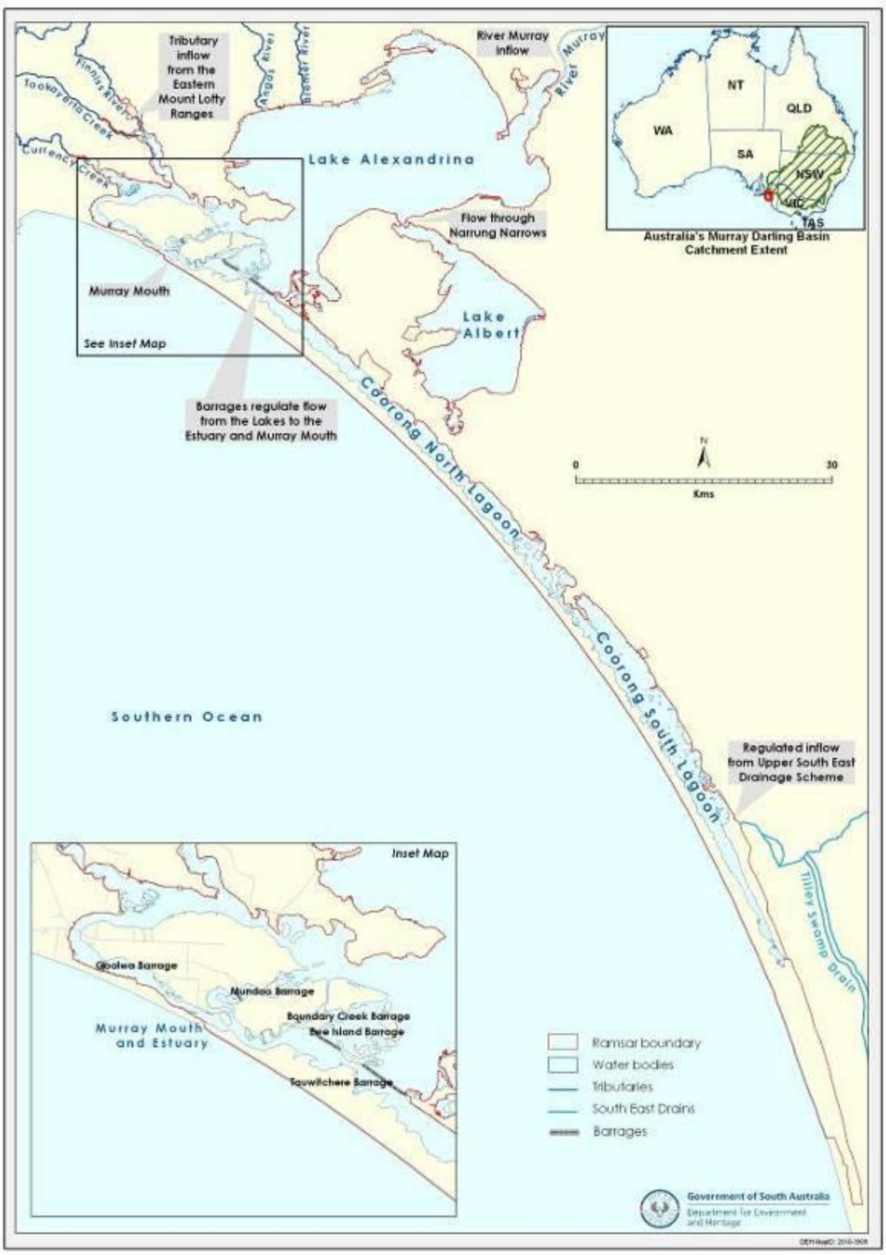
3 Background

3.1 Site Description

Lake Alexandrina and Lake Albert (the Lower Lakes) and the Coorong form an area known as the Coorong, Lower Lakes and Murray Mouth (CLLMM). Lake Albert lies to the south-east of Lake Alexandrina, connected via Narrung Narrows (a narrow channel also known as Albert Passage) near Point McLeay (DEH, 2010).

As seen in **Figure 3**, Lake Albert is a terminal lake - it is not physically connected to the Coorong and experiences no through flow of river water (Ebsary, 1983). Its main inflow of water comes from Lake Alexandrina through the Narrung Narrows, supplemented by inputs from rainfall, local runoff and groundwater flows. Wind patterns (speed and direction) can significantly impact the water levels.

Figure 3: The Coorong, Lower Lakes and Murray Mouth area



The Lower Lakes cover approximately 650 square kilometres which make them the largest freshwater body in South Australia (DEH 2000). As detailed in **Figure 3**, Lake Albert is landlocked and Lake Alexandrina is isolated from the Murray Mouth and Coorong by five barrages (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere), with 593 independently operated gates, constructed between 1935 and 1940 to provide fresh water for irrigation, stock, and domestic purposes (MDBC, 2006). The Coorong is connected to the Southern Ocean at the Murray Mouth.

Since the construction of the barrages, water levels in 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 have been primarily used to ensure irrigation supply through summer when the River Murray and tributary inflows, and rainfall, are lowest, and evapo-transpiration[3] is greatest. (Phillips and Muller 2006, p 190).

The Narrung Causeway was built in the early 1960s and extends approximately halfway across the Narrung Narrows from the Poltalloch side. The Causeway may have changed the flows into and out of Lake Albert and created silting in the Narrung Narrows and in Lake Albert (DEH 2010).

3.2 Conservation Significance

The CLLMM is one of six 'icon' sites under The Living Murray program. The region supports numerous threatened and migratory species protected under state and international agreements, and state and federal legislation.

In 1985, the CLLMM region (of which Lake Albert is a part) was designated a 'Wetland of International Importance' under the Ramsar Convention on Wetlands. 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, comprising 23 Ramsar wetland types. The environmental and conservation value of the CLLMM has been summarised in a number of studies. The ecological description of the Ramsar site was assessed and reported on by Phillips and Muller (2006).

Under the Ramsar Convention, Australia has an obligation to promote the conservation of listed wetlands. The ecological character of the site is a matter of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act), which regulates actions that will have or are likely to have a significant impact on the ecological character.

The site also supports numerous water birds that rely on the wetlands for migration stop-overs, breeding habitat or as refuge during droughts. Forty-nine species of birds have been recorded, including 25 species listed under international migratory bird agreements. Three agreements on migratory birds place obligations on the Australian Government (DEH, 2010 – Appendix 1):

- Japan-Australia Migratory Bird Agreement (JAMBA) – states that "each government shall endeavour to take appropriate measures to preserve and enhance the environment of birds protected under the Agreement".
- China-Australia Migratory Bird Agreement (CAMBA) – states that each government will "take appropriate measures to preserve and enhance the environment of migratory birds".

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[3] Evapotranspiration is the process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants.

- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) – requires each government to “appropriate measures to conserve and improve the environment of birds protected under Article 1 of this Agreement”.

3.3 Environmental Profile

Lake Albert and the broader CLLMM region support a diverse range of ecosystems, both within the lakes and in the surrounding environment. There are six wetlands fringing Lake Albert: Narrung; Narrung Narrows; Belcanoe; West Kilbride; Marnoo Complex; and Waltowa Swamp (**Figure 4**). These wetlands provide important habitat for a range of species assessed as having ‘high’ conservation value[4].

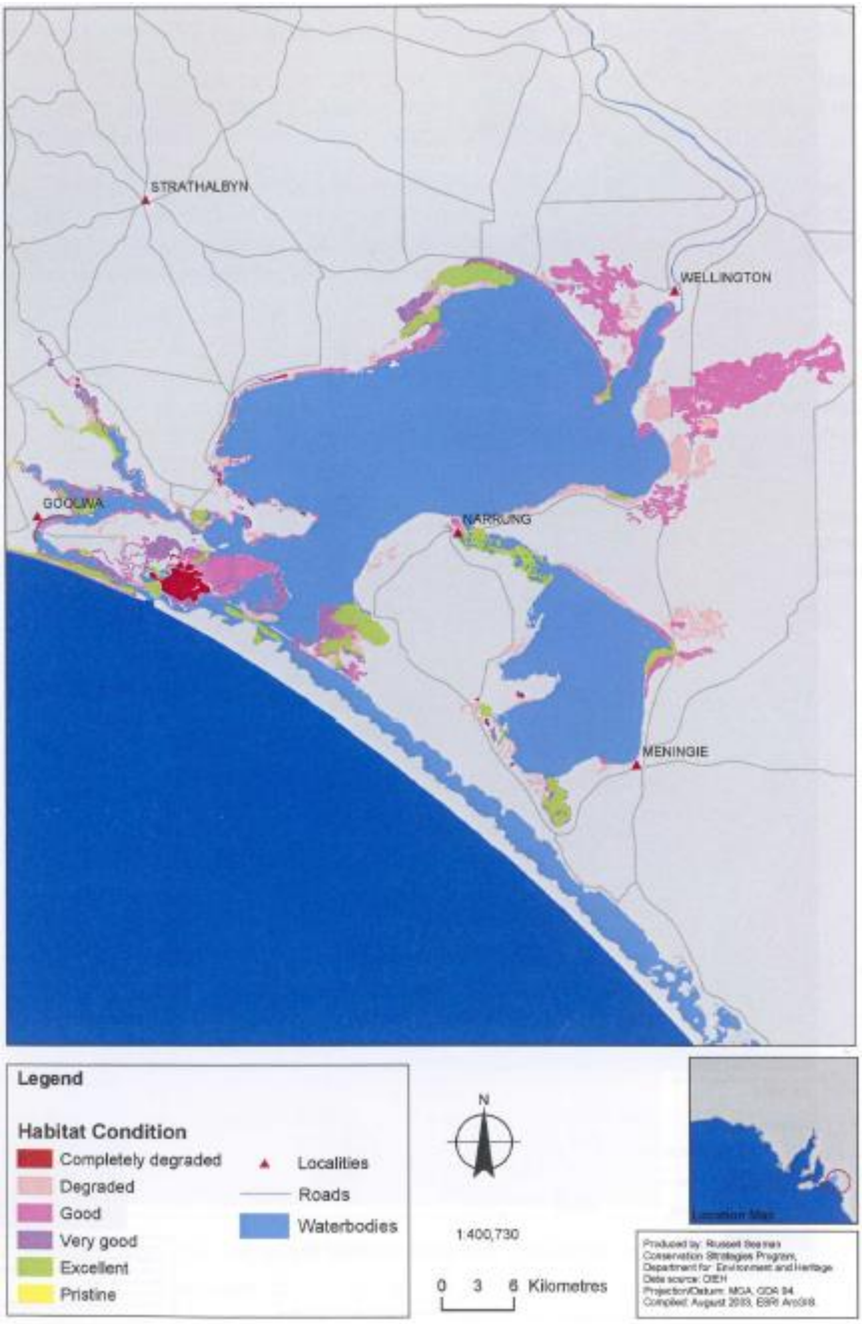
Figure 4: Lake Albert fringing wetlands

Source: DEWNR (2013)

Habitat condition assessed in 2003 surrounding Lake Albert is generally in a more degraded state than habitats within Lake Alexandrina and the Coorong. Those habitats with high conservation value include Narrung Narrows, Waltowa Swamp and Bascombe Bay (Seaman 2005). Refer to **Figure 5** to see the habitat condition of the CLLMM site.

[4] Discussed in more detail in the Literature Review (DEWNR, 2013b, Table 2).

Figure 5: Habitat condition – fringing Lake Albert



Between 2006 and 2010, habitats within Lake Albert underwent significant changes as water levels declined and salinity increased. Areas such as Waltowa Swamp on the lake edge lost their diverse reed beds and aquatic plants. The dry and acidified lake beds that occurred as water levels dropped below sea level disconnected all lake edge habitat from many areas once wetlands started to become dominated by terrestrial plants.

Following the drought, there has been generally a positive response in wetland and lake edge habitat recovery. The complementary management actions of the CLLMM Recovery Program such as fencing and revegetation has assisted in habitat recovery.

3.3.1 Water Quality (pre-drought)

Water quality in Lake Albert and Lake Alexandrina were assessed as being 'poor' in 1998 when compared against Australian guidelines for fresh and marine water quality. Samples collected over two years revealed:

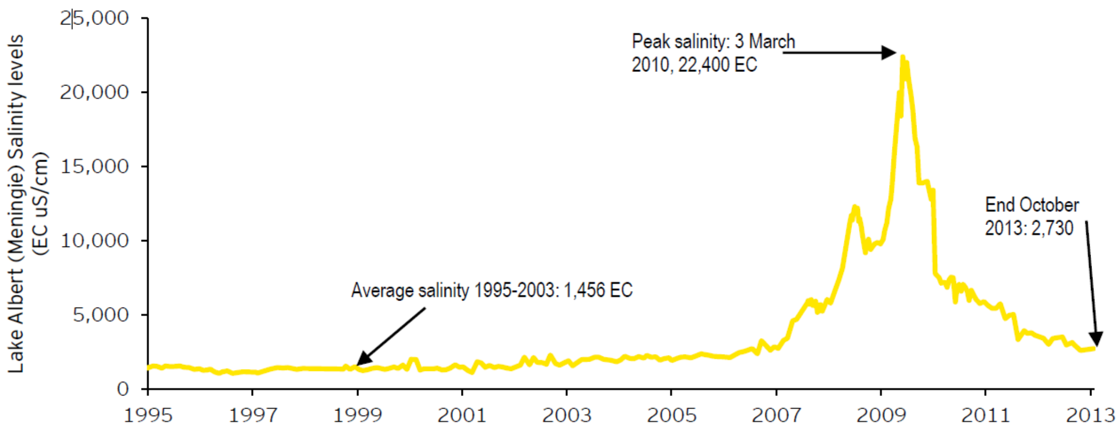
- high turbidity in Lake Alexandrina (not at Lake Albert)
- moderate nitrogen and phosphorus concentrations
- concentrations of heavy metals exceeding national guidelines for the protection of aquatic ecosystems at some sites
- salinity exceeding the guidelines for good quality drinking water at some sites.

Early accounts of Lake Albert and the CLLMM region suggest that rising salinity levels have been a primary concern post-European settlement (summarised in Sim and Muller, 2004). There is also evidence of salinity being recognised as a major issue for the Lower Lakes since the Early 1900s[5].

Peaks in salinity generally occur during summer (**Figure 8**) due to lower than normal operating water levels, peak groundwater return flows and high evaporation rates (Ebsary, 1983). Return irrigation flows also increase salinity, with Meningie (at the northern end of the Coorong on the shores of Lake Albert) salinity at its highest toward the end of the irrigation season (end of summer).

Figure 6 shows the historically recorded salinity levels at Lake Albert. More detail on the salinity levels during the 2006 - 2010 drought is provided in Section 3.5.

Figure 6: Historical recorded salinity levels in Lake Albert (Meningie), 1995-2013.



Source: EY (2014), with reference to EPA information supplied on 17 December 2013.

3.4 History of water use

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 (Ebsary, 1983).

[5] The Literature Review (DEWNR, 2013b) Section 5.1 has more information.

Construction of the barrages provided additional security of water quality which 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.

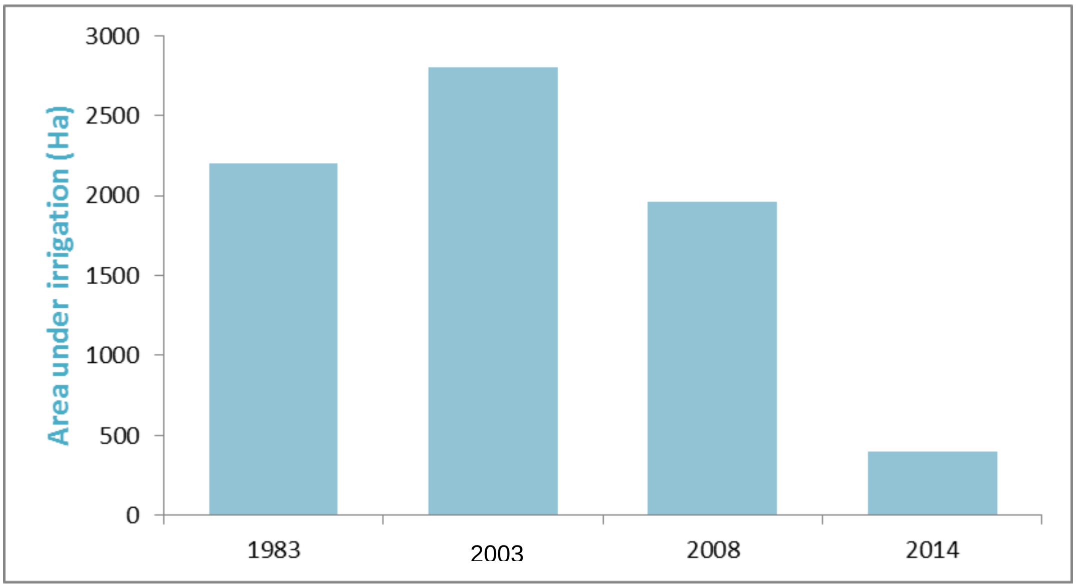
Irrigation was initially limited to properties along the lake fringes due to the cost of pumping water over large distances. However, irrigation increased from the 1960s, due to access to better, labour saving irrigation equipment (Ebsary, 1983).

The South Australian Government froze the issuing of additional water entitlements in 1968 in recognition of the stress on the system during the 1967/68 drought. As such, the irrigated area increased in the early 1970s (due to the use of dormant licences) and then remained relatively constant to the mid-1980s.

In 1983, Ebsary noted that approximately 2200 Ha 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.

As seen in **Figure 7**, the irrigation area in the Lake Albert region peaked at approximately 2800 Ha in 2005 but then declined rapidly during and following the drought as water became less available and salinity levels too high for sustaining pre-drought farming activities. By 2013, the irrigation area declined by nearly 80 % (from 2005) to approximately 400 Ha (EY, 2014).

Figure 7: Historical Land areas used for irrigation in Lake Albert region



Source: EY (2014) and Neil Shillabeer pers comm 4 February 2014.

3.5 Impact of drought on Lake Albert environment

The 2006 - 2010 drought led to significant changes in water availability and water quality at Lake Albert.

During this period, the Murray-Darling Basin experienced the worst conditions since records began in 1891, with 2006/07 - 2008/9 being particularly severe (DEH, 2010). The region experienced the longest period of low flows since river regulation, with more than 12 years of below-average rainfall. Record high temperatures in this region and across much of Australia also resulted in increased evaporation. These difficult conditions were exacerbated by over-allocation of water within the system, and therefore resulted in a detrimental impact on the dependent environment, communities and businesses.

The unprecedented low water levels also prevented regular releases of water at the barrages. Under favourable operating conditions, barrage releases allow for flushing to reduce the accumulation of nutrients, sediment, algae and salt in the Lower Lakes from upstream inflows (Mosley *et al.*, 2012, EPA 2013). They provide numerous important benefits to maintain the ecological character of the lakes, the connectivity for the passage of aquatic biota and the estuarine conditions in the Murray Mouth region. Between 1975-76 and 1996-97 average annual barrage discharge volume was 6023 GL. Since then, the average annual barrage discharge has significantly reduced to only 890 GL (DEH, 2010). Prior to September 2010, the last water release to the Murray Mouth from the Lower Lakes was a minor discharge (63 GL) in 2006-07 when unseasonal, localised rainfall in the Easter Mount Lofty Ranges could not be regulated and flowed into Lake Alexandrina (DEH 2010).

Low water levels led to increased salinity and the exposure of acid sulfate soils, with significant impacts on a range of environmental, social and economic metrics in the region. More specifically:

- increasing salinity threatened the local agricultural sector and dependent communities
- the exposure of acid sulfate soils led to potentially irreversible changes to the ecological character of the region (DENR, 2010)
- a habitat assessment of Ramsar wetland sites in the CLLMM (Thiessen, 2010) concluded that the wetland habitat condition of the majority of wetlands surveyed had 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”.

A brief description of these impacts is provided below.

Salinity

During the recent drought, salinity of the Lower Lakes increased to high levels. Inflows were less than evaporative losses from the surface of the lakes, so salt, sediments, nutrients and algae accumulated instead of being discharged to the sea (DEH, 2010; Mosley *et al.*, 2012, 2013).

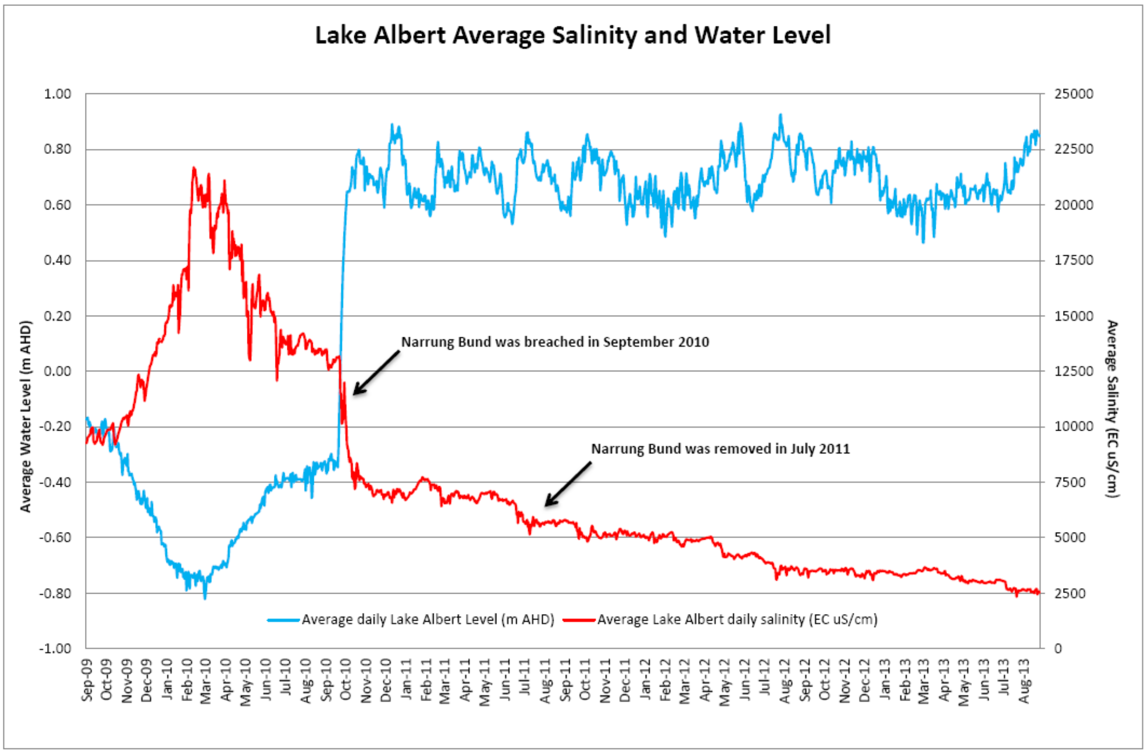
Salinity in the Lower Lakes is influenced by freshwater inflows, occasional seawater ingressions over the barrages, water extraction rates, rainfall and evaporation across the water surface. It is the only point in the Murray-Darling Basin where salt can be discharged from the system.

