Coorong Infrastructure Investigations

Technical Review

Department for Environment and Water

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Building exceptional outcomes together

Document History and Status

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1 Introduction

The Coorong is widely regarded as a unique and important wetland that provides important ecological, cultural, social and economic values at local, national and international scales. In 1985, the Coorong and Lakes Alexandrina and Albert wetland was designated as a 'Wetland of International Importance' under the Ramsar Convention. 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 Ramsar listing (DEW 2019a). As a contracting party to the Ramsar Convention, Australia has made a commitment to maintain the ecological character of this site and implement planning processes that promote its conservation.

An overview map of the region showing key sites of significance is shown in Figure 1.

The Coorong is the only estuary within the Murray-Darling Basin, forming the end-of-system connection for the River Murray to the Southern Ocean. The main sources of flows to the Coorong come from the River Murray (via the barrages), from the South East drainage network and tidal exchange through the Murray Mouth. These flows sources are all key in controlling water quality and water levels in the Coorong's North and South Lagoons, which ultimately influence the ecological character of the site.

Over-allocation of Murray–Darling Basin flows and the Millennium Drought further reduced freshwater flows at the northern extent of the Coorong, which has impacted water quality and led to an ongoing ecological decline throughout the Coorong and Lower Lakes. Furthermore, freshwater that historically flowed into the Coorong South Lagoon via wetlands and watercourses of the South East, has been substantially reduced through the construction of an extensive drainage network over the past 150 years. By the end of the Millennium Drought, the CLMMM region was on the brink of ecological collapse (DEW 2019b).

Whilst the majority of the site is slowly recovering, the ecology of the Coorong South Lagoon in particular has remained in a degraded state. The effects of reduced freshwater flows are most evident in this area, with high salinity, reducing water levels and increasing eutrophic conditions creating water quality conditions that have impacted a number of key aquatic species. For as long as the South Lagoon remains under stress, it is not considered sufficiently resilient to absorb the impacts of a changing climate. In particular, the risk of sea level rise, combined with reduced inflows from the River Murray will constrain the effectiveness of existing operational levers used to manage flows through the systems.

In recognition of the need for intervention to halt further ecological decline and promote system recovery and resilience, the South Australian Government's Healthy Coorong, Healthy Basin (HCHB) Program (jointly funded by the Australian and South Australian Governments), part of the broader 'Project Coorong', has been implemented. This initiative includes a suite of on-ground works, management tools, research, trials and investigations, and other activities which will be undertaken with the aim of getting the Coorong, and specifically the South Lagoon, back on track for a healthy future.

Phase One of HCHB includes the Coorong Infrastructure Investigations Project (CIIP), which aims to investigate the feasibility of multiple long-term operational infrastructure options to improve system flexibility to respond to present and future water availability, water quality and ecological requirements.

In recognition of the limitations in effective management of water within the system and the long-term threat posed by climate change, a range of major infrastructure and management options have been identified over the past two decades, aimed at improving the delivery of water to the Coorong and the ability to manage it for ecological benefit. The objectives of each option investigated has often varied but have generally aimed to address two key biotic indicators of salinity and water level. In more recent times nutrient loads have emerged as a key ecological indicator of concern with further work needed to understand nutrient dynamics within the Coorong and its impacts. Assessments of the feasibility and benefits/impacts of previously considered infrastructure and management options will also need to consider how they may help to mitigate the current eutrophic condition, with specific emphasis placed on the South Coorong.

Key infrastructure options or construction activities investigated over time have included:

- Options to maintain an open Murray Mouth, including mitigating the need for dredging and providing greater seawater exchange with the Coorong (e.g. training walls)
- A connecting pipe or channel between Lake Albert and the Coorong to improve environmental water delivery to the Coorong (e.g. Lake Albert-Coorong Interconnector)
- Creating improvements to the connectivity between the North and South Lagoons and the Lower Lakes through dredging at key locations.
- Augmenting the South East Flows Restoration Project with additional water from the South East through extension of the Northern Floodway to the south of Blackford Drain
- Options to regulate and maintain water levels in the Coorong South Lagoon (e.g. Parnka Point Regulator)
- Options to pump seawater from the Coorong South Lagoon to the Southern Ocean to provide a 're-set' to the system.
- A connecting pipe or channel between the Coorong South Lagoon and the Southern Ocean to enable seawater exchange.