As seen in **Figure 8**, as water levels in the CLLMM region dropped during the recent drought, salinity levels increased. In September 2009, Lake Albert salinity levels peaked at more than 20,000 EC units (EPA, 2013).

Following significant rainfall and flooding in the Murray-Darling Basin throughout winter and spring 2010, the Narrung Bund was breached and salinity levels in Lake Albert quickly dropped to approximately 10,000 EC.

This initial dramatic decrease in salinity was a product of dilution upon the refilling of the lake with fresher water. Salt export is more difficult to achieve, and therefore further decline in salinity was (and continues to be) more gradual. By June 2012, salinity had declined to between 3400 and 4300 EC. The salinity in early March (taken 4 March) was approximately 2548 EC[6], higher than the long term average of approximately 1500 EC.

Figure 8: Lake Albert salinity and water level (2009-2013)



Source: DEWNR (2013b)

High salinity is particularly problematic for the agricultural sector. **Table 1** provides a summary of salinity tolerances (for drinking water) of different livestock, including requirements for healthy growth, requirements for maintenance and maximum concentrations tolerated.

During the drought and for several years following the drought, salinity levels at Lake Albert were above 4000 EC. This is higher than the maximum tolerance for healthy growth for dairy cattle, which is the primary agricultural value in the region. Whilst current salinity levels are adequate to supply drinking water for dairy cattle, and new pipelines were installed around the Lower Lakes in the drought, a return to lower flows may see salinity levels quickly increase to be unsustainable for livestock.

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[6] Average of Warringee, Waltowa and Meningie telemetered stations at 6am on 4 March 2014 – Water Connect website

Table 1: Salinity tolerances for livestock and poultry drinking water (PIRSA, 2007)

Animal	Maximum concentration for healthy growth (EC)	Maximum concentration to maintain condition (EC)	Maximum concentration tolerated (EC)
Sheep	6000	13000	*
Beef cattle	4000	5000	10,000
Dairy cattle	3000	4000	6000
Horses	4000	6000	7000
Pigs	2000	3000	4000
Poultry	2000	3000	3500

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

Acidification

Acid sulfate soil occurs naturally in coastal and fresh water areas where there are large amounts of iron, sulfate and organic material, and are a natural part of the ecosystem (DEH 2010). But low water levels can expose previously submerged sulfidic sediments (or Potential Acid Sulfate Soil - PASS). Although PASS is benign when inundated, it can oxidise to form sulfuric acid when exposed to oxygen, and become Actual Acid Sulfate Soil (AASS). Acidification can release toxic metals and metalloids such as manganese, aluminium and arsenic during the drying. This can also happen during re-wetting of the soil, which can have significant detrimental impacts on the ecosystem and other system functions. From a health perspective, direct contact with these soils can contribute to eye and skin inflammation. Acid sulfate soil can also impact local infrastructure, agricultural productivity and Ngarrindjeri culture and cultural sites.

Whilst current water levels are not exposing any large areas of PASS, the extent of the risk when water levels are low was evident during the drought. The greatest exposure of PASS at Lake Albert was in March 2009. More than 18,000 hectares of acid sulfate soil was exposed in the lower lakes, resulting in acidic salts forming over much of the dried out lakebed (DEH, 2010; DENR, 2010). Large-scale acidification and metal release into surface waters occurred at various locations on the lake margins in 2008–2010 (Mosley *et al.* 2013; 2014).

It is estimated that the water level that triggers whole of lake acidification of Lake Albert is 0.75 m below sea level[7]. At the height of the recent drought, Lake Albert water levels dropped to -0.7 m AHD.

Narrung Bund was constructed in March 2008 and water pumped from Lake Alexandrina to Lake Albert to maintain Lake Albert water level above -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. Lake Albert water levels were recorded at approximately +0.69 m AHD[8] on 28 January 2014.

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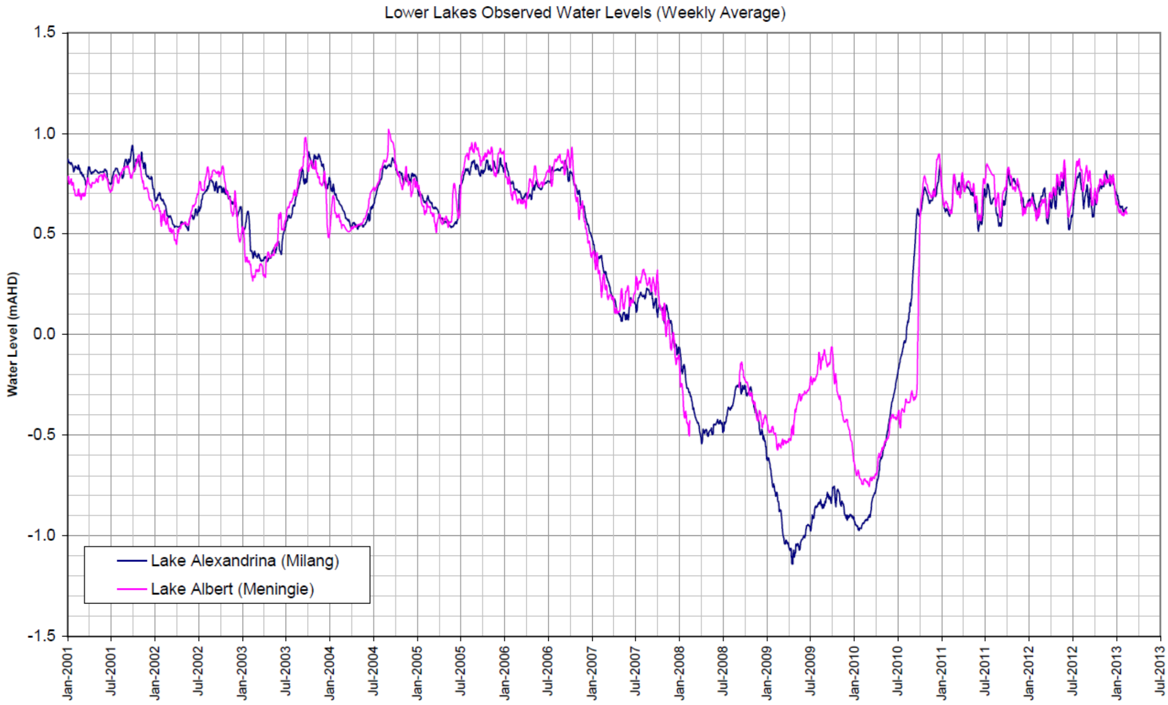
[7] Sea level is measured as the mean sea level from 1966-1968, which was assigned a value of 0.00 on the Australian Height Datum (AHD). The target level is therefore also referred to at -0.75 m AHD. The trigger was estimated by The Lower Lakes Acid Sulfate Soil Scientific Research, formed to investigate key knowledge gaps and assist with management decisions.

[8] Recorded at Meningie Sailing Club – Water Connect website

Figure 9 provides a summary of average weekly water levels in the Lower Lakes over a 13 year period.

Figure 9: Observed water levels in the Lower Lakes (2001-2013 weekly averages)



Source: BMT WBM, 2013

3.6 Basin Plan

The Murray-Darling Basin Plan, developed under the Water Act 2007 by the Murray-Darling Basin Authority (MDBA), provides a coordinated approach to water use across the basin's four States and the ACT.

The Basin Plan is an adaptive framework and will be rolled out over seven years. It aims to achieve a balance between environmental, economic and social considerations and sets new sustainable limits on extraction for consumptive use (considered to be an Environmentally Sustainable Level of Take or ESLT). This will result in additional water for the environment. The Basin Plan allows for further improvements in environmental outcomes through a sustainable diversion limits adjustment mechanism and a constraints management strategy. It is supported by Commonwealth investment in environmental water recovery through modernising irrigation infrastructure and voluntary water purchasing via the environmental water recovery strategy. Visit www.mdba.gov.au/what-we-do/basin-plan for more information.

A range of studies has been undertaken by the MDBA assessing the benefits to the environment of the recovery of the proposed volumes and implementation of an ESLT including MDBA (2011) and MDBA (2012). These reports demonstrated “improved environmental outcomes and an ability to avoid acidification risks” from the implementation of the Basin Plan for the Lower Lakes and the Coorong relative to the present conditions. MDBA (2012) confirmed there would be reduced risks by demonstrating that daily water level at the Lower Lakes for the baseline, Basin Plan (BP) 2400 GL/year, BP 2800 GL/year and BP 3200 GL/year scenarios for the period 1 July 2000 to 30 June 2009 will remain above 0.0 m AHD.

Bloss *et al.* (2012) noted that the additional volume available, albeit reduced, would provide higher flows to South Australia during drought years compared to baseline conditions.

Heneker and Higham (2012) and Gibbs *et al.* (2012) provided greater detail of the outcomes expected from implementation of the proposed ESLT with demonstrable benefits to Lake Albert salinity in the modelled results.

Salinity in Lake Albert is consistently and often significantly higher than that in Lake Alexandrina given the nature of their narrow connection via Narrung Narrows.

Table 2 presents salinity statistics for Lake Albert under Baseline Conditions and BP 2750 GL (known also as BP 2800 GL and referred to elsewhere in the Options Paper as BP 2800). As for Lake Alexandrina, the mean and median annual salinity is reduced, in this case by around 300 EC and 200 EC respectively. The reduction in maximum salinity is again most significant, with the additional flow under BP 2750 GL maintaining higher water levels and reducing the risk of disconnection and elevated salinity as seen during the recent drought.

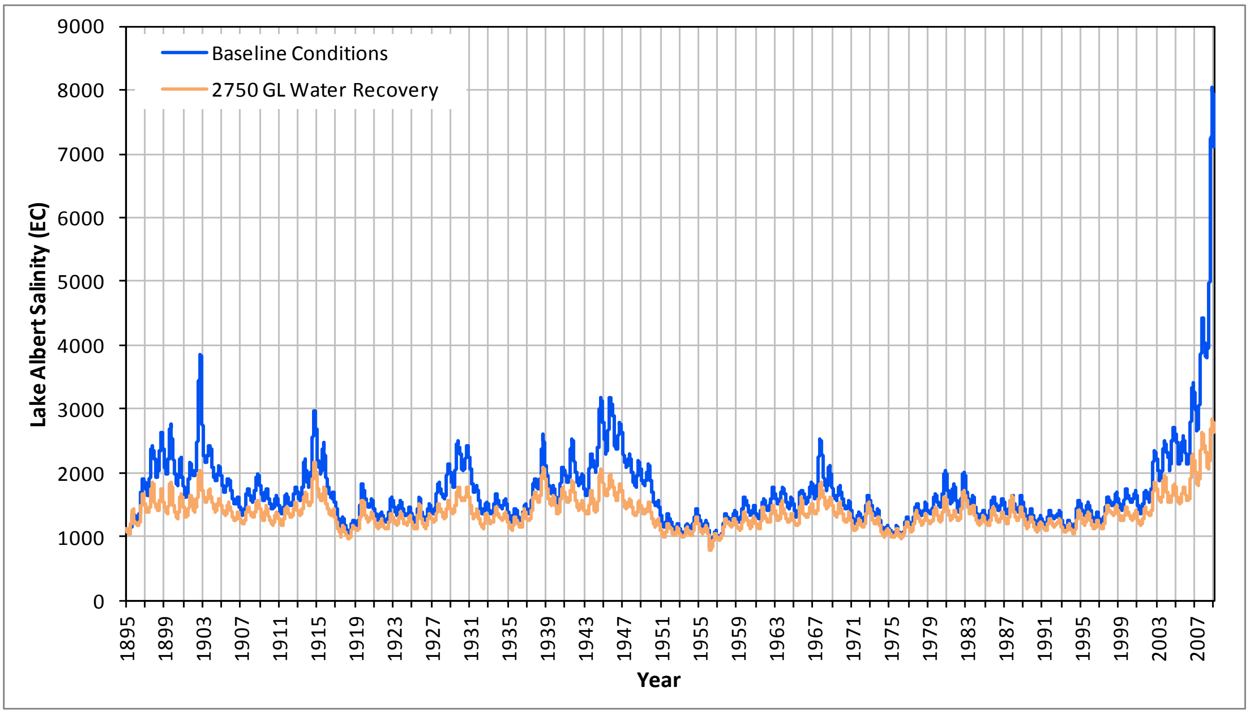
Table 2: Lake Albert salinity statistics - Baseline Conditions vs. BP 2750 GL

Statistics	Lake Albert salinity (EC)			
	1975 to 2008-09		1895-96 to 2008-09	
	Baseline	BP 2750 GL	Baseline	BP 2750 GL
Mean	1730	1385	1695	1375
Median	1480	1295	1550	1330
Minimum	1005	970	830	785
Maximum	8045	2850	8045	2850
10^{th} Percentile	1185	1110	1210	1115
90^{th} Percentile	2465	1775	2310	1685

Source: Heneker and Higham (2012)

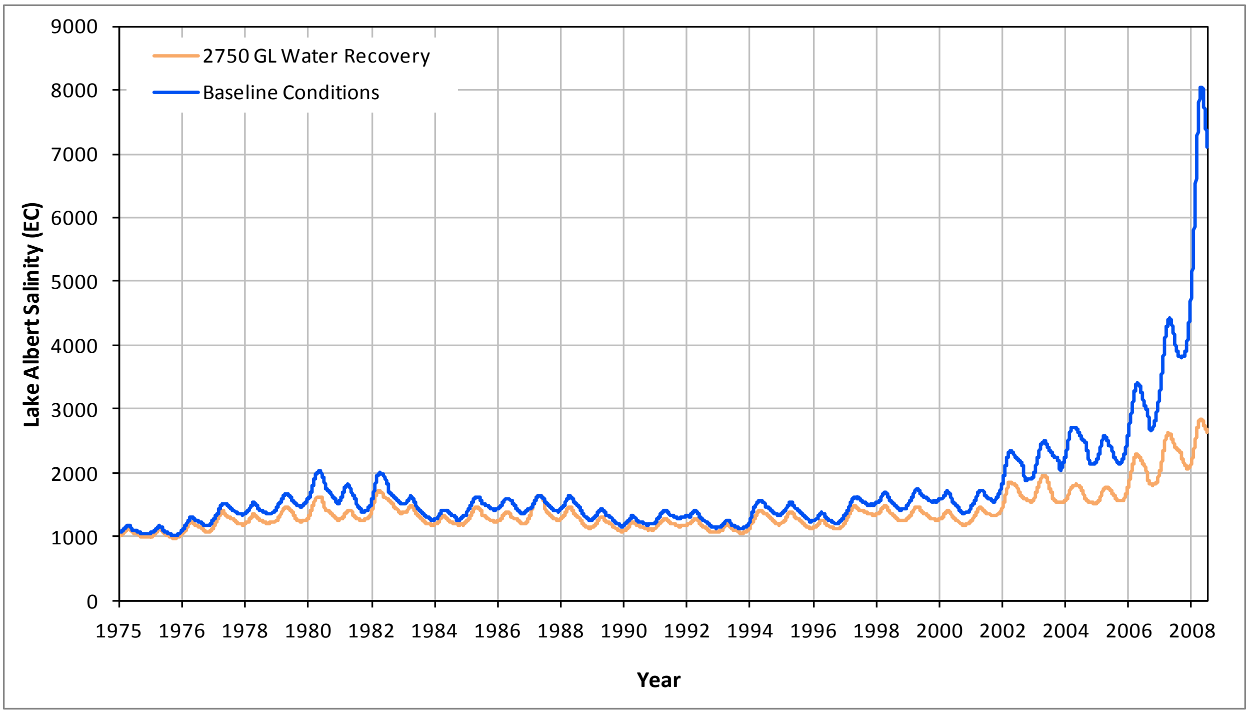
Figure 10 compares the salinity in Lake Albert under Baseline Conditions and BP 2750 GL for the period 1895-96 to 2008-09. There is a reduction of the elevated salinity levels of the recent drought period as well as a lowering of other peaks that are greater than 2000 EC under Baseline Conditions. However, the salinity in Lake Albert under BP 2750 GL is still likely to regularly exceed 1500 EC and approach 2000 EC. **Figure 11** provides this comparison for the MDBA assessment period (1975 to 2008-09).

Figure 10: Lake Albert salinity - Baseline Conditions vs. BP 2750 GL (1895-96 to 2008-09)



Source: Heneker and Higham (2012)

Figure 11: Lake Albert salinity - Baseline Conditions vs. BP 2750 GL (1975 to 2008-09)



Source: Heneker and Higham (2012)

Table 3 shows the percentage of time that the daily salinity in Lake Albert is likely to be, within a number of defined critical ranges. These salinity ranges are higher than those against which the salinity in Lake Alexandrina was assessed, given the salinity relationship between the two lakes. There is a large decrease in the percentage of days that the salinity in Lake Albert is between 1500 EC and 2500 EC. In addition, the risk of extremely high salinity levels that are greater than 2500 EC is reduced, although not eliminated, under BP 2750 GL.

Table 3: Daily Lake Albert salinity within critical ranges - Baseline Conditions vs. BP 2750 GL

Salinity range	Time within salinity range (%)			
	1975 to 2008-09		1895-96 to 2008-09	
	Baseline	BP 2750 GL	Baseline	BP 2750 GL
< 1000 EC	0	2	1	2
1000 - 1500 EC	53	76	43	73
1500 - 2000 EC	29	16	36	22
2000 - 2500 EC	9	4	14	2
> 2500 EC	9	2	6	1

Source: Heneker and Higham (2012)

Table 4 presents the number and duration of those periods where the daily salinity in Lake Albert exceeds each of the threshold salinity levels in **Table 3**. The number and duration of periods where the salinity is greater than 1,500 EC, 2,000 EC, and 2,500 EC are all significantly reduced. There are more periods of less than 1,000 EC with BP 2750 GL, which means that due to the salinity fluctuating around 1,000 EC, there are more periods greater than 1,000 EC even though the mean duration of each of these is less.

Table 4: Duration of Lake Albert salinity above threshold values - Baseline Conditions vs. BP 2750 GL (1895-96 to 2008-09)

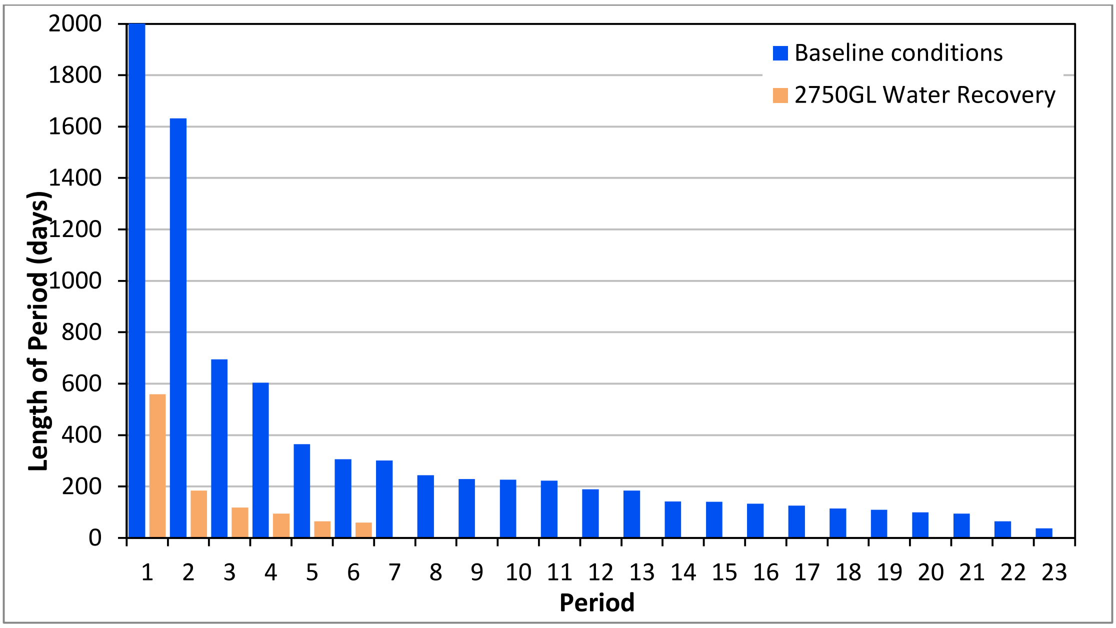
Salinity threshold (EC)	Lake Albert salinity			
	Baseline		BP 2750 GL	
	No. periods	Mean duration (days)	No. periods	Mean duration (days)
< 1000	2	140	8	105
>1000	3	13785	9	4530
> 1500	43	540	38	265
> 2000	23	360	6	180
> 2500	13	190	2	115

* Note: A period with salinity >2500 EC is contained within a period of salinity >2000 EC, both are within a period of salinity >1500 EC and all are within a period of salinity > 1000 EC.

Source: Heneker and Higham (2012)

Figure 12 shows the number and duration of events where the salinity is greater than 2000 EC under Baseline Conditions and BP 2750 GL, highlighting the potential reduction in extremely high salinity events under the Basin Plan. Without a Basin Plan, there would be 23 periods above 2000 EC for an average duration of 360 days. This is compared to only 6 periods of 180 days under the Basin Plan. The number of events above 2500 EC would be reduced from 13 to two and the length of these events would reduce from 190 to 115 days.

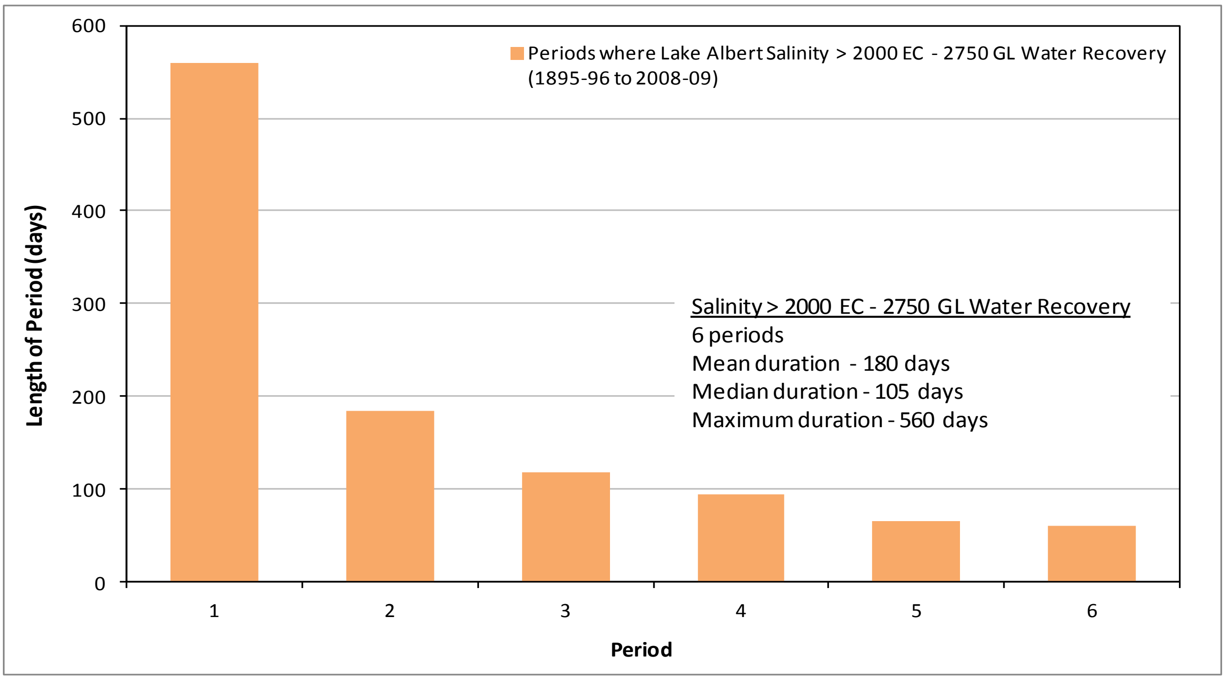
Figure 12: Length of periods with Lake Albert salinity > 2000 EC - Baseline Conditions and following the Recovery of 2750GL



Source: Heneker and Higham (2012)

Figure 13 below shows only the length of periods when Lake Albert salinity is greater than 2000 EC under the Basin Plan scenario of 2750 GL.

Figure 13: Length of periods with Lake Albert salinity > 2000 EC - BP 2750 GL



Source: Heneker and Higham (2012)

The modelling undertaken by the MDBA and analysis by SA and the MDBA indicates that the maximum salinity, duration of events exceeding 2000 EC and minimum water levels are all substantially improved with the recovery of 2750 GL and full implementation of the Basin Plan. Murray-Darling Basin inflows would need to be worse than those experienced during the

Millennium drought to see water levels fall below 0.0m AHD and the maximum salinity approach those experienced in the region that affected the environment and industry (if all assumptions inherent remain valid).

3.7 Socio-Economic Profile

The CLLMM region includes three local government areas; Coorong District Council, Alexandria Council and Rural City of Murray Bridge (note these council areas extend beyond the CLLMM region). 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 4000 are Ngarrindjeri people who live and work on their traditional lands, primarily around Meningie, Raukkan, and Narrung (ABS, 2011).

There is a high proportion of older people and median incomes are relatively low[9] (DEH, 2009). Despite the impacts of the drought, population levels have been steadily increasing in some of the larger regional towns due to the ‘sea change’ phenomenon. This contrasts with more agriculturally dependent communities, including Mannum and Meningie, which have decreased in size and viability as levels of farming have decreased (MDBC, 2011).

Meningie, the closest town to Lake Albert, had a population of 921 people in 2011, a decline in 2 % from 2006 (ABS, 2012). There was a relatively higher proportion of Indigenous people at 8.9 % (ABS, 2012). The Coorong District Council, in which Meningie is based, recorded that 38 % of the working population is employed in agricultural compared to 5 % in all of South Australian (ABS, 2011b). The high level of employment in agriculture emphasises the high degree of regional water dependence of the community. The Coorong District Council also has a comparatively high level of income support recipients at 12 % in 2009, compared to the South Australian average of approximately 9.5 % (SACES, 2012).

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 (EY, 2014).

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).

Commercial fishing is important to the local economy. The dominant species of commercial fishery in the region include yellow-eye mullet, mulloway, cockles, callop (golden perch), carp and to a lesser extent flounder and bony bream. **Figure 14** shows the impacts of the Lakes and Coorong Fishery on the total state product, output and household income from 2002/03 to 2011/12 (EconSearch, 2013). There is also a significant recreational fishery, however its value has not been estimated.

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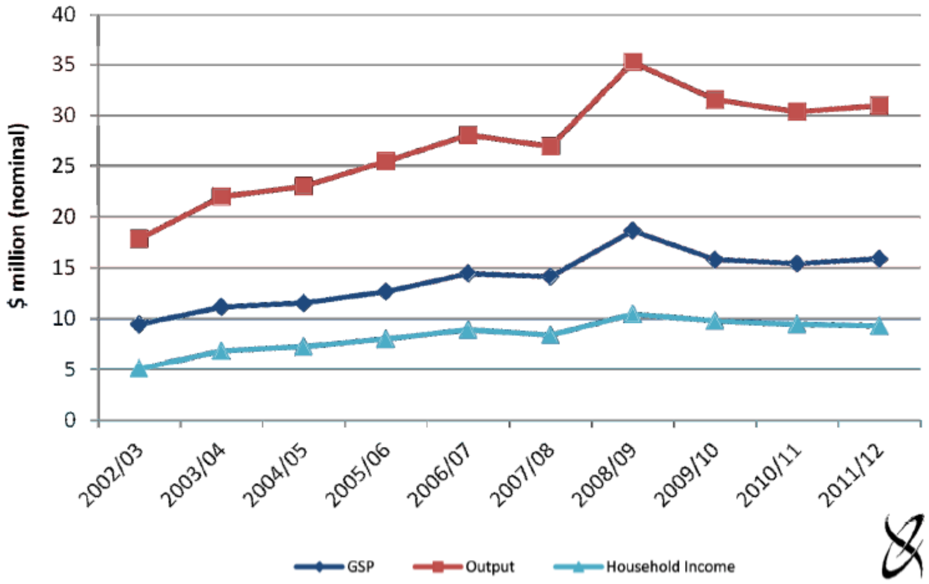
[9] This does not take into consideration personal savings or assets.

Figure 14: Total gross state product, output and household income impact of the Lakes and Coorong Fishery on the SA economy, 2002/03 to 2011/12 (Nominal $)



Source: EconSearch (2013)

Low water levels have resulted in the closure of a significant number of local primary production businesses. An example is in the dairy industry, where the inability of farmers to irrigate has forced the closure of many properties. This has had a flow-on impact to the local community, including 'damage to irrigated land values affecting council rate revenues, children leaving the local school as employment reduces and families moving away' (MDBC, 2011). Other industries, including tourism (particularly the boating and 'water-based' activities sector), have been adversely impacted by low water levels, reportedly suffering a 60-70 % reduction in level of activity. Small businesses, which make up the majority of local economic activity, have faced business down-turn, and economic and employment losses (MDBA, 2011b).

The region is considered to have had high social capital (DEH, 2009), however this has been eroded by the impact of low water levels, which has resulted in such occurrences as young people needing to travel away from home during the week to secure employment. This affects the wellbeing of family and community life (DEH, 2009). The three local government areas have average relative socio-economic advantage and disadvantage (SEIFA) scores of between 880 to 950, whilst the Australian average is 1000. Meningie's score is 948 (ABS, 2011b).

In times of water crises the community has displayed strong resilience, with many uniting to form action groups and shared platforms from which to communicate with government. The community is united by strong values around the natural environment and history, local assets (including schools, service clubs, sporting clubs and Environmental Action Groups) (DEH, 2009). The drought has resulted in long-term impacts on the community and its wellbeing, with impacts including health issues, increasing demand on community services, tensions and conflicts between community groups with competing interests, and changes to demographics (DEH, 2009).

3.8 Cultural Significance

The CLLMM region and surrounding areas represent the central homelands of the Ngarrindjeri people[10] and are central to Ngarrindjeri culture and spiritual beliefs. Ngarrindjeri people are descendants of the original indigenous inhabitants of the lands and waters of the River, Murray, Lower Lakes, Coorong and adjacent areas.

Ngarrindjeri creation stories (cultural and spiritual histories) about Yarluwar-Ruwe (Sea Country) demonstrate the physical and spiritual bond between the country and the people (DEWNR, 2013C).

Freshwater flows down the Murray-Darling system are seen by the Ngarrindjeri as the life blood of the living body of the River Murray, Lower Lakes and Coorong. The health of the region is seen as being intrinsically linked to the wellbeing of the Ngarrindjeri people and therefore improved water quality is key to sustaining Ngarrindjeri livelihoods (see text box).

"Ngurunderi taught us how to sustain our lives and our culture from what were our healthy lands and waters. Our lands and waters must be managed according to our Laws to make them healthy once again. As the Ngarrindjeri Nation we must maintain our inherent sovereign rights to our Yarluwar-Ruwe.

"Ngarrindjeri people have a sovereign right to make our living from the lands and waters in a respectful and sustainable way.

"Our culture and economy have always depended on the resources of our Yarluwar-Ruwe. We used and continue to use the resources of the land, but it was the saltwater and freshwater environments that provided us with most of our needs.

"Such was the wealth of sea and marine life such as fish, shellfish, eels, waterbirds and water plants that we have always lived a settled lifestyle. Our knowledge of our Sea Country will continue to underpin our survival and our economy."

Source: Ngarrindjeri Nation Yarluwar-Ruwe Plan: Caring for Ngarrindjeri Sea Country and Culture

The CLLMM region also includes the 'Meeting of the Waters' site (an area that includes the Goolwa Channel), recognised as the place where fresh and salt waters meet and mix and form an important place for the reproduction of life.

The Ngarrindjeri are committed to their country. They have made significant efforts over many years to be part of managing the region's environment in response to drought and over-allocation. They work closely with DEWNR through the Ngarrindjeri Regional Authority (NRA) to develop and deliver the CLLMM Recovery Program. DEWNR and the NRA have developed the Ngarrindjeri Partnerships Project to support Ngarrindjeri participation in the natural resource and cultural heritage management of the CLLMM. This project is a key outcome of the Kungun Ngarrindjeri Yunnan Agreement (KNYA) between the SA Government and the NRA (DEWNR 2013b).

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[10] The Ngarrindjeri People are the acknowledged traditional owners (as that term is defined in the Aboriginal Heritage Act, 1988 (SA)) of the Ngarrindjeri and Others Native Title Claim area (Kungun Ngarrindjeri Yunnan Agreement, 2009).

3.9 Related works and initiatives

The low water levels in the CLLMM region during the drought resulted in the exposure of acid sulfate soil materials, increased salinity and the disconnection of fringing wetlands, thereby altering the site’s ecological character.

As an emergency response to these deteriorating conditions the South Australian Government, in close collaboration with MDBA, industry, the community and academia, implemented a multi-million dollar strategy to avoid, minimise, and control the adverse impacts of acid sulfate soil in the region. The key management response in Lake Albert was the Lake Albert Water Level Management Project, which involved the construction of a temporary bund across the Narrung Narrows adjacent to the Narrung Causeway. Water could be pumped from Lake Alexandrina to Lake Albert to avoid drying and subsequent lake-wide acidification of Lake Albert.

The project was successful in meeting its primary objective of averting the acidification of Lake Albert through the implementation of the works and measures.

In addition to the actions above, there are other programs, actions and policies that have occurred or are planned that are relevant to a future management action at Lake Albert. These include:

- The Murray Futures Coorong, Lower Lakes and Murray Mouth Recovery program, of which the Lake Albert Scoping Study is a part, is delivering a range of projects to address environmental issues facing the region. Examples include the Meningie Lakefront Habitat Restoration Project, revegetation works, fencing the lake edge, and water quality and soil monitoring.
- The Murray-Darling Basin Plan, which is providing a coordinated approach to water use across the basin, including a watering plan to optimise environmental outcomes, water quality and salinity management plan, requirements for water resource planning compliance, mechanisms to manage critical human water needs, and monitoring and valuation requirements.
- Regional Natural Resource Management Plans and Water Allocation Plans, providing guidance for planning to meet the diverse environmental and water resource requirements for the region.
- The Murray Futures Lower Lakes Pipeline, completed in 2009 delivers secure quality water supply for the townships, communities and irrigators who draw water from lakes Alexandrina and Albert.

4 Problem Definition and Service Need

The project driver is underpinned by a number of issues or problems that have been monitored and investigated since before the 2006-2010 drought.

In this Options Paper, issues relating to the need for management options to reduce salinity in Lake Albert have been refined with representatives from DEWNR, the Environment Protection Authority (EPA) SA, SA Water and Department of Primary Industries and Regions SA (PIRSA). The service need outlined below aims to reflect the community concerns driving the need for the Scoping Study and the community feedback and input that has been provided throughout the investigation.

The following sections provide more detail on the service need, including a definition of the problems being addressed, the key objectives and the intended benefits.

4.1.1 Problem Definition

The need for the Scoping Study is driven by two key problems:

Problem 1: Lake Albert's prolonged recovery from the high salinity levels during the 2006-2010 drought is leading to community concerns about the social and economic consequences for the region.

As discussed in **Section 3.5**, since the Narrung Bund was breached, improvement in salinity levels in Lake Albert has been gradual. Current salinity levels at early March 2014 (2548 EC[11]) are still higher than the long term average of approximately 1500 EC. Modelling of the business as usual scenario (Base Case) under varying conditions demonstrates salinity levels may not return to historic levels in the short term.

This prolonged recovery is leading to significant community concerns about the viability of irrigation and pre-drought farming practices in the region and the socio-economic flow-on impacts that this would have. The associated direct and indirect impacts include:

- **Loss in agricultural value**: High salinity in the water impairs productivity of the land, leading to reduced yield and income for landowners (refer to **Table 6** for example). Furthermore, without assurance of a long term solution to this problem, existing local landowners may be reluctant to invest in the new infrastructure needed to return to higher value irrigation (from dryland farming). Higher value production is therefore constrained unless the risk of future increases in salinity is reduced.
- **Social and economic challenges for the community**. With a population of approximately 1000 people, economic uncertainty in one sector can have impact on the whole community. Reduced earning potential (current and future) in the agricultural sector will have flow-on impacts on other businesses. Economic hardship can also lead to a decline in the population which can adversely impact the local culture and put a strain on social infrastructure such as schools, sports clubs, parks, ovals, community centres and medical facilities.

Problem 2: There is uncertainty about the ability of government's planned interventions to provide longer term water quality certainty to businesses and the community.

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[11] Average of Warringee, Waltowa and Meningie telemetered stations at 6am on 4 March 2014 – Water Connect website

Commonwealth and state governments have taken significant steps to address over-allocation and other threats in the Murray-Darling Basin through the Basin Plan and other efficiency water supply investments. Through the enforcement of Sustainable Diversion Limits (SDLs), the Basin Plan is expected to help maintain salinity levels at Lake Albert at sustainable levels.

Under the Basin Plan 2800 GL/year scenario, there would only be two periods in a 114 year span where Lake Albert experiences salinity over 2500 EC and these periods would be for a mean duration of 115 days. This is in contrast to 13 periods of 190 days (mean duration) under a baseline scenario with no Basin Plan (Heneker and Higham, 2012).

However, the Basin Plan will be implemented in 2019, meaning that it will not assist with the immediate salinity impact at Lake Albert. The community feels there is not enough information to assure them that the Basin Plan will prevent a return to high salinity during a drought or that the Basin Plan will improve the rate of recovery following a drought period.

4.1.2 Objectives and Benefits

The objectives and intended benefits that relate to addressing the problems defined above include to:

- **Facilitate shorter and more predictable recovery from high salinity in Lake Albert following drought periods.** A key objective is to enable government to shorten the time it takes Lake Albert to recover from high salinity following drought conditions. A shorter recovery period in the future will avoid the extended socio economic impacts and costs to the local industry and community that the region is currently experiencing.
- **Provide the certainty needed for irrigators and other industries to continue operating and potentially expanding in the region.** A reliable management action is needed to reduce salinity in Lake Albert following drought periods to provide local irrigators with more business certainty. Whilst droughts cannot be avoided, ensuring that recovery is not prolonged will provide the confidence needed for landowners to invest in maintaining or growing production.
- **Recognise the Basin Plan intended outcomes.** Under the Basin Plan, there will be fewer instances of elevated salinity in Lake Albert and for shorter durations than previously experienced.

Addressing the defined problems will enable existing land users to be more profitable and encourage new or expanding investment. Increased confidence in the sustainability of the agricultural sector in the region will deliver benefits to the community more broadly. The benefits can be summarised as follows:

- Better management of business risk for Lake Albert agricultural sector
- Higher agricultural productivity as lower value land use (dryland farming) is converted to higher value land use (irrigation)
- Increased yield from existing land use
- New or expanded investment in region (due to increased business certainty)
- Improved productivity for fisheries
- Indirect benefits to other local businesses
- Maintain or grow local population, supporting social infrastructure and community culture
- Protection of local environment – including habitat and ecosystem services.

5 Method to Identify and Assess Options

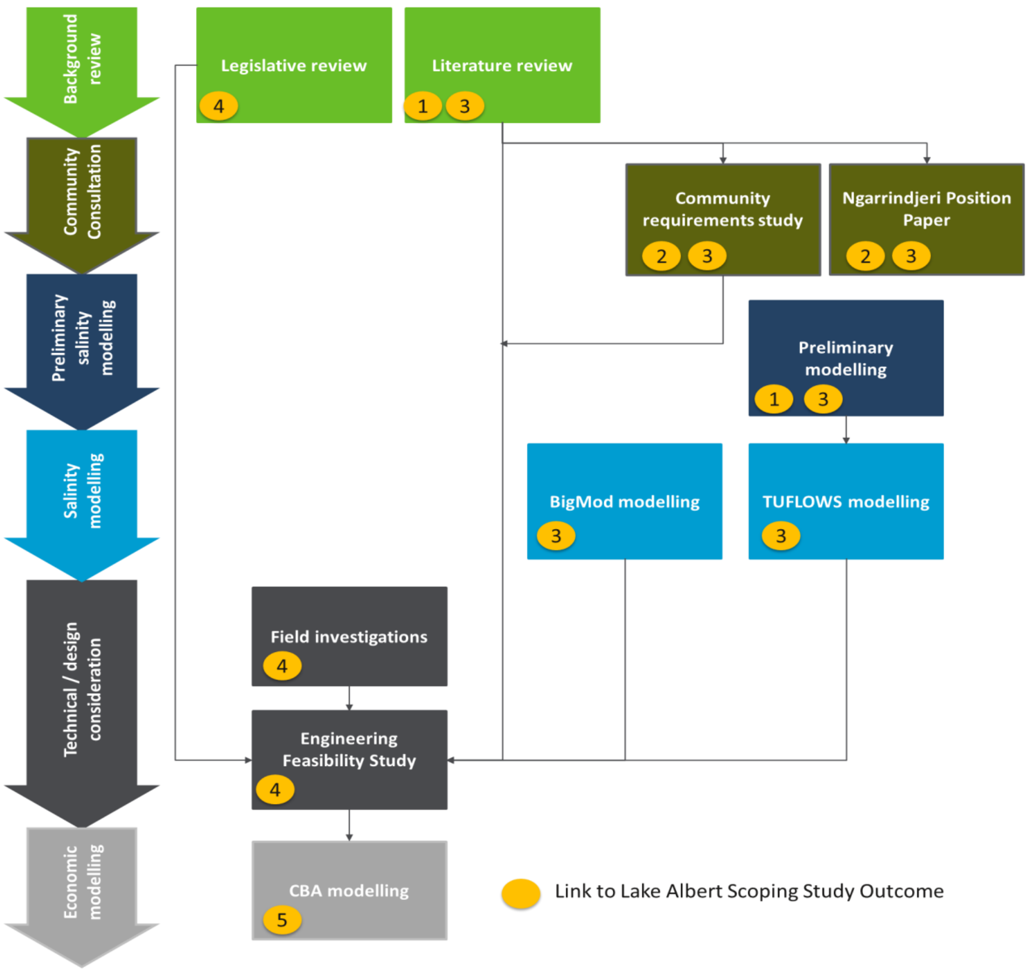
5.1 Lake Albert Scoping Study Investigations

The Scoping Study included a number of investigations.

Figure 15 illustrates how the studies relate to different stages of the Scoping Study and the information flow between these reports. The diagram also identifies how the studies contribute to the six Scoping Study outcomes:

1. Identifying water quality and flow requirements for managing salinity in Lake Albert and the Narrung Narrows
2. Identifying community requirements regarding Lake Albert and Narrung Narrows
3. Identifying potential management actions to achieve the environmental and social goals for Lake Albert and Narrung Narrows
4. Completing feasibility assessments on the potential management actions
5. Completing a cost benefit analysis on the feasible management actions
6. Where appropriate, producing a Business Case to seek funding for the implementation of the preferred management action(s).

Figure 15: Scoping Study process



Source: SKM, 2014

The key studies are listed and described in **Table 5**. As many management options have been looked at historically, not all studies considered the same options. As such, the following table also summarises the options considered within each study.

Additional information on outcomes from these studies is provided in **Section 6**.