In addition, improvements to existing operations have been investigated to a lesser extent, including options to improve water delivery to the Coorong South Lagoon through operational improvements to the barrages.

Options have in some cases been considered as standalone options, whilst in other cases they have been considered in conjunction with other options, for example seawater pumping in conjunction with dredging at Parnka Point.

This report provides a high-level summary of each of the major infrastructure works completed to date, and for each option includes details of:

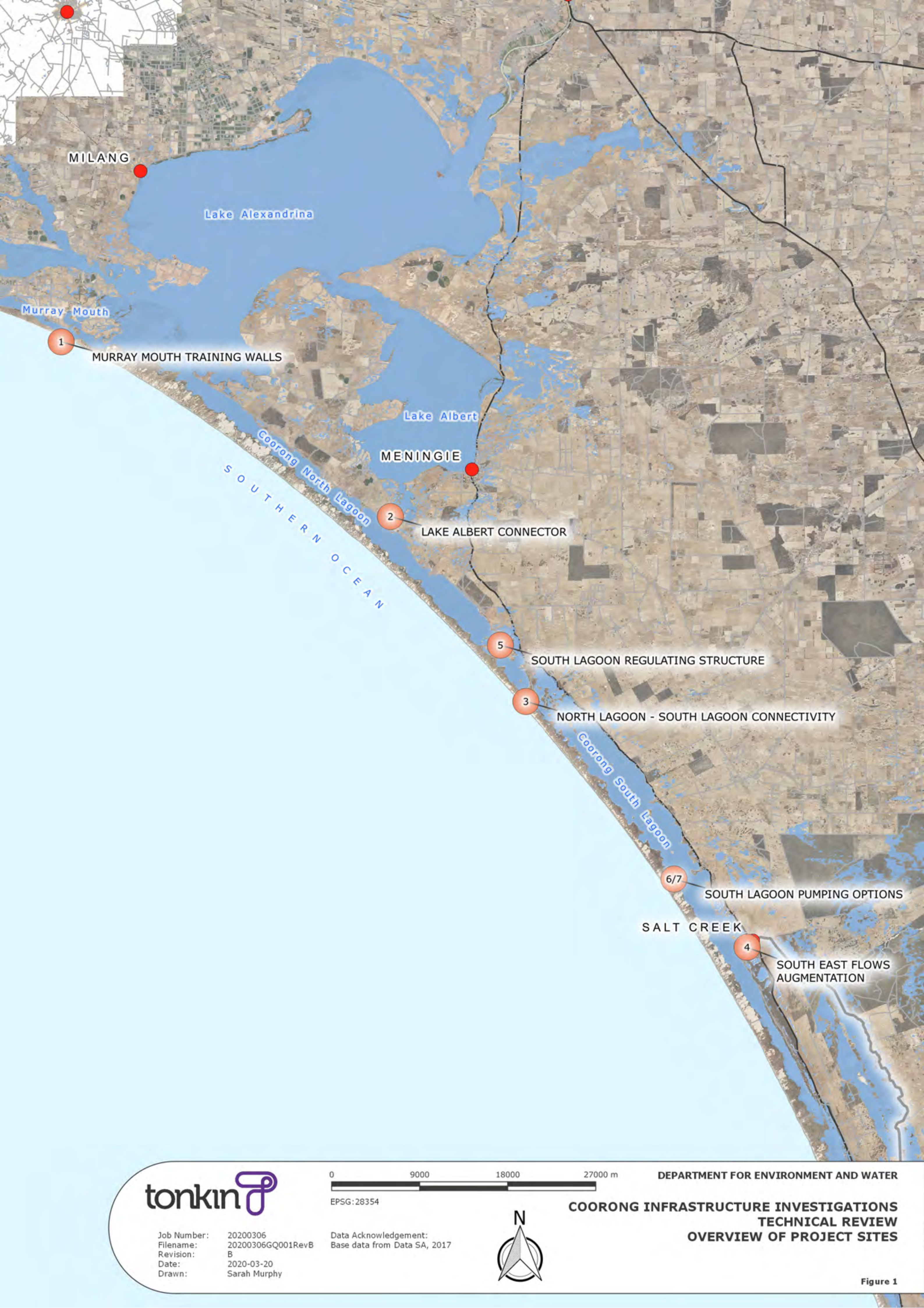
- The option(s) investigated
- The purpose of the option(s), including the intended outcomes and whether they were specifically targeted at the Coorong South Lagoon
- Previous investigations undertaken
- The outcomes of any previous consultation undertaken
- Potential environmental, social, cultural and economic benefits identified through previous work
- Construction and operational costs, if known
- Key knowledge gaps and further information required in considering the option(s) further.