Table 5: Summary of studies completed for the Scoping Study

Description	Management options considered
Literature Review	
The Lake Albert Scoping Study Literature Review forms part of Phase One of the Lake Albert Scoping Study. The Literature Review: • Details the past and present environmental conditions in Lake Albert and Narrung Narrows. This includes a description of the climate, geology, conservation significance, soil, topography, water quality and ecology of the site. • Identifies and summarises investigations that have been undertaken to date relating to potential management options. • Summarises the environmental, social and economic value of the region, including a description of land use changes before and after the drought. A review of water entitlement figures demonstrates that rapid change of land use from irrigation to dryland agriculture between 2006 and 2010. The review considers three options which are explored further in this summary report. However, it is important to note that the literature review was undertaken prior to the completion of the engineering review and more recent water quality modelling. As such, information specifically relating to the assessment of options should be based on more recent studies (discussed within this summary table).	Potential management options discussed in the literature review include: • Dredging the Narrung Narrows (Option 1) • Removal of the Narrung Causeway (Option 2) • Constructing a channel/pipe from the southern end of the Lake Albert to the Coorong (Option 3 and Option 4) • Construction of a permanent regulating structure in the Narrung Narrows (Option 5) • Lake Cycling - referred to as Variation of water levels in Lake Albert and Alexandrina (Option 6) Additional Options listed and discussed in the Literature review that have been discarded for various reasons (consultation and technical feasibility studies) include: • Groyne through the centre of Lake Albert • Central Bund in Lake Albert • Other Acid Sulfate Soil (ASS) and water saving options
Legislative Review	
The review outlines the legislative approvals likely to be required for the management actions being considered as part of the Lake Albert Scoping Study. The legislative approvals which have been identified in this review as being required are not exhaustive, and are subject to refinement as management actions are further developed.	Management actions considered include: • Dredging the Narrung Narrows (Option 1) • Narrung Causeway Removal or Modification (Option 2) • Coorong Connector (Option 3 and Option 4) • Permanent structure in the Narrung Narrows (Option 5) • Lakes cycling (option 6)
Community Requirements Study Report	
This study explores the needs and wants of the community with regard to action plans for Lake Albert.	The following management actions were considered

Description	Management options considered
The review was based on 10 in-depth interviews and two focus group sessions with community leaders and stakeholders and 189 telephone surveys. An online survey was also made available but did not attract further responses. Dredging of the Narrung Narrows was almost universally supported as a viable way to support natural flows. A permanent structure in the Narrung Narrows was least supported.	• Dredging of Narrung Narrows (Option 1) • Removal or modification of Narrung Causeway (Option 2) • Coorong Connector (Option 3 and 4) • Permanent structure in Narrung Narrows (Option 5) • Lakes cycling (Option 6)
Preliminary Modelling Report	
BMT WBM was commissioned to undertake a desktop investigation to provide an initial assessment of potential management options to improve salinity levels within Lake Albert. A review of the environmental characteristics of the Lower Lakes was undertaken to develop a conceptual model of key factors influencing salinity within Lake Albert. The results of this investigation were used to determine the boundary conditions, Base Case assumptions, and the scenarios to be tested within the more detailed TUFLOW FV modelling (see below). The report provided an initial assessment of management options based on desktop research. The preliminary assessment suggested that: • Dredging would provide relatively limited benefit • The installation of a permanent water level structure in Narrung Narrows is likely to be the least effective at reducing salinity in Lake Albert • A Coorong Connector Channel will likely be most effective, likely to reduce salinity values within Lake Albert to below 1800 EC within 6 to 12 months of operation. This analysis and the preliminary results were then assessed further using detailed salinity modelling (including BigMod and TUFLOW FV discussed below).	The following management actions were considered • Dredging of Narrung Narrows (Option 1) • Removal or modification of the Causeway (Option 2) • Connection to the Coorong (Option 3/4) • Permanent water level structure in Narrung Narrow (Option 5) • Water level manipulations (Lake Cycling – Option 6)
MSM Bigmod Report	
This study uses Murray-Darling Basin Authority's long term MSM Bigmod modelling suite to model the potential change in water management and salinity levels within the Lower Lakes. Bigmod is a computer model that conceptualises and simulates the River Murray system. It divides the river into a number of river reaches to model flow and salinity, losses, inflows, extractions, the operation of storages and weirs based on specified rules and the diversion of water into branches. The aim of the study is to assess the relative salinity benefit in Lake Albert for the several potential management actions. Key assessment outputs include:	Management actions considered include: • Narrung Narrows dredging (Option 1) • Removal or modification of Narrung Causeway (Option 2) • Coorong Connector (Option 3 and 4) • Lakes cycling strategies (Option 6) • Short-term pumping All options were compared to the Basin Plan model run (which can be considered to be the Base Case or do nothing option).

<table>
<tr><th>Description</th><th>Management options considered</th></tr>
<tr><td>The relative salinity benefit in Lake Albert of a proposed channel between Lake Albert and the Coorong
The effect of the channel discharge on the salinity of the Coorong and Murray mouth depth
The relative salinity benefit in Lake Albert of dredging the Narrung narrows to increase the flow between Lakes Alexandrina and Albert
The relative salinity benefit in Lake Albert of lake cycling when sufficient water is available to restore water levels in the lower lakes.</td><td></td></tr>
<tr><td colspan="2">TUFLOW FV modelling Report</td></tr>
<tr><td>BMT WBM was commissioned by DEWNR to undertake a range of studies aimed at improving the understanding of salinity transport and mixing mechanisms in Lake Albert.
Salinity dynamics of the Lower Lakes and Coorong were modelled to evaluate the effectiveness of six potential management options designed to reduce salinity levels in Lake Albert.
Twelve scenarios were tested to assess the impact of varying wind conditions, inflow and evaporation as well as initial salinity (tested at 400/5000 EC and 700/2000 EC)[12]. 400/5000 EC was chosen to represent a ‘recovery from drought’ scenario and 700/2000 EC was chosen to represent approximate current conditions.</td><td>Management actions considered include:
Base Case
Dredge Narrung Narrows and Remove Causeway (Option 1 and Option 2 combined)
Coorong Connector (Option 4/5)
Permanent Water Level Control Structure at Narrung (Option 5)
Lake Cycling (two variations of this option) (Option 6)</td></tr>
<tr><td colspan="2">Field Investigations - Geotechnical, Acid Sulfate Soil and Ecological Investigations Report</td></tr>
<tr><td>SKM was engaged by DEWNR to undertake a range of field investigations, including an environmental assessment at three target locations at the southern end of Lake Albert and the inlet to the Narrung Narrows adjoining Lake Alexandrina and Lake Albert.
The objective of the study was to obtain site-specific design information to inform the Engineering Feasibility Study. The study included:
A geotechnical investigation at target locations to inform design development of management actions. This comprised 3 boreholes at Narrung Narrows and 10 boreholes at the potential Coorong Connector locations.
A site-based Acid Sulfate Soil (ASS) assessment at target locations to determine potential ASS risks. It is noted that soil field pH tests are only indicative and cannot be used as a substitute for laboratory analysis to determine the presence or absence of ASS.
Environmental Assessment. This was a desktop review of environmental assets and included a</td><td>Options considered in the analysis include
Dredging of Narrung Narrows (Option 1)
Permanent regulator at the inlet to the Narrung Narrows (Option 5)
Removal or modification of the Narrung Narrows Causeway (Option 2)
Coorong Connector alignment 1 (Option 3/4) Coorong Connector alignment 2 (Option 3/4)
Coorong Connector alignment 3 (Option 3/4)</td></tr>
</table>

[12] 400/5000 EC refers to 400 EC in Lake Alexandrina and 5000 EC in Lake Albert. 700/2000 EC refers to 700 EC in Lake Alexandrina and 2000 EC in Lake Albert.

<table>
<tr><th>Description</th><th>Management options considered</th></tr>
<tr><td>summary of environmental values, as well as direct short-term impacts and possible long-term/indirect impacts from each proposed management action
• A topographical and engineering detail survey over each proposed alignment for the Coorong Connector and at the Western and Eastern Banks of the Narrung Narrows to provide inputs for further refinement of options.</td><td></td></tr>
<tr><td colspan="2">Engineering Feasibility Report (including designs and cost estimates)</td></tr>
<tr><td>DEWNR engaged SKM to undertake a two part engineering feasibility study of potential management actions to manage water quality in Lake Albert and the Narrung Narrows. The study comprised the following tasks:
• Part 1: Engineering Feasibility Review
• Part 2: Concept Design and Costing of two management options – dredging and Coorong Connector
The report provided:
• A qualitative assessment of costs and benefits associated with each option (Multi-criteria assessment)
• Infrastructure requirements, design considerations and preliminary cost estimates for some options
.</td><td>Options considered in the Multi-Criteria Analysis include:
• Dredging of the Narrung Narrows (Option 1)
• Removal or partial removal of the Narrung Narrows Causeway (Option 3)
• Modification of the Narrung Narrows Causeway (Option 2)
• Coorong Connector alignment 1 (pipe and channel) (Option 3/4)
• Coorong Connector alignment 2 (pipe and channel) (Option 3/4)
• Coorong Connector alignment 3 (pipe and channel) (Option 3/4)
• Permanent regulator at the inlet to the Narrung Narrows (Option 5)
Design and costs were provided for two management options - Dredging of the Narrung Narrows and a Coorong Connector. Dredging was considered as it was the option most supported by the community and the Coorong Connector was investigated because this was the option that was most effective at reducing Lake Albert salinity levels (based on the salinity modelling results).
The engineering report considers three alignments of the Coorong Connector option. Both a pipe and a channel Coorong Connector were considered, however the channel was identified as the preferred alternative given the likely higher complexity and cost of a pipe connection.
The report does not consider the Do Nothing option (Base Case) or the Lake Cycling Option (Option 6) as these options do not require additional infrastructure.</td></tr>
<tr><td colspan="2">Cost Benefit Analysis</td></tr>
<tr><td>DEWNR engaged Ernst and Young (EY) to conduct an economic cost benefit analysis (CBA) which quantifies the costs and benefits of a management action.</td><td>Whilst several options are referred to in the report, only the Coorong Connector Channel management action is assessed quantitatively in the economic CBA (Option 3).
The CBA was undertaken following salinity modelling which illustrated that the Coorong</td></tr>
</table>

Description	Management options considered
	Connector and Lake Cycling were most effective at reducing salinity levels in Lake Albert. The salinity benefits were much higher for the Coorong Connector, but the associated cost is also significantly higher. As such, the CBA focuses on assessing whether the Coorong Connector (the more expensive option) delivered net benefits to the State. The CBA report also provides a qualitative assessment of the Lake Cycling management option.

6 Management Options Considered

The key management options that have been considered for Lake Albert across a range of studies include:

- Base Case: Do Nothing Option
- Option 1: Dredging of the Narrung Narrows
- Option 2: Removal or Partial Removal, or Modification of the Narrung Causeway
- Option 3: Construction of a Coorong Connector (channel)
- Option 4: Construction of a Coorong Connector (pipe)
- Option 5: Construction of a Permanent Regulating Structure in the Narrung Narrows
- Option 6: Lake Cycling (or lake manipulation)

These are discussed in more detail in the following sections.

6.1 Base Case: Do Nothing

6.1.1 Description

The Base Case involves undertaking no further management actions, but assumes the Basin Plan 2800 GL/Year scenario. Lake Albert would continue to experience elevated salinity levels particularly during prolonged drought periods.

6.1.2 Design Considerations

There are no design considerations for the Base Case.

6.1.3 Salinity Impact

TUFLOW FV Modelling (BMT WBM, 2013) estimated Base Case salinity over a three year period for 12 different scenarios (differencing wind/tide conditions, inflows evaporation and starting salinity). The results of the modelling indicated that:

- higher wind years (represented by 2010/11 wind and tide conditions) are more effective at reducing salt concentration at Lake Albert than low wind conditions (represented by 2008/09 wind and tide conditions)
- higher annual inflows assist in the reduction of Lake Albert salinity
- higher annual net evaporation restricts the reduction in Lake Albert salinity.

6.1.4 Cost Estimate

There are no infrastructure costs associated with the Base Case.

6.1.5 Community Perspective

The community has indicated strong support for a management option that addresses the problems identified in **Section 4**. Based on the consultation undertaken by Square Holes (2013), there was a consistent view amongst farmers, fishers and the general members of the community that action was needed and that doing nothing is not a desired option. This is because it has taken four years to lower salinity and the community feels there are no actions to protect Lake Albert from another drought.

6.1.6 Legislative Considerations

There are no specific legislative considerations for the Base Case. However, as has been noted earlier, the ecological character of the site is protected under the national *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).

6.1.7 Summary of Advantages and Disadvantages

The following table summarises the advantages and disadvantages of the Base Case.

Table 6: Summary of Base Case advantages and disadvantages

Advantages	Disadvantages
No capital costs Aligns with Basin Plan recovery scenario	Does not address the problems discussed in **Section 4.1.1**. Most significantly, Lake Albert will continue recovering from high salinity (following drought) slowly. This will lead to direct costs for the agricultural sector in the region, and indirect costs to other businesses and the community more broadly. Ecologically, there would be impacts when salinity exceeds 5,000 EC, particularly if this state is maintained for a period of time. This is not expected to occur under the Basin Plan, unless unprecedented hydrological conditions are experienced. Changes in salinity between 1,000 and 5,000 EC, poses minimal ecological impact as within this range there is not a substantial shift in ecological state.

6.2 Option 1: Dredging of the Narrung Narrows

6.2.1 Description

Flow between the fresher Lake Alexandrina and the more saline Lake Albert is primarily wind driven. Dredging of the Narrung Narrows would involve dredging sediment along the Narrows and removing potential flow restrictions through the Narrung Narrows. This aims to optimise the wind driven flow between the two lakes as the predominant south/south-west winds push water from Lake Albert to Lake Alexandrina. Option 1 would require the removal and disposal of approximately 6 million cubic metres of material, which would potentially require on land disposal and treatment. The option was initially explored by Ebsary (1983) with the expectation that as the water in Lake Alexandrina is almost always less saline than that in Lake Albert, wind driven flows across the widened Narrung Narrows could enhance the freshening effect.

6.2.2 Narrung Narrows

The Narrung Narrows have not changed significantly over time, as seen comparing the following aerial images from 1963 and 2006/07 in **Figure 16** and **Figure 17**.

Figure 16: Aerial image of the Narrung Narrows, 1963 shortly after the Narrung Causeway was constructed; assumed water level +0.75 m AHD

Figure 17: Aerial image of the Narrung Narrows in 2006/07; assumed water level at -0.3 m AHD

In comparing the above historic images, it can be noted that:

- there is some visual difference in the channel due to the differing water depths between the 1963 image of approximately +0.75 m AHD and the 2006/07 image of approximately -0.1 m AHD
- the area on the Lake Albert side of the Causeway has not changed considerably in this 40 year period
- the reed islands have not changed considerably in size or number.

6.2.3 Design Considerations

A number of different channel widths and profiles have been proposed and modelled in studies such as Ebsary (1983). Key design features and considerations for the Dredging of the Narrung Narrows are summarised in the following table:

Table 7: Option 1 Dredging of the Narrung Narrows – Design features and considerations

Design considerations	Description
Modelled dredged volumes	Recent modelling undertaken by BMT WBM (2013) assumed a maximum dredge volume of 6 million cubic metres would be required. The modelling logic was to begin with the greatest dredge volume and if benefit was found, the dredge volume would be reduced until a realistic benefit to effort ratio was identified. As the modelling indicated negligible benefit with the maximum dredge volume, subsequent modelling with smaller dredge volumes was not undertaken.
Dredging dimension description	The channel would be a minimum of 200 m wide, with an invert of -2 m AHD that runs for approximately 12 km between Lake Alexandrina and Lake Albert (BMT, 2014). See **Figure 18**.
Geotechnical considerations	The general subsurface profile of the Narrung Narrows site, as identified in a recent field investigation works (SKM, 2013) at the ferry end of the Narrung Narrows, is fill materials overlying loose sand and soft clay, followed by loose to medium dense sand. Dense to very dense sand was encountered at approximately -12 m AHD and very stiff to hard clay was encountered at approximately -20 m AHD.
Acid sulfate soil	Samples field tested in the Narrung Narrows (located near the ferry) on 13 February 2013 by CSIRO showed a strong likelihood of PASS (Potential Acid Sulfate Soil). Sediment samples taken from three locations within the Narrung were classified as hypersulfidic (pH fell to < 4), and would therefore pose a high acidification hazard should sediment be disturbed. Laboratory analysis is required in order to confirm this finding.
Disposal options	Due to the estimated volume of extracted material (6 million cubic metres), entire on land disposal would likely be the required disposal option in lieu of submerged disposal or side casting into the channel fringe areas. This option would require excavation by a cutter suction dredge with the material transferred via a pipeline to the desired location for on land dewatering and containment in order to treat the material for re-location or final disposal.

6.2.4 Salinity Impact

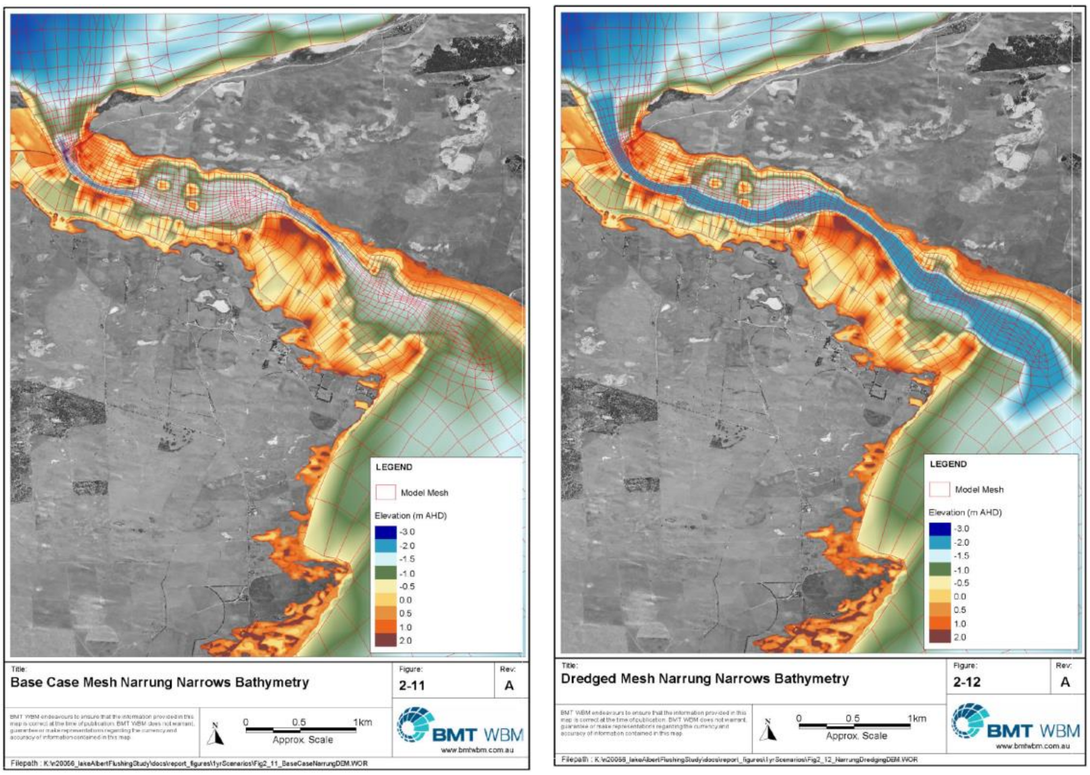
Preliminary and detailed modelling suggests that dredging would have negligible (if any) impact on salinity reduction in Lake Albert. More specifically:

- **Preliminary modelling (BMT WBM, 2013)** indicated that dredging provides minimal benefit. As with causeway removal, it will slightly increase wind exchange efficiency, however it is unable to generate any increase in net water volume change. A small amount of net mass change is only likely during wind events, but the overall benefit is expected to be limited.

- **MSM Bigmod Modelling** was used to assess the relative salinity benefit of dredging[13]. The results when compared to the Base Case showed no improvement in salinity reduction.
- **TUFLOW FV Modelling** considered the impacts of dredging and the removal/modification of the Narrung Causeway (options 1 and 2 combined)[14]**.** As can be seen in **Figure 19** and Figure 20, dredging was less effective than the Base Case at reducing salinity under most low wind conditions. At higher wind conditions, there was only marginal improvement in salinity reduction relative to the Base Case. This was the case for all initial salinity levels tested. Apart from one scenario (Scenario 8), salinity levels did not reach average historical levels of 1500 EC within the three year assessment period.

  A combination of dredging and Lakes Cycling was also modelled in MSM Bigmod. The results indicate that increasing the conveyance of the Narrung Narrows in addition to Lakes Cycling has very little additional benefit to Lake Albert salinity.

Figure 18: The bathymetry of Narrung Narrows presently (left), and modified in the model mesh to represent a large dredging effort to make the Narrows a minimum of 200m wide and 2m deep. This requires the removal of 5-6 million cubic metres of sediment.



Source: BMT WBM 2014

[13] This was done by modelling the impact of doubling the conveyance of the Narrung Narrows.

[14] The dredging includes the removal of 5-6 million m^3 of sediment to create a channel that is a minimum 200 m wide, with an invert of -2 m AHD that runs for approximately 12 km between the two Lakes. If displaced either side of the Narrows, this sediment would be piled 2.5 m high and 100 m wide for 12 km.

Figure 19: Option 1 Dredging of the Narrung Narrows – TUFLOW FV modelling results for Lake Albert salinity (EC) at end of 3 year simulation (700/2000 EC Initial Condition)

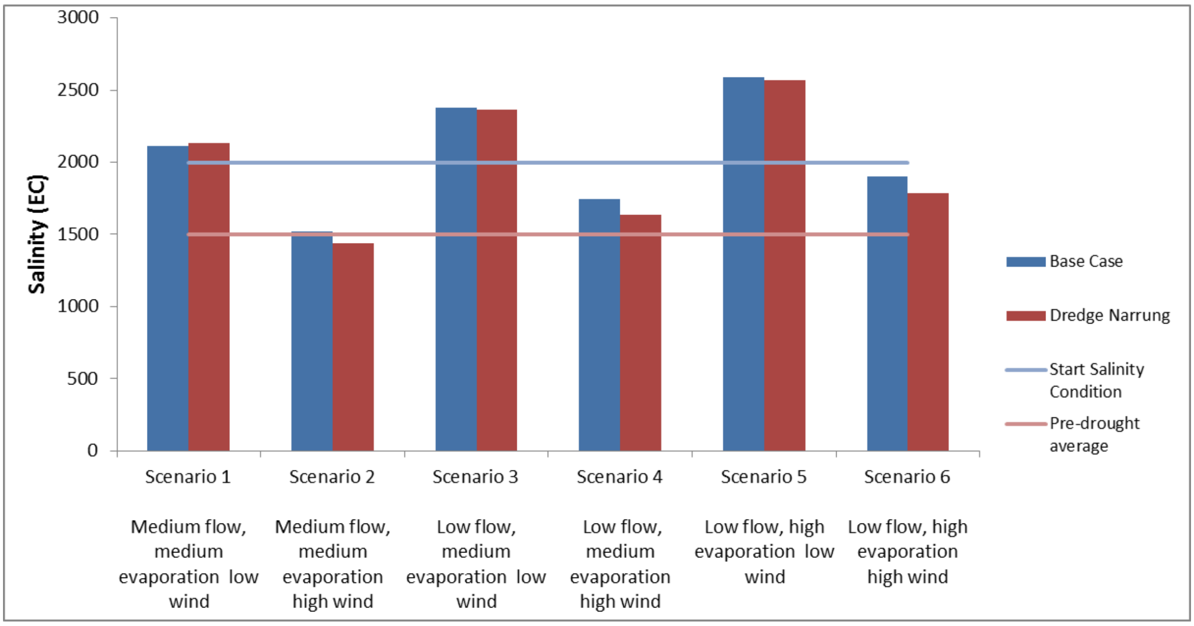
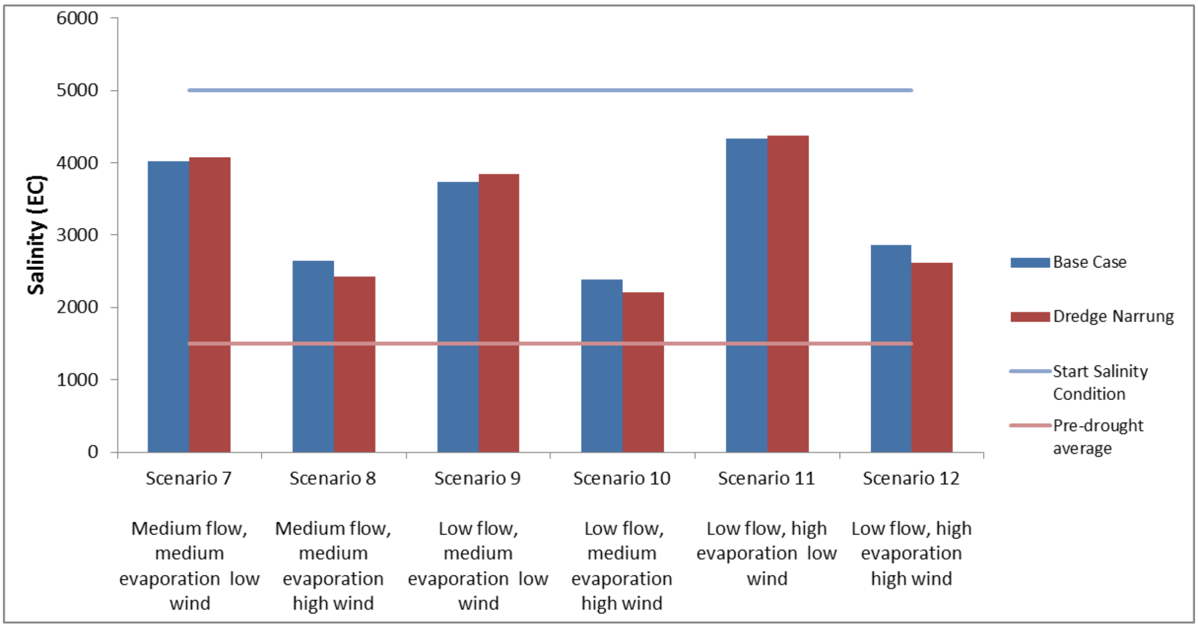


Figure 20: Option 1 Dredging of the Narrung Narrows – TUFLOW FV modelling results for Lake Albert salinity (EC) at end of 3 year simulation (400/5000 EC Initial Condition)



The reason dredging Narrung Narrows does not substantially improve the salinity in Lake Albert can be explained. Because of the terminal nature of the Lake Albert, wind driven mixing is the most important factor in exporting salt from Lake Albert. Increasing the conveyance of Narrung Narrows by dredging improves the rate of exchange between the two lakes but it does not increase the overall volume of exchange. There are a few scenarios (under low wind conditions of 2008/09) in which the Base Case outperforms the Dredging option. A possible explanation is that the volume of dredging (5-6 million m^3) is of similar magnitude to typical wind driven exchange volumes (2 to 20 GL). Dredging would mean that the volume of water residing in Narrung Narrows would increase by 5-6 GL, which will reduce the volume of water that will actually be transported from the Narrows into the main body of either lake where it could mix.

This reduced mixing opportunity is the main reason that dredging is less effective at removing salt from Lake Albert than the Base Case (Rohan Hudson, BMT WBM, pers. comm. April 2014).

Cost estimate

The indicative pre-design estimate for the dredging and disposal of 6 million m^3 of material from the Narrung Narrows (and associated works) is $119 million. This cost is based on a disposal site being available within 5km and project delivery and works contingencies. This preliminary estimate was developed prior to any concept or detailed design being undertaken for this option and is only intended to provide an indication for cost range comparison.

6.2.5 Community Perspective

The community indicated strongest support for dredging the Narrung Narrows. It was the most popular potential management action, gaining 82 % support with only 9 % of people stating they were not supportive.

Some community members suggested that the Narrung Narrows had not changed markedly over time (considering historical images and oral history) and dredging was unnecessary as Narrung Narrows would maintain itself. See **Figure 16** and **Figure 17** for historic images of Narrung Narrows from 1963 and 2006/07 respectively.

Those who supported the potential management action indicated that it was essential that the dredging was undertaken in a way that supports natural flows and does not involve shifting sediment from one area just to have it build up in another.

The NRA stated in their position paper (November 2013) “there exists no support for any form of engineering, construction or breaking of the ground as such is inconsistent with the above principles and positions of the Ngarrindjeri and for this particular project no exceptional circumstances have been made out.”

6.2.6 Legislative Considerations

Dredging the Narrung Narrows would trigger a number of legislative approvals as outlined in the following table. The approvals required will depend on the extent of dredging and disposal options proposed.

Table 8: Option 1 Dredging of the Narrung Narrows – Legislative considerations

Legislative approval	Comment
Environment Protection and Biodiversity Conservation Act 1999	The Narrung Narrows are located in a listed wetland of international importance (the Coorong, and Lakes Alexandrina and Albert Ramsar site), which is protected as a matter of national environmental significance under the EPBC Act. The area is also known to support a wide range of threatened and migratory species protected as matters of national environmental significance under the Act. A self-assessment of potential impacts to matters of national environmental significance would most likely be needed, though it is expected that this self-assessment would not find that significant impacts would occur as a result of this management action.
Water Act 2007 and the Water Amendment Act 2008	Notification to the MDBA would likely be required under the MDB Agreement.
Aboriginal Heritage Act 1988	In line with the CLLMM Recovery Project’s Aboriginal Heritage Risk Management process, it is expected that a cultural heritage survey of the site

Legislative approval	Comment
	and search of the Aboriginal Heritage Register would be required to ensure that no Aboriginal sites, objects or remains are impacted by the removal works. A Section 23 authorisation may be required for the dredging works as the site is of significance to the Ngarrindjeri. The NRA may also wish to develop a Kungun Ngarrindjeri Yunnan Agreement to establish a working relationship with DEWNR for this management action.
Crown Land Management Act 2009	A 'licence to occupy' may be required if the lay-down, site office or construction areas are to be located on Crown land.
Development Act 1993	If the dredged material is proposed to be disposed of on land, then a development application may be required depending on the current use of the disposal location (e.g., may constitute development under the Development Act - change in the use of land).
Environment Protection Act 1993	Dredging works are expected to require a licence from the Environment Protection Authority under the Environmental Protection Act. The contractor responsible for the removal/modification works will also likely be required to undertake water quality monitoring as part of an environmental management plan for the works. For previous projects, water quality monitoring results have been communicated periodically to the EPA. The EPA may also choose to undertake their own water quality monitoring to ensure that parameters are not exceeded. If the dredged material is proposed to be disposed of on land, then Acid Sulfate Soil testing would likely be needed and possible options for treatment developed.
Harbors and Navigation Act 1993	A temporary boating exclusion may be needed to prohibit boats entering the area while the Causeway is being removed.
Local Government Act 1999	DEWNR may need to liaise with the local council to inform them of the proposed works and to review against the Local Government Act.
Native Vegetation Act 1991	If native aquatic vegetation (e.g. *Phragmites* and *Typha*) are cleared in the process of dredging the Narrung Narrows, then it is likely that approval under the Native Vegetation Act will be required. This would involve a native vegetation assessment and preparation of a native vegetation management plan to be approved by the Native Vegetation Council.
Natural Resources Management Act 2004	A Water Affecting Activity Permit would likely be required for this management action as it would involve undertaking a water affecting activity (i.e. excavating or removing rock, sand or soil from a lake).

6.2.7 Summary of Advantages and Disadvantages

The following table summarises the advantages and disadvantages of Option 1.

Table 9: Option 1 Dredging of the Narrung Narrows – Advantages and disadvantages

Advantages	Disadvantages
• Strong community support • This management action does not require any new structures or modification to existing structures • This management action requires no permanent on-ground construction works other than temporary works associated with a land based disposal site.	• Marginal impact on salinity relative to the Base Case and therefore not considered to be a cost effective solution • The cost is expected to be significant and highly variable. Costs are dependent upon ground conditions, dredging volumes, sediment quality, discharge distance and type, silt containment and land access

Advantages	Disadvantages
• No impact on the current operating regime.	• Significant dredging/excavation required • High risk of exposure of PASS material and mobilisation based on CSIRO preliminary assessment • Complexities and costs of disposal and ongoing treatment of dredged material are significant • Disruptions during dredging on the ferry and recreational use of the Narrows due to required dredging exclusion zones. The impact may be greater to recreational and commercial fishermen depending on the timing of dredging works. • Sediment plume mobilisation may impact primary industries for the duration of dredging works. • Additional dredging may be required in the future to maintain increased flows following sediment build-up. • Dewatering/settlement/treatment ponds may potentially require extensive processing and treatment over time for the management of dredge material. • No increased water level manipulation ability.

6.3 Option 2: Removal, Partial Removal or Modification of the Narrung Causeway

6.3.1 Description

The causeway was built in the early 1960s (pre 1963) to allow the ferry to operate in adverse weather conditions. This potential management option involves either:

- Full or partial removal, of the Narrung causeway to improve flows
- Installation of infrastructure such as culverts within the existing causeway to improve flow whilst retaining the causeway in its current location.

6.3.2 Design Considerations

As discussed in **Section 6.3.3** and **Section *7***, this management option was assessed as not effective in improving Lake Albert Salinity relative to the Base Case. It was therefore not included in the Engineering Feasibility Study and a concept design has not been developed.

Table 10: Option 2 Removal, partial removal or modification of the Narrung Causeway – Design features and considerations

Design considerations	Description
Geotechnical considerations	Based on testing of boreholes at the ferry location (SKM, 2013), the general subsurface profile of the causeway material comprises 4.2 m of fill material, which comprises loose to medium dense sand, underlain by loose to medium dense sand and firm to stiff clay.

Design considerations	Description
Acid sulfate soil	Samples field tested in the Narrung Narrows (located near the ferry) on 13 February 2013 by CSIRO showed a strong likelihood of PASS (Potential Acid Sulfate Soil). Sediment samples taken from three locations within the Narrung were classified as hypersulfidic (pH fell to < 4), and would therefore pose a high acidification hazard should sediment be disturbed. Laboratory analysis is required in order to confirm this finding.

6.3.3 Salinity Impact

Preliminary and detailed modelling suggests that removal or partial removal of the Narrung Causeway would, at best, only marginally improve salinity at Lake Albert when compared to the Base Case. In some cases, this option delivers worse salinity outcomes than the Base Case. The impacts were consistent with those assessed for Option 1. More specifically:

- **Preliminary modelling** results for Option 2 were consistent with those provided for Option 1 (Dredging of the Narrung Narrows – see **Section 6.2.4**), indicating that there would mainly be some benefit during high wind events.
- **MSM Bigmod Modelling** was used to assess the relative salinity benefit of removal/modification of the causeway[15]. The study results, when compared to the Base Case showed no improvement in salinity impact.
- **TUFLOW FV Modelling** considered the impacts of dredging and the removal/modification of the Narrung Causeway (Option 1 and Option 2 combined). As discussed in **Section 6.2.4** and illustrated in **Figure 19** and **Figure 20**, the modelling results indicated that there would only be some reduction in salinity under high wind conditions relative to the Base Case. In most low wind conditions, this management options resulted in an increase in salinity levels relative to the Base Case.

6.3.4 Cost Estimate

Given the marginal and potentially negative improvement in salinity outcomes, this option was not considered viable (**Section 7**) and therefore was not designed or costed in any detail.

6.3.5 Community Perspective

Removal or partial removal of the Narrung Causeway was supported by the community as the causeway was viewed as an impediment to natural flows. Some believed that this option would need to be delivered in conjunction with a bridge over the Narrows, which was acknowledged as a higher cost. Overall, 62 % of those consulted were supportive and 16 % were not supportive. Some of the community members that did not support this option believed that the likely high cost did not justify the end result (Square Holes, 2013).

Installation of culverts in the Narrung Causeway was a specific modification option considered in the consultation process. Some 55 % of the community indicated support while 24 % of respondents did not support this option. However, this management action did trigger some confusion during surveys as people did not know what culverts were, leading to an inability to provide comment.

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[15] This was done by modelling the impact of increasing the conveyance of the Narrung Narrows – consistent with the approach used to assess the impact of Option 1 (Dredging of the Narrung Narrows.

The NRA stated in their position paper (November 2013), “there exists no support for any form of engineering, construction or breaking of the ground as such is inconsistent with the above principles and positions of the Ngarrindjeri and for this particular project no exceptional circumstances have been made out.”

6.3.6 Legislative Considerations

Removal or partial removal of the Narrung Causeway would trigger a number of legislative approvals as outlined in the following table. It is important to note that the approvals required would depend on the extent of dredging and earthworks proposed in and around the causeway associated with its removal or modification.

Table 11: Option 2 Removal, Partial Removal or Modification of the Narrung Causeway – Legislative considerations

Legislative approval	Comment
Water Act 2007 and the Water Amendment Act 2008	Notification to the MDBA would likely be required under the MDB Agreement.
Aboriginal Heritage Act 1988	In line with the CLLMM Recovery Project's Aboriginal Heritage Risk Management process, a cultural heritage survey of the site and search of the Aboriginal Heritage Register would likely be required to ensure that no Aboriginal sites, objects or remains are impacted by the removal works. A Section 23 authorisation is unlikely to be necessary as the management action involves removal of a foreign structure.
Crown Land Management Act 2009	A 'licence to occupy' may be required if the lay-down area and site office is proposed to be located on Crown land.
Environment Protection Act 1993	If the management action proposes removal of the Causeway by dredging, then a licence to dredge will likely be required from the Environment Protection Authority. The contractor responsible for the removal/modification works will also likely be required to undertake water quality monitoring as part of an environmental management plan for the works. For previous projects, water quality monitoring results have been communicated to the EPA. The EPA may also choose to undertake their own water quality monitoring to ensure that parameters are not exceeded.
Harbors and Navigation Act 1993	A temporary boating exclusion may be needed to prohibit boats entering the area while the Causeway is being removed.
Local Government Act 1999	DEWNR may need to liaise with the local council to inform them of the proposed works as the Causeway is under the care and control of council.
Natural Resources Management Act 2004	A Water Affecting Activity Permit would likely be required for this management action as it would involve undertaking a water affecting activity (excavating or removing rock, sand or soil from a lake).

6.3.7 Summary of Advantages and Disadvantages

Table 12 summarises the advantages and disadvantages of the partial or full removal of the Causeway.

Table 12: Option 2 Partial or Full Removal, or Modification of the Causeway – Advantages and disadvantages

Advantages	Disadvantages
• General community support (3rd preference from the management options presented). • Modification is likely to be the third lowest cost option (following Base Case and Lakes Cycling) but if the Causeway was removed, costs would increase substantially. • The site has good access and removal would be a standard process. • Minimal maintenance costs expected, although periodic dredging may be required to maintain increased flows following sediment build-up.	• No significant impact on salinity – therefore not likely to be an effective solution • Significant excavation is associated with this management action as well as potential dredging. Complexities and cost of disposal of excavated/dredged materials are significant • There is a high risk of PASS exposure or mobilisation. Disposed material would most likely need to remain submerged or treated on-land prior to land based disposal • Additional dredging may be required in the future to maintain increased flows following sediment build-up • The Ferry will be shut down for construction and modifications, leading to disruptions to primary industries and commercial activities along with landowners and recreational users of the Narrows • Reducing the length of the Causeway would increase the length of the ferry crossing. This would affect future ferry operation and maintenance, should a bridge not be constructed. • There is a risk that the impacts will not be feasible or acceptable from a transport planning and approvals perspective. (It is noted that removing the ferry would not be desirable as the alternative route is approximately 45 km, the longest of any ferry crossing in SA). This will particularly impact the township of Raukkan.

Table 13 provides additional advantages and disadvantages as they relate to the modification of the causeway.

Table 13: Option 2 advantages and disadvantages – Modification of the Causeway

Advantages	Disadvantages
• Reduced impact on ferry operation in comparison to partial or full modification of the Causeway • Reduced excavation of natural material in comparison to partial or full modification of the Causeway.	• Low community support • No significant impact on salinity – therefore not likely to be an effective solution • Reed removal and dredging would be required to facilitate this option and therefore there is risk of Potential Acid Sulfate Soil exposure and mobilisation • If all or part of the Causeway was to be replaced with concrete culverts, a stability review of the structure would be required • Cost risks are associated with suitable foundations on which to install culverts and

Advantages	Disadvantages
	also the degree to which dredging would be required • Additional dredging may be required in the future to maintain increased flows following sediment build-up • Minor disruption to ferry operations during construction • Low risk of some impact on primary industries and recreational users during construction and if dredging is required.

6.4 Option 3: Construction of a Coorong Connector (channel)

6.4.1 Description

This option involves constructing a channel between Lake Albert and the Coorong North Lagoon to improve salt export from Lake Albert and includes at least one control structure for flow regulation, system control and management.

Three alignments were considered and are shown in **Figure 21** below. Alignments 1 and 2 were suggested by the Meningie Lakes Narrung Irrigators Association and identified by DEWNR on 28 March 2013, and Alignment 3 is defined by URS (2006).

These alignments were indicative only, and are refined in the concept design phase (discussed in more detail below).

Figure 21: Possible alignments or the Coorong Connector between Lake Albert and the Coorong.

Source: SKM (2014)

6.4.2 Design Considerations

A concept design and cost estimate was developed for the Coorong Connector channel option by SKM (2014) to a level suitable for the development of a future business case.

The concept design considerations were informed by the following:

- **Agreed water levels**. The adopted maximum and minimum proposed operating levels for Lake Albert applied to the concept design were +0.80 m AHD (maximum) and +0.50 m AHD (minimum). This was confirmed by DEWNR on 16 October 2013 as the historical lake fluctuating levels (refer to the Engineering Feasibility report (SKM, 2014)).
- **Consideration of alignments/locations**. The relative length and excavation volumes of the three alignments are provided in the table below. Although Alignment 3 provides connectivity into the main lake, it requires a significantly longer channel in comparison to alignments 1 and 2. Given the higher extracted volumes, Alignment 3 was considered to

be less cost effective than the other alignments. Although Alignment 2 is 155 m longer, dredging requirements for Alignment 1 are expected to be more extensive. Given the similar excavation volumes and noting the environmental and potential increased dredging impacts associated with Alignment 1, the concept design only considered Alignment 2.

Table 14: Preferred Coorong Channel alignments based on preliminary channel sizing

	Alignment 1	Alignment 2
Length	1,670 m	1,825 m
Excavation volume for disposal (balance between cut and fill)	195,349 m^3	244,000 m^3

- **Volume of water to be passed through the channel**. Channel width and dimensions were sized based on the need to pass up to 1 GL per day and up to 300GL/year. This is the transfer target identified in the salinity modelling report, which is likely to reduce salinity levels within Lake Albert below 1,800 EC within 6 to 12 months of operation (WBM, 2014).
- **Relative cost and performance of a pipe versus channel option**. Following analysis of the possible options for the Coorong Connector, a channel was selected for the concept design in preference to a pipe. A channel is considered to be more cost effective than a pipe (noting that three or more large (2400 mm diameter) pipes would be required), delivering a similar water delivery volume at the same proposed driving heads for a likely higher comparative cost. A channel is also considered to be less complex to operate and maintain than a piped system. More detail on why a channel is preferred to a pipe is provided in **Section 6.5.2**.
- **Options for control structure positioning**. Regulating control structures are located at the upstream and downstream ends of the channel to allow for flow management and control, enabling the Coorong to be isolated from Lake Albert and to undertake maintenance activities. The flow structures comprises numerous box culverts with penstocks (undershot triple leaf gates) controlled via onsite operation.

Key design features for the Coorong Connector (Channel) based on Alignment 2 are summarised in **Table 15**.