Cost estimates

Costs reported within this document vary in age, with some costings having been developed as early as 2009. Cost estimates have not been updated to present day figures, however in each case, an indication of potential cost increase since the estimates were prepared has been given based on the Reserve Bank of Australia Inflation Calculator[1]. This calculator provides an indicative cost increase based on an average inflation rate. Both of these figures are reported within. It should be noted that the potential cost increases do not take into account changes in technology or construction methodologies that may have occurred over time or materials and construction costs that may have varied in response to

[1] https://www.rba.gov.au/calculator/annualDecimal.html accessed 19 March 2020

economic factors other than standard inflation. All costs should be considered as a guide only and have not been verified by Tonkin as part of this work.



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DEPARTMENT FOR ENVIRONMENT AND WATER

COORONG INFRASTRUCTURE INVESTIGATIONS
TECHNICAL REVIEW
OVERVIEW OF PROJECT SITES

Figure 1

2 Option 1 – Maintaining an Open Murray Mouth

Options to maintain or improve the openness of the Murray Mouth are intended to maintain or enhance tidal flow exchange between the Southern Ocean and the North Lagoon of the Coorong. If the Murray Mouth closes the Coorong will drop in water level and increase in salinity (BMT WBM 2009).

Since 2002, dredging operations have been undertaken at the Murray Mouth almost continuously; with a break between 2010 and 2014, and a short period in late 2016 following high flows within the River Murray (Department for Environment and Water n.d.-b). In the period since 2002 and 2010, dredging has supported the management of salinity in the Northern Lagoon to approximately 40 g/L. Salinities further south and in the South Lagoon have steadily increased over time as tidal influence is less pronounced moving away from the mouth (Department for Environment and Water n.d.-b).

2.1 Option Description

Previously investigated options for maintaining an open Murray Mouth can be classified as:

- those that remove sand from the estuary
- those that prevent sand from entering the estuary.

Whilst numerous options have been explored over the years, the following four options have been investigated in detail:

- continuation of the existing dredging strategy: involving maintenance of current dredging practices, which includes dredging a channel profile to meet diurnal tidal ratios with a flexible dredging schedule.
- dredging with increased channel dimensions: involving the use of more than one dredge to create a larger dredged channel to improve tidal penetration along the Coorong, increasing tidal flushing and exchange of water between the north and south lagoons. The option was based upon a 120 m wide channel with a reduced level of -3.5 mAHD. The additional dredging required was estimated at 4000 m^3/day versus the existing rate of 2000 m^3/day.
- fluidisation of sand at the Murray Mouth: involving injections of air or water underneath the sand to cause it to act as a fluid. This uplifts the sand and makes it easier to flow out to sea. Fluidisation would operate during ebb tides (i.e. outflow tides), such that the uplifted sand would flow out to sea. Sand fluidisation was considered as an adjunct to dredging rather than as a standalone option as it was not considered effective over the long term. Options for both fixed and mobile (barge mounted) infrastructure were considered.
- construction of training walls at the Murray Mouth out into the Southern Ocean: involving construction of groynes and revetment each side of the mouth to intercept the coastal longshore transport of sand and prevent it from blocking the mouth. Dredging of the required channel profile would be needed initially, with the training walls designed to reduce the reliance on continued dredging. There may also be a need for a sand bypass system to prevent accumulation of sand against the training walls. A conceptual representation of the training wall option is shown in Figure 2.

The top three are options to remove accumulated sand, whilst the final option is considered the only practical means of reducing sand accumulation within the estuary given the prevailing wave and tidal regime.

DEPARTMENT FOR ENVIRONMENT AND WATER

COORONG INFRASTRUCTURE INVESTIGATIONS
MURRAY MOUTH TRAINING WALLS
2008 CONCEPT

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Figure 2

2.1.1 Previous Assessments

An investigation commissioned by the Department of Water, Land and Biodiversity Conversation (DWLBC) in 2004 (WBM / L&T 2004) assessed 12 options for improving Murray Mouth openness, including a combination of infrastructure works and varied management options, including alternative management options for the lower lakes. These options were reviewed in 2009, with four options considered worthy of further investigation. The options were considered as standalone options for improving exchange with the Coorong as well as in conjunction with other actions such as seawater pumping to the South Lagoon and increasing drainage flows from the South East region (now known as the South East Flows Restoration Project).

Some modelling was undertaken as part of the 2009 study to provide a quantitative measure of the likely impact on the hydrodynamic and salinity regime of the Coorong and the sand flow through the mouth in response to each of the proposed schemes. No modelling of the complex coastal processes associated with the training wall option was undertaken. Instead the assessment was based on the available understanding of the sand transport processes and rates, as well as consideration in qualitative and semi-quantitative terms of the likely effects the scheme works would have in preventing or reducing the sand transport through the mouth and other likely impacts.

In 2010, a technical feasibility assessment of each of the options considered was also completed (Department for Environment and Heritage 2010a). The feasibility assessment found that continuation of the current Murray Mouth program was the preferred option for several reasons. In particular:

- The key objectives of the dredging program were being met (open Murray Mouth and meeting diurnal tidal ratios)
- Existing dredging was the lowest cost solution to maintain effective Mouth openness
- The existing dredging program had shown a significant reduction in operational cost over the previous three years and was continuously improving.
- The dredging schedule was inherently flexible due to contract operating regimes.

The ecological benefits and disbenefits of dredging the Murray Mouth were also reviewed in 2009 following more than five years of continuous dredging (Lester et al. 2009). A hydrodynamic model and an ecosystem state model for the Coorong were used in sequence to assess the likely consequences of possible future scenarios for the Coorong. The hydrodynamic model used forcing data for climate, tides, winds and flows over the barrages to provide predictions of water levels and salinity along the length of the Coorong for a 20-year model run. The ecosystem state model used the hydrodynamic simulations together with flows over the barrages as inputs to a scheme for predicting the resultant mix of ecosystems states along the length of the Coorong.

The modelling indicated that under the historic or median future, the at-the-time 'current' drought sequence (i.e. the millennium drought) was the only sequence of long enough duration where intervention such as dredging was recommended. However, it was noted that under what was considered the 'extreme climate change scenario' at the time, dredging was likely to be required on an ongoing and frequent basis. The effect of the current dredging operation when assessed for an extended drought (i.e. with no flows from the River Murray barrages) was clear – "*In the absence of barrage flows, dredging of the Murray Mouth provides a source of water to replace evaporative losses, and is likely to be preventing the ecological collapse of the region.*" (Lester et al. 2009).