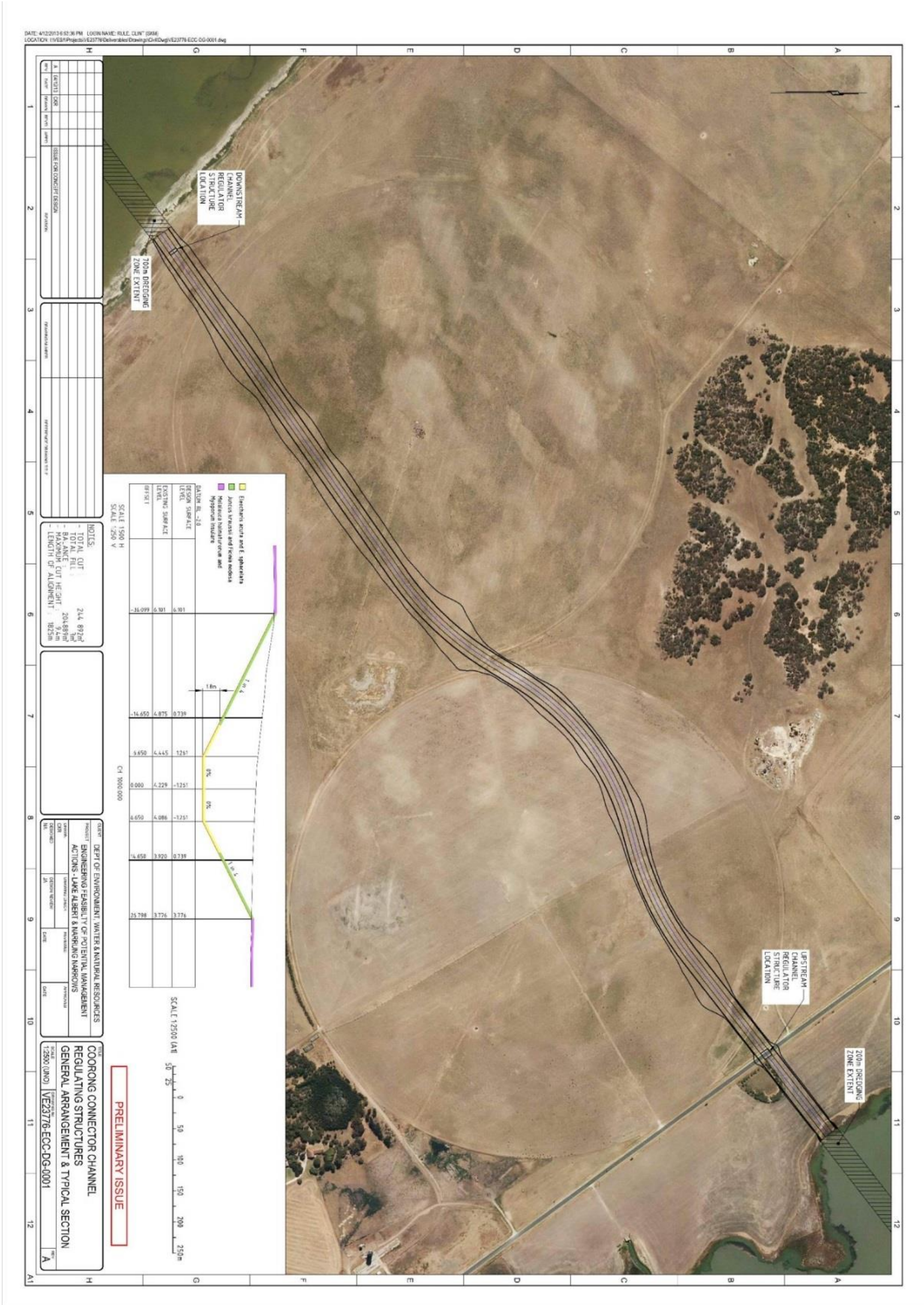
Table 15: Option 3 Construction of a Coorong Connector (channel – Alignment 2) – Design features

Design considerations	Description
Alignment Description	• Distance = 1825 m • Maximum cut height (from channel invert) = 9.4 m • Channel has a trapezoidal cross section with a 13.3m base width and 1V:4H sloping sides.
Excavation volume	• Total required volume for offsite disposal 244,000 m^3. This is the volume of sand to be removed from the Narrung Peninsula to form a channel. Any proposed dredging upstream (Lake Albert) or downstream (Coorong) of the channel is an additional volume of works. Disposal of up to 5km from the excavation site has been allowed for in the cost estimate. Side casting has not been discounted and is likely to be the preferred disposal method.
Regulation	The channel will be regulated with manually operated gates.

Design considerations	Description
	The gates can be opened and closed by a lockable spindle and have been sized to allow operation by a single person. The gates can be operated at various heights with the added ability to control the number of gates open at any one time to regulate flow through the channel.
Traffic and pedestrian access (culvert design)	The upstream control structure, located at the point where the proposed channel crosses the existing roadway incorporates a 12 m length of culverts to provide space for a single lane trafficable roadway (as presently existing) with a pedestrian footpath on one side. The culverts attached to the downstream control structure are 4.8 m long to provide access for farm vehicles across the channel. The culvert units in a regulating structure would be 4 bays wide.
Gate selection	The gate type selected was a penstock Triple Leaf Gate that enables manual operation without the need for a power source or storage and manual lifting associated with stoplogs. The gates can be opened and closed independently to regulate flow and can be opened/operated at any height. Due to the highly saline environment, gate material selection was considered. Based on cost impacts, marine grade aluminium gates have been proposed with the addition of sacrificial anodes to protect the gates from corrosion.
Impact on properties	The channel alignment runs through three properties with different titles including Aboriginal Land Trust land.
Ongoing operation and maintenance requirements	Operation and maintenance requirements include the following: • Regular monitoring for any obstructions or deterioration in the gates or channel. • Ongoing dredging of the inlet and outlet of the channel to maintain the invert level and remove sediment build up.
Vegetation for channel protection	Proposed revegetation of the channel banks has been considered which comprises native indigenous species such as: • *Eleocharis acuta* and *E. sphacelata* along the base of the channel and on the lower inundated region of the batters • *Juncus kraussii* and *Ficinia nodosa* on the upper region of the batters • *Melaleuca halmaturorum* and *Myoporum insulare* at the top of the channel. This vegetation aims to improve bank stability and minimise surface water erosion of the channel whist providing native habitat that would support local flora and fauna.
Geotechnical considerations	The soil from ground surface to three metres below the invert level of the proposed structure is generally shallow topsoil overlying loose to very dense sand. Cemented sand with strength equivalent to very weak rock was encountered.
Acid Sulfate Soil (ASS) along alignment	Samples that were field-tested along the Coorong Connector Alignments 1, 2 or 3 all reported field pH levels (pH_F) greater than four (4), suggesting samples from these locations are not representative of ASS (hypersulfidic or hypersulfuric sediments). The soils are considered unlikely to be PASS.
Acid Sulfate Soil (ASS) within Lake Albert and Coorong	Dredging into Lake Albert (200 m) and the Coorong (700 m) will be required. The material to be dredged is likely to contain Potential Acid Sulfate Soil (PASS) and treatment and disposal on land or underwater will be required.

The proposed layout showing the channel alignment and cross section is provided in **Figure 22**.

Figure 22: Concept design of Coorong Connector Channel (SKM, 2014)



Source: SKM (2014)

6.4.3 Salinity Impact

Preliminary and detailed modelling suggests that a Connector would be the most effective management option at reducing salinity at Lake Albert. More specifically:

- **Preliminary modelling** indicated that this management option could significantly reduce salinity levels in both Lake Albert and sections of the Coorong. Ebsary (1983) assessed this management option as showing considerable benefit thought at a greater cost to Lake Cycling. Further modelling (BMT WBM, 2006) indicated that based on a simulation of five years between 1993 and 1998 (when lake inflows were fairly high), this management option could reduce salinity in Lake Albert from ~2500 EC to ~500 EC within six months and maintain it below 1000 EC for the remaining four years of the simulation. A desktop review of these past studies indicated that a Coorong Connector management option with discharges up to 1 GL/day should be investigated, as well as a number of channel widths and depths.
- **MSM Bigmod Modelling** was used to assess the relative salinity benefit in Lake Albert of a connector between Lake Albert and the Coorong. A number of Connector options and scenarios were considered, including:
    - A range maximum Connector capacities (500, 1000 and 1500 ML/day)
    - Different operating rules – lake levels, and salinity levels

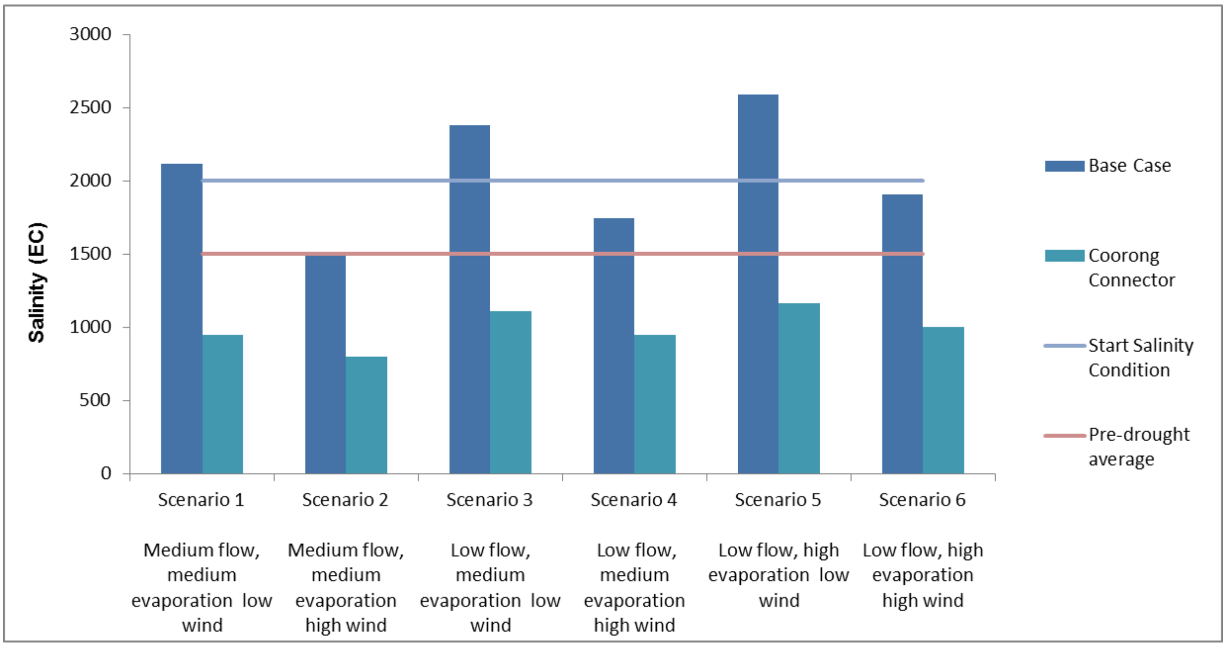
  The options were assessed against the Basin Plan 2800 model run (Base Case) using a range of varied metrics repressing salinity, frequency of operation, duration, water level and flow.

  The results indicated a reduction in mean annual salinity in Lake Albert as flow through the Connector increased. Three Connector options modelled provided a benefit in comparison to the Base Case (i.e. Basin Plan 2800 GL/yr model results). The results also indicated that a Connector would reduce the duration of events when Lake Albert salinity exceeds 1500 EC in the Base Case modelling. Options evaluated had little effect on the salinity and Murray Mouth depth for the Coorong, possibly due to the outflow from the channel being relatively small in comparison to the total barrage discharge.
- **TUFLOW FV Modelling** assessed the impact of the Connector option on salinity in Lake Albert and the Coorong. The channel modelled was approximately 2 km long, 15 m wide, with an invert of -1 to -1.5 m AHD and flow of approximately 1 GL/day. The Connector was identified as the most efficient option for reducing salt concentration in Lake Albert. It was effective at reducing salinity relative to the Base Case under all of the 12 scenarios modelled, as can be seen in **Figure 23** and **Figure 24**. Furthermore, under each scenario, the Connector results in salinity levels being reducing below the long term average within a three year period. More specifically:
    - For the six scenarios modelled for initial salinity conditions of 400/5000 EC, the salt concentration in Lake Albert reduced from 5000 EC to below 1185 EC in all conditions (flow, evaporation and wind/tide) at the end of the three year simulation. The range of salinity reduction varied between 76 % and 83 %[16].

[16] Relative to between 13 % and 52 % for the Base Case

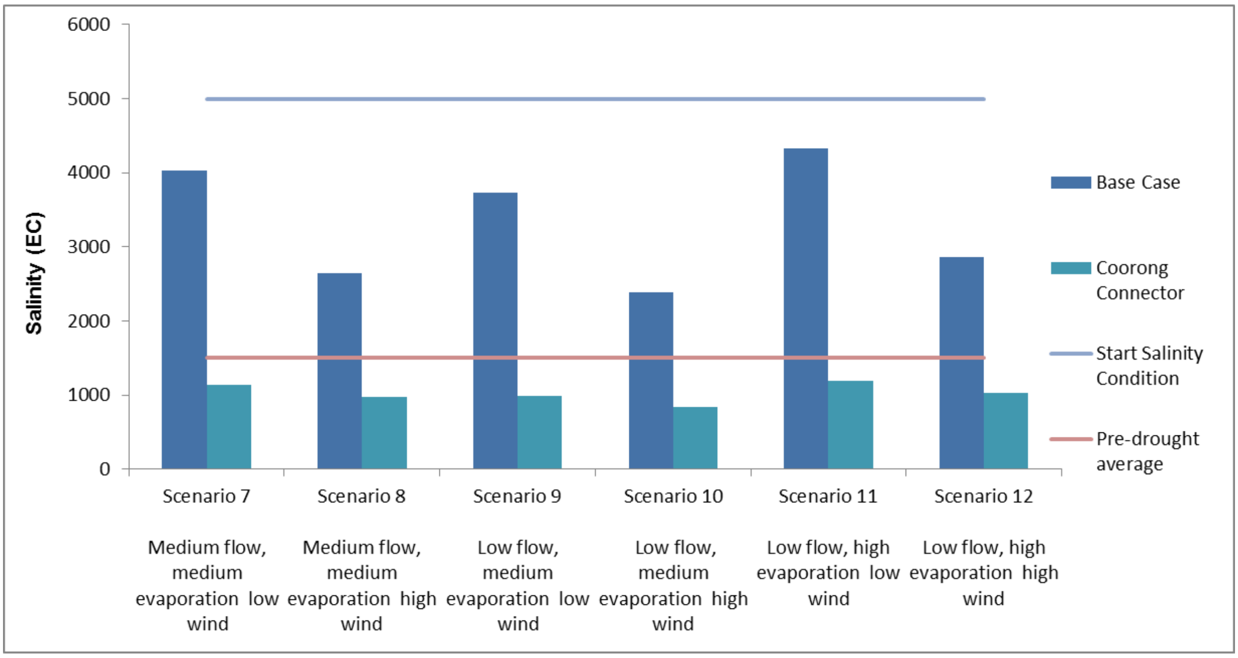
- For the six scenarios modelled for initial salinity conditions of 700/2000 EC, the salt concentration in Lake Albert reduced from 2000 EC to below 1185 EC in all conditions (flow, evaporation and wind/tide) at the end of the three year simulation. The range of salinity reduction varied between 42 % and 60 %[17].

Figure 23: Option 3 Construction of a Coorong Connector (channel) – TUFLOW FV modelling results for: Lake Albert salinity (EC) at end of 3 year simulation (700/2000 EC Initial Conditions)



[17] Relative to between 5 % and 30 % for the Base Case

Figure 24: Option 3 Construction of a Coorong Connector (channel) - TUFLOW FV modelling results for Lake Albert Salinity (EC) at end of 3 year simulation (400/5000 EC Initial Conditions)



6.4.4 Cost Estimate

The engineering estimate for the Coorong Connector channel Alignment 2 is approximately $18.97 million (+/-30 %, 2013/14 dollars) including design activities and additional construction contingencies.

6.4.5 Cost Benefit Analysis

A Cost Benefit Analysis (CBA) was undertaken by EY (2014) to assess the economic viability of management options. The CBA followed salinity modelling which illustrated that the Connector and Lakes Cycling were most effective at reducing salinity levels in Lake Albert (refer to **Section 6.4.3**, **Section 6.7.3** and **Section 7**). Whilst the salinity benefits were much higher with the Connector, the associated costs are also greater.

As such, the CBA focused on assessing whether the Connector, as the more significant investment, delivered net benefits to the state. The CBA report also noted that dredging the Narrung Narrows and the removal of the causeway presented significant engineering challenges for only marginal improvement in salinity.

The costs and benefits quantified in the CBA over a 25 year assessment period (discount rate of 7 %) are listed in **Table 16**.

Table 16: Option 3 Coorong Connector (channel) – Quantified costs and benefits in the CBA (discount rate of 7 %)

Cost/benefit	Description	Estimated Value (PV)
Costs		
Construction costs	Based on SKM's high level pre-feasibility cost estimate in the Engineering Feasibility Study (2014).	$18.97 million
Operating costs	Operating costs are based on preliminary high level cost estimates in the Engineering Feasibility study (SKM, 2014).	$1.60 million

Cost/benefit	Description	Estimated Value (PV)
	Construction of the channel would also require periodic dredging at both ends of the channel.	
Benefits		
Increased productivity for existing irrigators	This benefit captures the improvement in agricultural productivity as a result of reduced salinity. Lower salinity facilitates improved growth and reduces the amount of water required (needed to keep water table from rising when salinity is high). The CBA assumes a 25 % increase in productivity relative to the Base Case based on a salinity levels reducing to 1000 EC from an assumed Base Case level of 2000 EC. This benefit only applies to the irrigated land under the Base Case scenario (400 Ha).	$0.45 million
Increased productivity of agricultural output to changes in land use from dryland to irrigated dairy	Changes in salinity and improved landowner confidence about ongoing water quality may drive landowners to shift to higher value irrigation. The example used in the CBA is a shift from dryland dairy farming to irrigated dairy. The CBA uses two valuation approaches (land value and cash flow approach)[18] to provide a cross reference for possible values. As discussed below, several scenarios for area of land converted from dryland to irrigated dairy were tested.	$2.7 million to $4.7 million
Residual value of assets	A residual value for the assets with a longer useful life that the assessment period has been included. The residual value has been based on the estimated useful life of the asset (100 years), asset cost ($22.9 million), and the percentage of the asset value remaining at the end of the model period (75 %).	$2.3 million
Environmental impacts	During the drought, there was significant environmental and ecological degradation, as salinity levels reached 20,000 EC. However, ecosystems in the Lake Albert region are not largely impacted under the Base Case salinity level (approx. 2000 EC). As such, environmental benefits have not been included in the CBA. The CBA notes that the Coorong Connecter may results in some environmental benefits or costs that were not quantified in the analysis: • Ability to recover from high salinity events faster will mean that the environment will be exposed to shorter periods of high salinity during or following future droughts. • Potential environmental costs have also not been considered relating to discharge of lake water to the Coorong.	NA

Source: EY (2014)

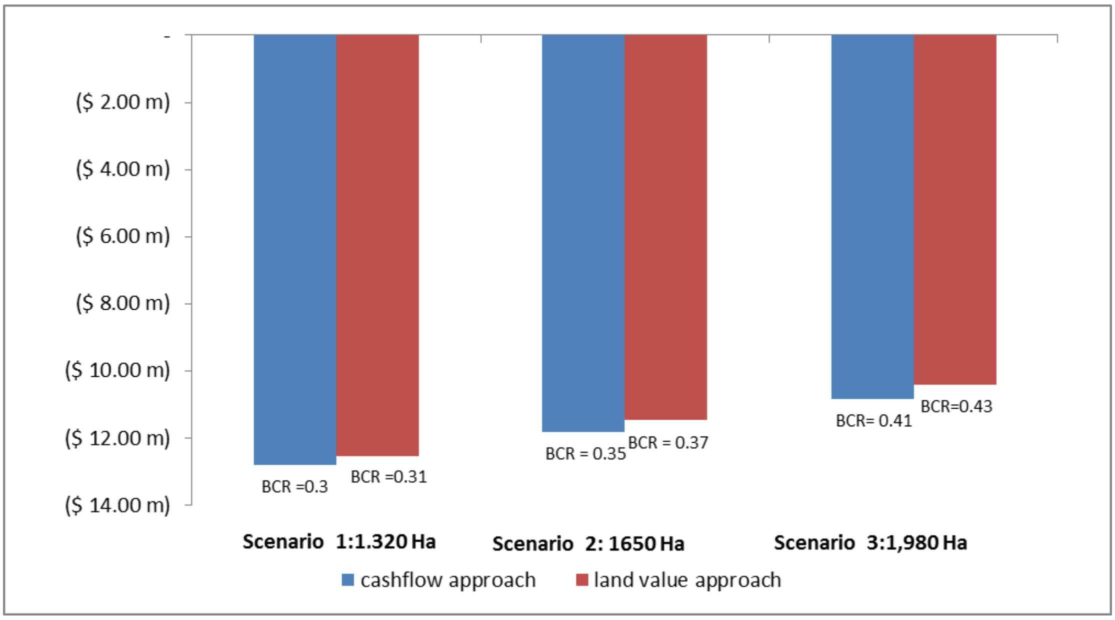
[18] EY used a land value approach [(land value of irrigated dairy minus land value of dryland dairy) x area change] as well as cash flow approach [(income from irrigated dairy minus income for dryland dairy) x by area of land change].

A key input to the analysis is the assumed area of land converted from dryland to irrigated agriculture (dairy). The analysis assumes that under the Base Case there would be no change to current levels of irrigation (400 Ha, see **Figure 7**). The alternative scenarios considered include irrigation area increasing to between 1320 Ha and 1980 Ha, with the mean of 1650 Ha also tested. This range is considered to be consistent with other studies recently undertaken into the potential irrigated land are in the Lake Albert region (EY, 2014).

The net costs and benefits of the Connector are presented in **Figure 25**. As seen from **Table 16**, a shift to higher value irrigation from dryland farming has the greatest impact on the CBA results. The assumed irrigated land area is therefore the variable that results in the largest potential range of benefits. The results also vary slightly depending on method used to value the change in land use[19] .

The results for the various scenarios and approach are presented below, with the estimated Benefit Cost Ratio being between 0.30 and 0.41.