2.1.2 Outcomes of Previous Community Consultations

No known previous community consultations for options other than continuation of the existing dredging schedule have been undertaken.

2.2 Potential Benefits

2.2.1 Environmental

The technical feasibility report (Department for Environment and Heritage 2010a) and the investigation into effects on ecology (Lester et al. 2009) noted ecological benefits of a more open Murray Mouth.

Mouth constriction and closure would prevent tidal flows to and from the Coorong; keeping the mouth open ensures that tidal flows continue and the exchange between the estuarine waters of the North Lagoon and Southern Ocean continue. If the Murray Mouth closes, salinities would rapidly rise due to a combination of lack of diluting tidal inflows and evaporation (BMT WBM 2009). The generally negative ecological impacts of rising salinity and reduced water levels have been examined and documented in numerous publications.

Hydrodynamic modelling indicated that for each of the alternative options to the current dredging schedule, at most minor changes in the conditions of the wider Coorong, including the South Lagoon, are expected (BMT WBM 2009). Training walls are expected to have the greatest effect; with a somewhat increased tidal range due to a larger entrance channel being established and maintained. However, the difference compared with the existing dredging schedule is still likely to be small.

Whilst the hydrodynamic modelling showed little difference to water levels, depths and annual salinity range, this was not the case for ecosystem states within the Coorong (Lester et al. 2009). Modelling for varied dredging scenarios indicated that more sites within the South Lagoon were predicted to be in a healthy ecosystem state with higher levels of dredging.

For all options considered in detail, opening the Murray Mouth has the greatest effect near the Murray Mouth, with increased variability in salinities caused by tidal movements. Moving south, the effects of the tidal variations are reduced until they have little effect, particularly within the South Lagoon.

2.2.2 Social and Cultural

The technical feasibility report (Department for Environment and Heritage 2010a) noted that the Ngarrindjeri place a high value on the mixing of waters between the Murray Mouth and the sea; such as the embedding of the closure of the mouth in their stories. Closure of the mouth would cause significant cultural trauma to the Ngarrindjeri people (Department for Environment and Heritage 2010a). Dredging is currently undertaken in consultation with the Ngarrindjeri to ensure these operations can help maintain the mixing of the waters, whilst minimising impacts to cultural values.

There is also a recreational value associated with quality of the Coorong, and closure of the Mouth would undermine this value; particularly commercial and recreational fishing, boating and bird watching.

2.2.3 Economic

Several economically important fish species depend on the openness of the Murray mouth. Ensuring that it stays open assists the economic viability of commercial and recreational fishing in the area (Department for Environment and Heritage 2010a).

With direct linkages to improved ecological health within the Coorong it is also intuitive that maintenance of an open Murray Mouth will have economic benefits related to tourism within the Coorong National Park and other nearby areas.

2.3 Potential Impacts

2.3.1 Environmental

Environmental impacts of maintaining an open Murray Mouth are dependent upon the option implemented. Potential environmental impacts caused by dredging in estuarine environments were noted by Lester et al., 2009. These included both physical impacts (i.e. impacts on physical processes and water quality) and biotic impacts. Potential physical impacts included:

- Changed bathymetry, altered current velocities and wave conditions
- Increased turbidity
- Altered sedimentation regime and characteristics
- Oxidation of sediments
- Increased release of heavy metals
- Increased eutrophication

Potential biotic impacts included:

- Removal of biota
- Shifts in the dominance and patterns of recolonisation and community structure
- Reduced abundance and species diversity
- Creation of new habitats in the dredged area
- Removal of seagrass in some areas
- Smothering of seagrasses.

Increasing the channel dimensions within the estuary to increase tidal penetration within the Coorong is expected to increase net sand inflow to the estuary, and hence requires additional dredging.

Greenhouse gas emissions were noted as an environmental impact (Department for Environment and Heritage 2010a). Typical average annual fuel use was about 1.37 million litres of diesel and 45,000 litres of petrol; equivalent to 4000 tonnes of CO_2. No other environmental impacts were experienced throughout the existing dredging schedule (Department for Environment and Heritage 2010a).