Figure 25: Option 3 Construction of a Coorong Connector (channel) – CBA Results: Net Present Value (NPV, $m, discount rate of 7 % over 25 years) and Benefit Cost Ratio (BCR)



Source: EY (2014)

The CBA also involved a breakeven assessment. It estimated that the project would need to result in a total irrigated area of between 5,179 Ha and 5,607 Ha for the benefits to equal the costs. This means that in order for the Connector to deliver a net benefit to society the irrigated land would need to increase by at least 4779 Ha from the current 400 Ha. This increase is significantly higher than the historical peak of 2801 Ha.

To return to historical levels of irrigated land area, significant investment would be needed in milking equipment, sheds, vehicles, irrigation equipment and supporting infrastructure, which must be paid off over a longer time horizon (EY, 2014). Based on DEWNR consultations with landholders in the region through the Community Reference Group, this step change in investment is unlikely. Increases beyond this historical peak are considered to be even less likely.

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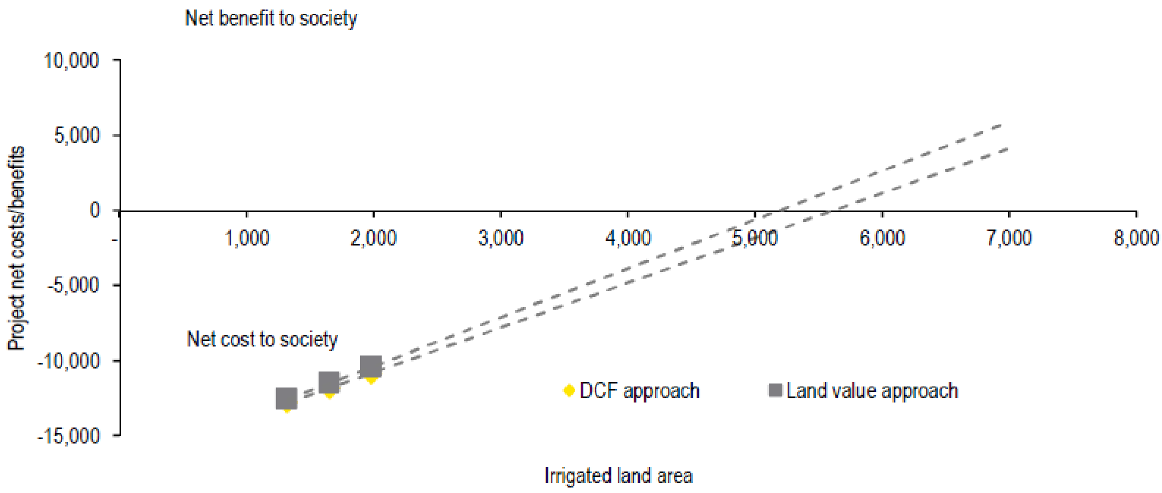
[19] Depending on whether a land value approach or cash flow approach was used.

The following diagram (**Figure 26**) summarises EY's breakeven analysis on changes in irrigated land area. It represents the results from the three scenarios tested as well as the linear relationship between NPV and the irrigated land area. Increases in the irrigated land area result in greater benefits to society (all else being equal). Where the trend line intersects the horizontal axis is the breakeven land area the project represents neither a cost nor a benefit to society.

Figure 26: Breakeven analysis on changes in irrigated land area



Source: EY, 2014

In addition to the CBA, the Threshold Approach was taken to calculate the dollar value required for qualitatively assessed benefits, namely social and environmental benefits for the project to break even. Using the figures from **Table 16**, for this project to break even, the Present Value of all the other benefits (environmental and social) would need to be at least $13.12 million (under the higher estimate of production benefits) or $15.12 million (under the lower estimate of production benefits).

6.4.6 Community Perspective

The Connector was the second most popular management action identified (with 63 % support and 16 % being unsupportive).

It was considered to have merit as it changed Lake Albert from a terminal lake to a flow through lake, thereby improving water quality with the possibility of increasing the quality to that similar to Lake Alexandrina.

Some community members (mainly irrigators) were of the opinion that the Connector was the only potential management action that would be viable and that the other options would be of limited benefit.

The main issue discussed was the environmental impact of the Connector on the Coorong. The community agrees an environmental impact study would need to be completed.

The NRA stated in their position Paper (November 2013), "there exists no support for any form of engineering, construction or breaking of the ground as such is inconsistent with the above principles and positions of the Ngarrindjeri and for this particular project no exceptional circumstances have been made out."

6.4.7 Legislative Considerations

Construction of a Connector channel would trigger a number of legislative approvals as outlined in **Table 17**. The approvals required would depend on the extent of dredging proposed.

Table 17: Option 3 Construction of a Coorong Connector (channel): Legislative consideration

Legislative approval	Comment
Environment Protection and Biodiversity Conservation Act 1999	Lake Albert and the Coorong North Lagoon are located in a listed wetland of international importance (the Coorong, and Lakes Alexandrina and Albert Ramsar site) which is protected as a matter of national environmental significance under the EPBC Act. The area is also known to support a wide range of threatened and migratory species protected as matters of national environmental significance under the Act. Given that this management action proposes construction of a permanent structure and extensive excavation to connect Lake Albert (a terminal lake) to the Coorong, it is possible the Minister would require the State to undertake further assessment (i.e. preparation of an Environmental Impact Statement). This would increase the timeframe for this approval significantly.
Native Title Act 1993	This management action may be considered (wholly or partly) inconsistent with continued existence, enjoyment or exercise of Native Title. As such, it is recommended that notification under Section 24KA of the Native Title Act be provided to the registered native title claimants (Ngarrindjeri Regional Authority) and SA Native Title Services. Advice from the SA CSO should be sought on this matter.
Water Act 2007 and the *Water Amendment Act 2008*	Notification to the MDBA may be required under the MDB Agreement. This management action may also require liaison and negotiation between DEWNR, SA Water and the MDBA regarding ownership of the structure, ongoing maintenance and operation of the structure.
Aboriginal Heritage Act 1988	In line with the CLLMM Recovery Project's Aboriginal Heritage Risk Management process, a cultural heritage survey of the site and search of the Aboriginal Heritage Register would be required to ensure that no Aboriginal sites, objects or remains are impacted by the removal works. A Section 23 authorisation is unlikely to be necessary as the management action involves removal of a foreign structure. The NRA may also wish to develop a Kungun Ngarrindjeri Yunnan Agreement to establish a working relationship with DEWNR for this management action.
Crown Land Management Act 2009	A 'licence to occupy' may be required if the lay-down area and site office is proposed to be located on Crown land. Permission may also be required to construct the structure itself on Crown land.
Environment Protection Act 1993	The contractor responsible for the removal / modification works would likely be required to undertake water quality monitoring as part of an environmental management plan during the construction works. For previous projects, water quality monitoring results have been communicated to the EPA. The EPA may also choose to undertake their own water quality monitoring to ensure that parameters are not exceeded.
Harbors and Navigation Act 1993	This management act would result in a permanent change to navigation in Lake Albert. As such, DEWNR is expected to be required to liaise with the Department of Planning, Transport and Infrastructure. A temporary boating exclusion would also be required during the construction process.

Legislative approval	Comment
Local Government Act 1999	DEWNR will likely be required to liaise with the local council to inform them of the proposed works.
Native Vegetation Act 1991	If native aquatic vegetation (e.g. *Phragmites* and *Typha*) are cleared during construction works then it is likely that approval under the Native Vegetation Act will be required. This would likely involve a native vegetation assessment and preparation of a native vegetation management plan to be approved by the Native Vegetation Council.
Natural Resources Management Act 2004	A Water Affecting Activity Permit would likely be required for this management action as it would involve undertaking a water affecting activity (excavating or removing rock, sand or soil from a lake).

6.4.8 Summary of Advantages and Disadvantages

Table 18 summarises the advantages and disadvantages of Option 3.

Table 18: Option 3 Construction of a Coorong Connector (channel) – Advantages and disadvantages

Advantages	Disadvantages
• Most effective management option at reducing salinity in Lake Albert relative to the Base Case across all scenarios tested • Strong community support (second most preferred management option), noting however that Ngarrindjeri do not support any engineering intervention. • Whilst significant excavation would be required; the majority is on land so PASS exposure would be reduced relative to some other management options. • Only minor road closures / disruptions during construction of regulating structure(s). Therefore minimal impact on primary industries and landholder activity in close proximity. • No impact on ferry and recreational use of the Narrows. • Increased ability and flexibility of discharge water from the current terminal lake hence drawing fresher water through the Narrung Narrows. • Construction works are significant but not complex.	• Unknown impacts on the Coorong ecology in terms of salinity, turbidity and water level • To be confirmed environmental water requirements and policy • Some excavation/dredging of sediment in Lake Albert and the Coorong would be required at the inlet and outlet; this presents a risk of exposing and mobilising PASS • Excavation and disposal are the most significant activities associated with the option and the cost is dependent upon ground conditions (ease of excavation), estimation of excavation volumes (extent of excavation spoil quality (disposal requirements) and location of a disposal site near the alignment. Other significant capital costs include the new regulating structure and bridge(s). • If trenching was undertaken significant dewatering would be required during construction • Land acquisition/easements would be required for the length of the channel as well as for a soil disposal sites • Ongoing operation and maintenance activities will be required including removal of sediment build, regulating structure operation etc. Automation of the regulator could be considered to reduce on-ground operation requirements. • Ngarrindjeri do not support any engineering intervention

6.5 Option 4: Construction of a Coorong Connector (pipe)

6.5.1 Description

This Option is similar to Option 3 in that it provides a passage between Lake Albert and the Coorong North Lagoon to improve salt export from Lake Albert. However, instead of a channel, Option 4 considers a pipe passage.

Much of the modelling undertaken to assess the impact of a Coorong Connector did not differentiate between a channel and a pipe. As with Option 3, three possible alignments were considered (refer to **Section 6.4.1** for more detail).

6.5.2 Design Considerations

Conceptual level models of the Connector pipe were developed for each of the alignments. The analysis results indicated that in order to pass up to 1 GL/day (up to 300 GL/year), three DN2400 pipes would be required at either Alignment 1 or 2, or four DN2400 pipes would be required at Alignment 3.

Given that a Connector will have the same impact on salinity at Lake Albert whether it is a channel or a pipe, the engineering feasibility study compared the two alternatives based on relative costs and complexity. A channel was selected in preference to a pipe on the following bases:

- Control of a piped system would be significantly more complex than that required for a control structure associated with a channel via the use of a single very large isolating valve or gates at both ends. Dredging would still be required for a pipe option along with inlet and outlet structures to stop sedimentation of the pipes. In regards to operation and maintenance, provisions for pigging of the pipe would be required for infrequent cleaning of growth build-up.
- Despite a pipe requiring less excavation, its footprint would be increased, to provide a safe horizontal offset for boring. Additional, substantial excavation and material disposal would be required for driving pits and removing the spoil from the placement/installation of the pipes. These additional complexities would offset the benefit associated with reduced excavation.
- A pipe was expected to have a higher cost of supply in comparison to a channel given that three to four pipes (sized DN2400) would be required and would need installation, testing and commissioning, valving/control infrastructure, manhole access, inlet or outlet structures and dredging, etc. The geotechnical and acid sulfate soil description is the same as that discussed in **Table 15**. The construction risks and challenges associated with pipe jacking are greater than for open cutting and as such would also require consideration for full depth trenching, shallow burial or above ground installation options to reduce geotechnical risks and also spoil removal and disposal.

6.5.3 Salinity Impact

The salinity impacts were not considered separately for a pipe and channel. For a given daily flow, the impacts on salinity are expected to be the same for both.

For the salinity impacts refer to **Section 6.4.3**.

6.5.4 Cost Estimate

Following analysis of the possible options for the Connector, a channel was selected in preference to a pipe. To achieve the volume transfer required (1 GL/day), a pipeline would require three or more large (2400 mm diameter) pipes and deliver similar benefits to that of a channel for a greater cost. Analysis of the pipeline option considered it to be more complex and expensive to construct, operate and maintain than a channel based system for a range of reasons including; piping footprint requirements, ongoing pigging, operations and maintenance. Preliminary costs were assessed for comparative purposes only for a pipeline option. As a concept design was not developed, pricing was based on available pipe diameters in Rawlinsons (2012) for pipes half the required diameter to transfer the 1 GL/day flow criteria. The initial estimate totalled over $11 million for supply only, excluding delivery. Later, a quote was sought from a supplier for 5500 m of pipe (to allow for 3 pipes so 1 GL/day could be transferred) and this quote was $42 m-$52 m depending on the material of the collar and the individual pipe length for supply and delivery only. Both this quote and the estimate generated from Rawlingsons exclude installation, testing, commissioning, valving/control infrastructure, manhole access, material disposal and management, inlet or outlet structures and dredging requirements at the inlet and outlet, operations and maintenance. The project cost for pipe installation would far exceed that of a channel installation.

6.5.5 Community Perspective

The community consultation indicated that a Connector could involve either a channel or pipeline. Views were not sought on the different design alternatives. As such, the community perspective is the same for Option 4 as Option 3 (refer to **Section 6.5**).

The NRA stated in their position Paper (November 2013), “there exists no support for any form of engineering, construction or breaking of the ground as such is inconsistent with the above principles and positions of the Ngarrindjeri and for this particular project no exceptional circumstances have been made out.”

6.5.6 Legislative Considerations

Legislative considerations for a Connector pipe and channel are the same. Refer to **Section 6.4.7** for details.

6.5.7 Summary of Advantages and Disadvantages

Table 19 summarises the advantages and disadvantages of Option 4. In most cases they are the same as for Option 3 (Connector channel). Therefore the following table highlights advantage and disadvantages specific to a pipe design.

Table 19: Option 4 Construction of a Coorong Connector (pipe) – Advantages and disadvantages

Advantages	Disadvantages
• Same advantages as for Option 3 (refer to **Section 6.4.8**) • Coorong Connector (pipe and channel) is most effective at reducing salinity in Lake Albert relative to the Base Case across all scenarios tested • Strong community support (Coorong Connector is the second most preferred management	• High costs for the supply and delivery of very large pipework and valving • Complexity of design and construction increasing the costs, with a multiple number of pipes required to achieve the necessary flow capacity • Cost and complexity highly dependent on ground conditions

Advantages	Disadvantages
option), noting however that Ngarrindjeri do not support any engineering intervention. • Whilst significant excavation would be required; the majority is on land so PASS exposure would be reduced relative to some other management options. • Only minor road closures/disruptions during construction of bridge(s). Therefore minimal impact on primary industries and landholder activity in close proximity. • No impact on ferry and recreational use of the Narrows. • Increase in the ability and flexibility of discharge water from the current terminal lake, hence drawing fresher water through the Narrung Narrows.	• Challenging construction, mobilisation and installation techniques/methods. Pipe jacking would require significant temporary works. Other pipe jacking risks include confined space work, ingress of water and deviation of alignments (due to voids/groundwater/rock). • If trenching was undertaken significant dewatering would be required during construction • Land acquisition/easements would be required for the length of the channel as well as for soil disposal sites • Increase in maintenance and operation costs for the new pipes including confined space access for operators Some excavation/dredging of sediment in Lake Albert and the Coorong would be required at the inlet and outlet; this presents a risk of exposing and mobilising PASS. • Ngarrindjeri do not support any engineering intervention

6.6 Option 5: Construction of a Permanent Regulating Structure in the Narrung Narrows

6.6.1 Description

This option involves construction of a permanent water regulating structure within the Narrung Narrows channel to enable the manipulation of water levels between the two lakes as a means of controlling inflow and outflow and managing water quality.

The regulator would enable operators to temporarily hold water in Lake Albert at higher target levels while Lake Alexandrina's water level is drawn down. Under suitable conditions, the water would be released from Lake Albert into Lake Alexandrina, driven by the differential head and favourable wind conditions. This would enable larger volumes of water and salt to be flushed from Lake Albert to Lake Alexandrina compared to that achievable under normal operating conditions. During normal conditions, the regulator would remain open to retain levels through inflows. This option would require a change in the lake operating regime.

Modelling undertaken for this option has indicated that wind is a key influencer in the export of salt from Lake Albert.

The regulator option serves a dual operational purpose. Ebsary (1983) considered the use of a regulator to selectively control the timing of water flow into Lake Albert based on River Murray inflow and water quality conditions. In particular, operations could restrict the inflow of poor quality water into Lake Albert during periods of increasing flow and rising flood waters. This would enable the export of this water through the barrages, prior to Lake Albert being re-connected to receive better quality water.

6.6.2 Design Considerations

A concept design for this management was not developed for the following reasons:

- The operating conditions needed to deliver water to the lake relate to the timing of delivery of water for the lakes and Coorong. These conditions cannot be met in practice under current operational constraints, and therefore this option cannot realise the intended benefits. Ebsary (1983) noted that a structure across the Narrung Narrows would seriously inhibit the wind induced mixing between the lakes, resulting in the overall management option being of little benefit.
- Ebsary (1983) indicated that inflow to Lake Albert could be achieved to an extent by utilising the existing river regulating structures and barrages. This option was therefore considered to not be cost effective.
- There is limited stakeholder support. As discussed in **Section 6.6.5** this was the community's least preferred management option.
- There are limited impacts on Lake Albert salinity, as identified in more recent modelling. Recent modelling further demonstrated that this management option does not deliver the necessary salinity benefits to Lake Albert (refer to **Section 6.6.3**).

6.6.3 Salinity Impact

Preliminary and detailed modelling suggests that construction of a permanent regulating structure in the Narrung Narrows would not be effective at reducing salinity levels at Lake Albert. More specifically:

- **Preliminary modelling study** indicated that the installation of a permanent water level structure in Narrung Narrows to isolate Lake Albert during periods of high salinity in Lake Alexandrina is the least likely option to assist in the reduction of the currently high levels of salinity in Lake Albert. It was recognised that such a structure could be effective at maintaining salinity levels sometime in the future once Lake Albert salinity levels had already been reduced. This could be achieved only by filling Lake Albert with lower salinity (typically winter) waters.
- **MSM Bigmod modelling** was not used to test the impact of the construction of a permanent regulating structure in the Narrung Narrows, due to the complexity of the scenario.
- **TUFLOW FV modelling found** that the Narrung Regulator option is the least efficient option for reducing salt concentration in Lake Albert under all conditions. Under most scenarios, this management resulted in higher salinity than the Base Case. As can be seen in **Figure 27** and
- **Figure** 28, this management resulted in higher salinity than the Base Case under all scenarios.

Figure 27: Option 5 Construction of a Permanent Regulating structure in the Narrung Narrows – TUFLOW FV modelling results for Lake Albert salinity (EC) at end of 3 year simulation (700/2000 EC Initial Conditions)

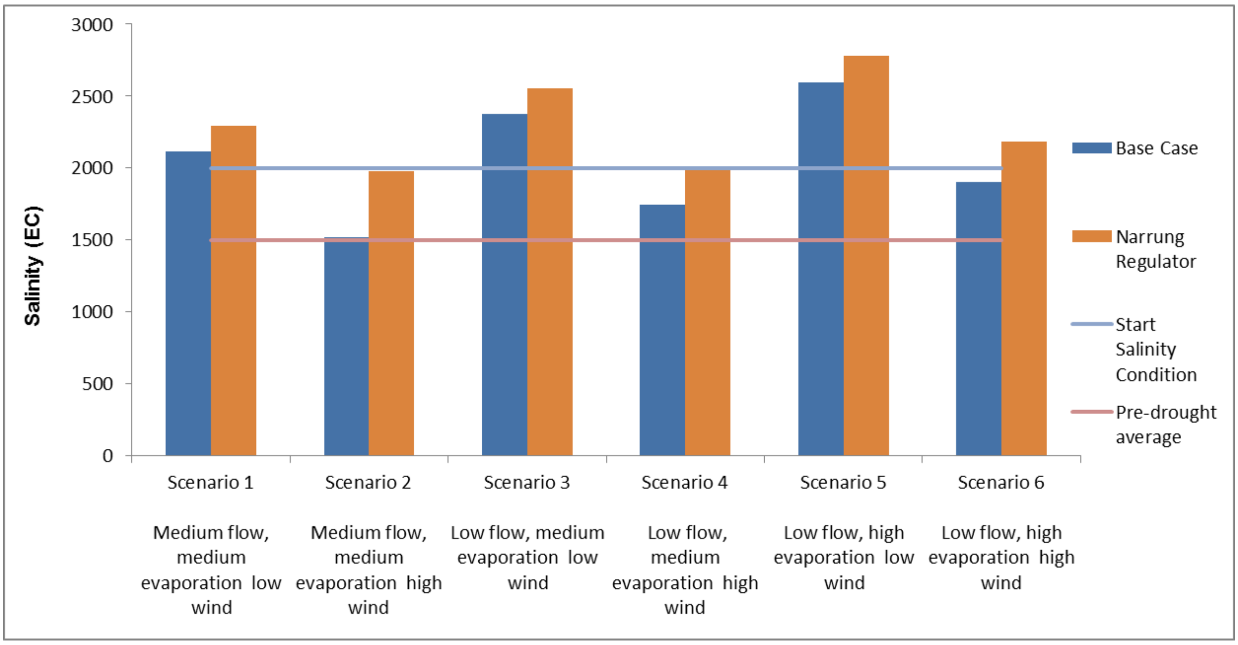
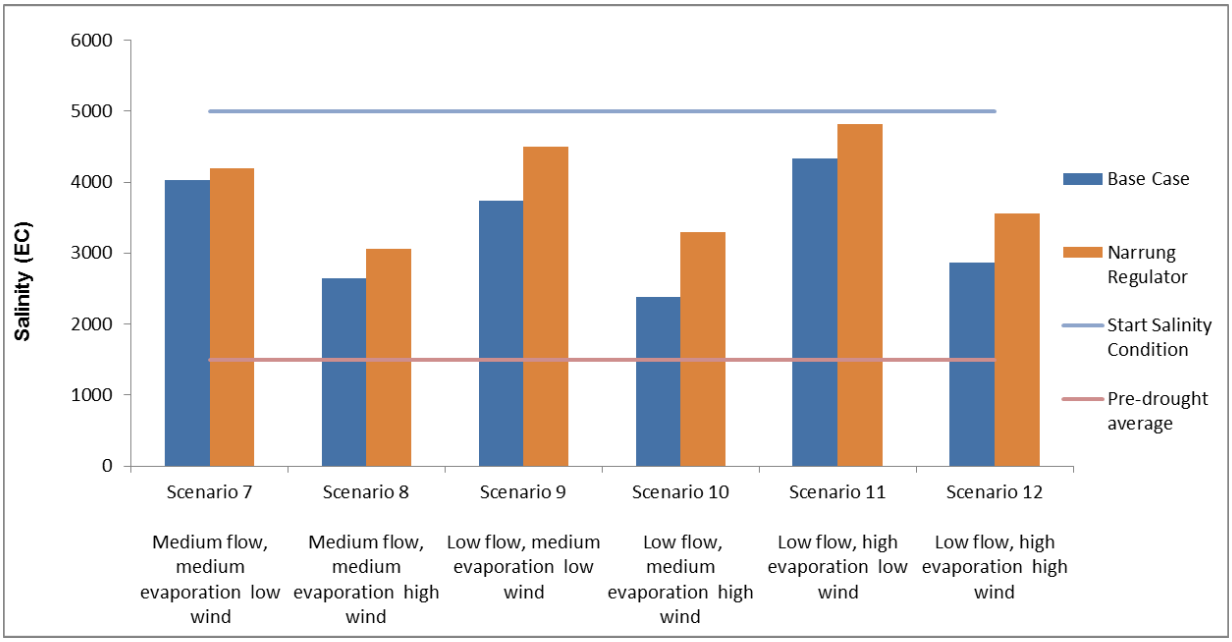


Figure 28: Option 5 Construction of a Permanent Regulating Structure in the Narrung Narrows – TUFLOW FV modelling results Lake Albert salinity (EC) at end of 3 year simulation (400/5000 EC Initial Conditions)



6.6.4 Cost Estimate

Given the limited benefit and stakeholder support for this option, a cost estimate was not developed.

6.6.5 Community Perspective

This option was the least favourable. It was supported by less than half of all respondents (45 %) while 37 % of respondents did not support this action.

Opposition was mainly due to concerns by some stakeholders that this option would be used to stop water from entering the lake. This would lead to high salinity with flow-on commercial, social and environmental consequences.

The NRA stated in their position paper (November 2013), “there exists no support for any form of engineering, construction or breaking of the ground as such is inconsistent with the above principles and positions of the Ngarrindjeri and for this particular project no exceptional circumstances have been made out.”

6.6.6 Legislative Considerations

Construction of a permanent regulating structure would trigger a number of legislative approvals. These are consistent with the triggers for the Coorong Connector (Option 5) as outlined in **Section 6.5.6**.

6.6.7 Summary of Advantages and Disadvantages

The following table summarises the advantages and disadvantages of the associated with Option 5.

Table 20: Option 5 Construction of a Permanent Regulating Structure in the Narrung Narrows – Advantages and disadvantages

Advantages	Disadvantages
• Potential to improve the management of lake levels and control flow into Lake Albert • Potential allowance for the replacement of the ferry with a trafficable structure.	• The Narrung Regulator option is the least efficient option for reducing salt concentration in Lake Albert under all conditions. • Significant disruption to the ferry operation during construction • Significant dredging works required with complex on water construction activities requiring on land or submerged disposal, increasing the risk for sediment plume creation and PASS exposure and mobilisation • Increased operation and maintenance requirements when compared to other management options due to the increased number of gates for operation and control • Significant ground disturbance which is based on variable/unknown ground conditions • A lock would be required to allow boat passage. This is an inconvenience for recreational and primary industry users of the Narrung Narrows as it would delay transfer speeds and disrupt traffic.

6.7 Option 6: Lakes Cycling (also referred to as lake level manipulation)

6.7.1 Description

This option refers to utilising existing barrage operating strategies between the Coorong and Lake Alexandrina to vary the level of the lakes. The general concept is that by filling Lake Albert with fresher water and then drawing down water in Lake Alexandrina, water (and salt) will be drawn out of Lake Albert and discharged through the barrages. This management action does not propose additional structures for operation.

In order to implement the active cycling of lake levels, a policy is necessary to document the lake levels within which the lake should be operated (and the associated information based on constraints). The community would be engaged in this process. This policy would work together with a formalised barrage operating strategy which describes how the barrages are operated to achieve these water levels and desired outcomes for the site, including improved water quality (salinity) in Lake Albert.

6.7.2 Design Considerations

Lakes Cycling was not considered as part of the Qualitative Engineering Feasibility study as this option uses existing infrastructure. There are therefore no design considerations for this option.

6.7.3 Salinity Impact

Preliminary and detailed modelling suggests that Lake Cycling would result in some improvement in salinity levels at in Lake Albert. More specifically:

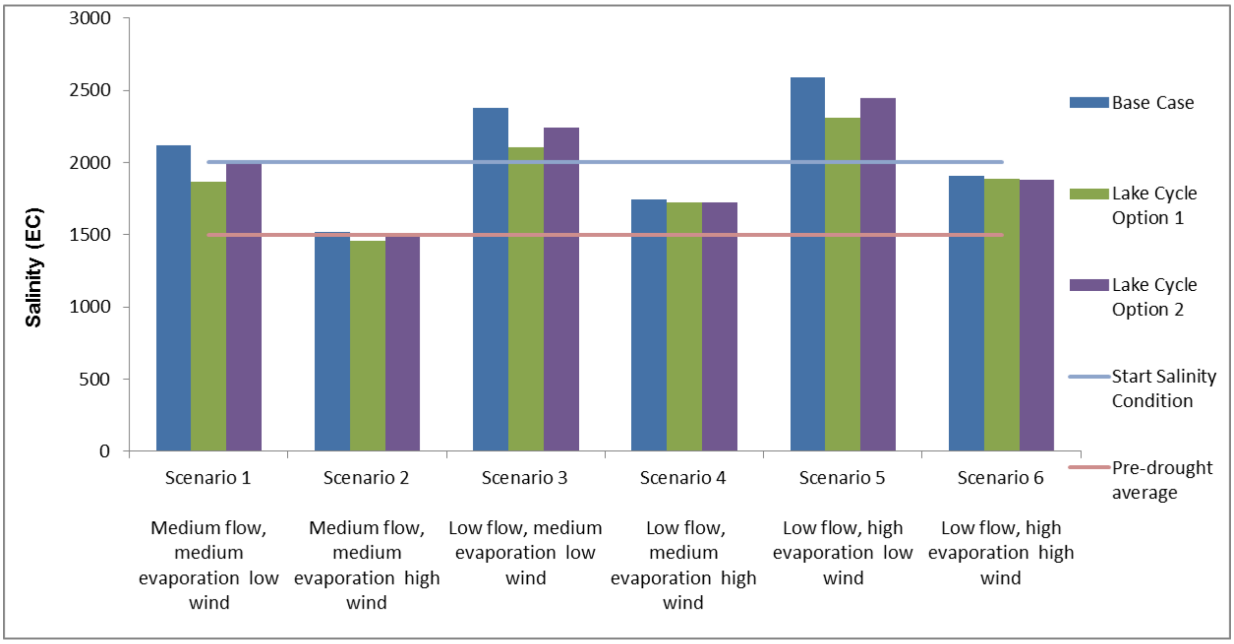
- **Preliminary modelling (BMT WBM, 2013)** indicated that the deliberate raising and lowering of lake levels can cause a significant increase in the flushing of salt from Lake Albert, estimated at 50 % increase in salt mass removal compared to the Base Case. This was the preferred option in the Ebsary (1983) study. The change is typically related to the magnitude of the water level variation, frequency of water level manipulations, wind induced export, relative timing of water level change and wind events, and evaporation. The model scenarios indicated that by deliberately raising and lowering lake levels, up to 35 % more salt could be exported from Lake Albert than if a static +0.7 m AHD lake level was adopted.
- **MSM Bigmod modelling** was used to assess the relative salinity benefit in Lake Albert from Lake Cycling. The management option tested involved manipulating water levels between +0.5 – +0.75 m AHD during a month period when sufficient water is available (in the latter 15 days of the month) to restore the water level of Lakes Alexandrina and Albert. The results indicated that Lake Cycling reduced mean daily salinity in Lake Albert by around 160 EC relative to the Base Case. However, it was also demonstrated that higher salinity periods are largely unaffected due to drought conditions and a lack of available water.

- **TUFLOW FV modelling** considered the impact of two alternative Lake Cycling options[20]:
    - Lake Cycling Option 1 - single large (+/-0.25 m) deliberate change in Lake Levels that occurs in November and December.
    - Lake Cycling Option 2 a single smaller (+/-0.15 m) deliberate change in Lake Levels that occurs in November and December.

As seen in **Figure 29** and **Figure 30**, the TUFLOW FV modelling result indicate that Lake Cycling is marginally more effective that the Base Case at reducing salinity levels in Lake Albert. The results also indicate that the contrast between Lake Cycling and the Base Case is greatest under low wind conditions, suggesting that this management option is more effective under those conditions. It is also more effective when higher lake level variations are introduced, with Lake Cycle Option 1 being more effective than Lake Cycling Option 2 under all scenarios tested.

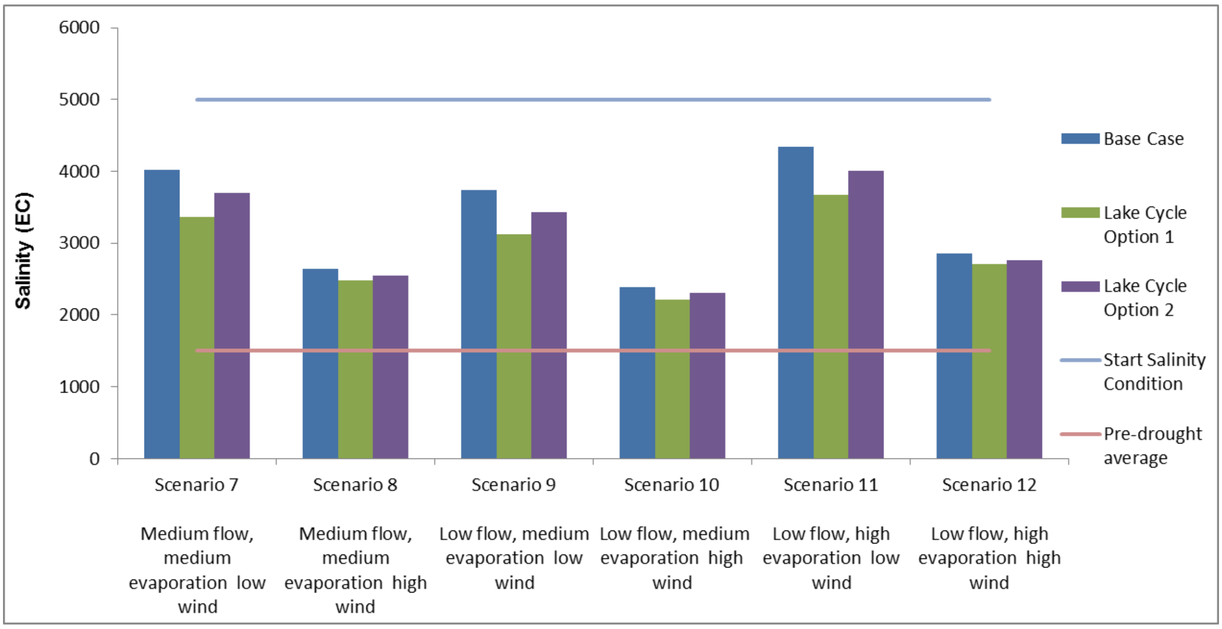
Modelling also suggested that under low flow conditions, Lake Cycling leads to slightly higher Coorong salinity levels than the Base Case or other options. This occurs as the lake is re-filled during summer when there is high evaporation.

Figure 29: Option 6 Lakes Cycling – TUFLOW FV modelling results for Lake Albert salinity (EC) at end of 3 year simulation (700/2000 EC Initial Conditions)



[20] It is noted that a natural lakes cycling pattern also exists under the Base Case as a result of variable inflow and evaporation. The options considered in the modelling are deliberate short term and larger variations in water levels which are incremental to the natural cycle pattern.

Figure 30: Option 6 Lakes Cycling – TUFLOW FV modelling results for Lake Albert salinity (EC) at end of 3 year simulation (400/5000 EC Initial Conditions)



6.7.4 Cost Estimate

A cost estimate for Lake Cycling has not been developed. However, it is noted that associated costs may be funded through SA Water's barrage operation program. It is therefore not expected that additional funding would be required for this option.

6.7.5 Cost Benefit Analysis

The CBA report only considered the benefits of this option qualitatively as attributing costs to the present Lakes Cycling operation is difficult to quantify; the majority of costs are borne by SA Water as part of barrage operations (Brenton Erdmann, SA Water pers. comm. 2014). The existing Lake Cycling approach could be expanded to be more proactive by constructing a remotely operated barrage system, which could be managed by an operator safely regardless of weather or light conditions, and quickly enough to respond to negative head events.

Key benefits identified included (EY, 2014):

- the ability to cycle the lakes according to the optimal environmental timing and conditions, rather than limited by the operational flexibility of staff availability, weather, light, or other factors
- the ability to prevent negative head events from occurring, and therefore allow for lake cycling more frequently and at shorter intervals
- reduced cost of labour
- the ability to implement a proactive Lake Cycling strategy, which would be based on the medium term environmental outlook.

The report highlights that there may be benefits to moving to a proactive, strategic lake cycling program regardless of whether there is any investment in remotely operated barrages. The CBA therefore suggested that the installation of remotely operated barrages should be pursued if the economic, environmental and social benefits are greater than the incremental costs.

6.7.6 Community Support

This option was supported by 61 % of survey respondents, with 16 % of respondents not supporting it. Those who do support it said that it would need to be in conjunction with the Coorong Connector if benefit was to be derived for Lake Albert.

The NRA stated in their position paper (November 2013), "Lake cycling is the only effective long term management option for Lake Albert, in line with the above positions, and benefits should be maximised through enhanced collaborations between various water management organisations across the basin, and processes including strategic use of environmental flows and appropriate water allocation principles."

6.7.7 Legislative Considerations

Lake Cycling only triggers one legislative approval as outlined in **Table 21**.

Table 21: Option 6 Lakes cycling – Legislative considerations

Legislative approval	Comment
Water Act 2007 and the Water Amendment Act 2008	This management action would likely require liaison and negotiation between DEWNR, SA Water and the MDBA if changes are proposed to be made to the operation and maintenance of the existing barrages.

6.7.8 Summary of Advantages and Disadvantages

Table 22 summarises the advantages and disadvantages of Option 6.

Table 22: Option 6 Lakes cycling – Advantages and disadvantages

Advantages	Disadvantages
• Low cost due to use of existing infrastructure • Potential for wetting and drying in wetlands that may stimulate ecological processes and nutrient cycling.	• More gradual decline in salinity levels relative to the Coorong Connector option • Natural conditions (flow, wind, water levels and Coorong tides) can impact the effectiveness of this management action • Effective implementation of option relies on water availability • Potential impacts to lake margins (localised erosion, disruption to bird breeding areas).

7 Shortlisting of Options

The six management options considered for managing salinity in Lake Albert were assessed for their viability using the criteria outlined in **Table 23**. These criteria reflect 'mandatory requirements', meaning that if an option scored a 'no' against any criterion, it was assessed as not viable and was not considered further in the Scoping Study.

Table 23: Assessment criteria used to test viability of management options

Criterion		Detail
1	Effectiveness	The management action delivers either: • Significant improvement in salinity outcomes relative to the Base Case **under most** conditions tested - relating to wind, evaporation, and flow; or • Marginal improvement across all conditions tested - relating to wind, evaporation, and flow
2	Project feasibility	Project feasibility refers to the delivery of the project being: • Technically feasible - where an engineering solution is available and the challenges are understood.
3	Community support	The community supports the management option. Given that the need for the project has been driven by community concerns about the social and economic consequences of high salinity at Lake Albert, it is imperative that the community supports and accepts any shortlisted management actions.
4	Acceptable delivery period	Given that the purpose of investment is to reduce Lake Albert's recovery period from the 2006-2010 drought, it is important that the management action can ***likely*** be implemented within 3 years. Delay in delivery will reduce the options effectiveness relative to the Base Case
5	Overall Compliance	The overall compliance does not take into account the cost benefit of any management action and only includes compliance from a technical and community viewpoint.

Table 24 summarises the compliance of the six management options against the criteria.

i. Only marginal improvement in some (nine) scenarios with outcomes being worse than the Base Case in four scenarios
ii. As above
iii. Not specifically addressed in consultation as a separate Coorong Connector option, but parts of the community have indicated interest in further investigating this option. Ngarrindjeri do not support any engineering intervention
iv. Expected to take longer to implement due to significant engineering challenges
v. Performs worse than the Base Case under all scenarios tested.

Based on the shortlisting process summarised in the above analysis, the following two options are considered to be viable for further assessment:

- **Option 3** Construction of a Coorong Connector (channel)
- **Option 6** Lake Cycling

These two options meet the four assessment criteria and were therefore assessed as part of a cost benefit analysis to provide additional information about their value for money.

Table 24: Management options' compliance against assessment criteria

	Criterion 1 Effectiveness	**Criterion 2** Project feasibility	**Criterion 3** Community support	**Criterion 4** Acceptable delivery period	**Overall compliance**
Option 1: Dredging of the Narrung Narrows	**NO**[i]	**YES**	**YES**	**MAYBE**	**NO**
Option 2: Removal, Partial Removal or Modification of the Narrung Causeway	**NO**[ii]	**YES**	**YES**	**MAYBE**	**NO**
Option 3: Construction of a Coorong Connector (channel)	**YES**	**YES**	**MIXED**[iii]	**MAYBE**	**MAYBE**
Option 4: Construction of a Coorong Connector (pipe)	**YES**	**YES**	**MIXED**[iii]	**NO**[iv]	**NO**
Option 5 Construction of a permanent regulating structure in the Narrung Narrows	**NO**[v]	**YES**	**NO**	**MAYBE**	**NO**
Option 6: Lake Cycling	**YES**	**YES**	**YES**	**YES**	**YES**

8 Conclusions

The Lake Albert Scoping Study reflects many of the objectives of the Coorong, Lower Lakes and Murray Mouth Long-Term Plan, with particular focus on the following:

- 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; predominantly freshwater
- There are adequate flows of suitable quality water to maintain Ngarrindjeri cultural life;
- Tourism and recreation businesses can utilise the lake
- Productive and profitable primary industries continue.

The Scoping Study, through the series of investigations and assessments detailed in this Options Paper, has achieved 1 – 5 of its intended study outcomes (outlined below) providing a basis from which to inform the future direction and management of Lake Albert.

1. Identifying water quality and flow requirements for managing salinity in Lake Albert and the Narrung Narrows
2. Identifying community requirements regarding Lake Albert and Narrung Narrows
3. Identifying potential management actions to achieve the environmental and social goals for Lake Albert and Narrung Narrows
4. Completing feasibility assessments on the potential management action(s)
5. Completing a cost benefit analysis on the feasible management action(s).

Hydrodynamic modelling was an integral component for the Scoping Study. Modelling provided a tool to evaluate the effectiveness of differing management actions against a range of climatic scenarios.

Results of MSM Bigmod and TUFLOW FV modelling indicated:

- Dredging Narrung Narrows and removal or modification of Narrung Causeway provide negligible benefit to Lake Albert salinity
- The Permanent Regulating Structure increased salinity in Lake Albert under the majority of climatic scenarios
- Lakes Cycling and the Coorong Connector provide a salinity benefit for Lake Albert.

As a result of the modelling investigation, dredging Narrung Narrows, removal or modification of Narrung Causeway and the Permanent Regulating Structure were discounted. Lakes Cycling and the Coorong Connector were progressed and the concept of ‘Temporary Reset Pumping’ arose as a variation of the Coorong Connector.

The Scoping Study identified three potential options to provide further improvement for Lake Albert salinity. These are:

3. Optimise the Lakes Cycling management action to maximise salt export from Lake Albert. Upgrading limited gates at Goolwa Barrage to allow for automatic closure could also be investigated.

4. Temporary Reset Pumping would involve a temporary system of pipes and pumps to reset Lake Albert's salinity in an emergency situation following drought. If this management action were to be implemented now, it is likely the timeframes for realising a salinity benefit would be no better than if Lakes Cycling was continued. Therefore, this management action is better thought of as a drought recovery measure. It is anticipated fewer legislative requirements would apply as this option is temporary. Such a proposal would need cross-jurisdictional support and would support the MDBA Drought Emergency Operating Framework.

5. The pre-feasibility cost estimate for the Coorong Connector is $19m +/-30% and Benefit Cost Ratio is marginal at 0.30 to 0.41. For the project to break even, an irrigated area of between 5179 Ha and 5607 Ha is required. The current irrigated area is 400 Ha, and the historic peak was in 2005 at 2801 Ha. A Threshold Approach was taken to calculate the dollar value required for qualitatively assessed benefits, namely social and environmental benefits, for the project to break even. Using the figures from **Table 16** the Present Value of all the other benefits (environmental and social) would need to be at least $13.12 million (under the higher estimate of production benefits) or $15.12 million (under the lower estimate of production benefits).

Considering the timeframes for implementation depend on climatic conditions and the efficiency of Lakes Cycling, historical salinity levels may be achieved before it is possible to build and operate a Coorong Connector.

Under the Basin Plan 2800 GL/year scenario, there would only be six periods in a 114 year span where Lake Albert experiences salinity over 2000 EC and these periods would be for a mean duration of 180 days. This is in contrast to 23 periods of 360 days (mean duration) under a baseline scenario with no Basin Plan (Heneker and Higham, 2012).

Should a severe drought occur in the future, a possible emergency action is implementing Temporary Reset Pumping to speed up the recovery of Lake Albert. This temporary option would cost less than a permanent Coorong Connector, both in terms of capital expenditure and operations and maintenance and would be quicker to implement due to its temporary nature.

The outcomes of the Scoping Study will be considered by the South Australian Government and relevant parties to determine the most appropriate next steps. Should a decision be made to progress with an outcome or option, a Business Case may be developed to support the preferred option.

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