Construction of training walls at the Murray Mouth will likely interrupt longshore sand transport (BMT WBM 2009). Whilst a large amount of north-south sand transport takes place, the net rate of sand flow from one side to the other is low. Failing to bypass longshore sand transport in both directions may lead to a persistent build-up of sand on one side, with erosion on the other side. Transport reversal may subsequently negate longshore transport, but there may be considerable variations of the shoreline on each side of the mouth over time. The long-term effects of training walls on longshore sand transport is yet to be investigated in detail, including the need for a sand bypass system. This represents a knowledge gap.

Environmental impacts, other than more global impacts associated with greenhouse gas emissions for example, will be primarily limited to the area of works, with environmental impacts specific to the South Lagoon unlikely.

2.3.2 Social and Cultural

No known adverse comments or experiences in the local community have been noted with continued dredging of the mouth other than occasional noise complaints. .

Whilst there has been no known consultation community on alternative options for maintaining an open Murray Mouth, the construction of training walls is likely to have the greatest social and cultural impacts. These are yet to be quantified, representing a knowledge gap.

2.3.3 Economic

No potential economic impacts were noted, other than the cost of ongoing maintenance and monitoring to the Murray-Darling Basin Joint Venture budget. This represents a potential knowledge gap.

2.4 Estimated Cost

The cost of infrastructure and operations for the options for maintaining an open Murray Mouth were prepared in 2009 (BMT WMB 2009). In each case an estimated 'capital' or construction cost was provided, along with annual operations and maintenance costs. Costs were then provided as a Net Present Value (NPV) over a 30-year lifecycle with an assumed 5% compound net interest rate.

All costs provided below are quoted in 2009 Australian dollars. The Reserve Bank of Australia Inflation Calculator indicates a change in cost between 2009 and 2019 of 23% at an average inflation rate of 2.1%.

- Continued dredging under 'existing' strategy (In 2009):
  - At the time, operational costs were in the order of $5m per year for dredging and an additional $1m per year for associated costs (management and monitoring).
  - There are no 'capital costs' associated with this option, which is inherently operational
  - Over the 30-year period, the NPV was estimated at between $21.7m and $43.3m for dredging and $4.4m to $8.8m for management and monitoring, depending on the dredging scenario / frequency.
- Additional dredging to improve tidal penetration within the Coorong (assumed twice the dredging quantity):
  - Annual costs were based on twice the dredging volume, but with a 15% operational efficiency
  - Over the 30-year period, the NPV was estimated at between $36.9m and $73.6m for dredging and $5m to $9m for management and monitoring, depending on the dredging scenario / frequency.
- Sand fluidisation at the mouth:
  - Operational costs for sand fluidisation were noted as uncertain (BMT WBM 2009), however were estimated at $0.5m per year for operation plus $0.25m per year for maintenance.
  - The initial set up cost was estimated between $2m for the barge mounted case and $5m for the fixed case
  - Over the 30-year period, the NPV was in the order of $8m to $12m (including the set-up cost in year 1). This cost would be over and above the cost of dredging.
- River Murray Training Walls:
  - Operational and maintenance costs were estimated at $0.3m per year for maintenance of the training walls and revetment, $0.7m per year for a sand bypassing system and $5m for initial dredging (assumed on-off)
  - The construction cost of River Murray training wall option was estimated at $38.6m for the training walls and revetment and $10m for a sand bypassing system (if required)
  - Over a 30-year period, the estimated NPV was $40m for training walls and revetments, $4.5m for dredging and $17m allowance for sand bypassing, indicating a total NPV of $61.5m.

2.5 Current Knowledge Gaps

The following knowledge gaps and necessary further work has been identified. This list should not be considered exhaustive, but represents some of the key issues:

- Options other than continuation of the current dredging scenario, if considered further, would require more detailed planning, design and impact assessment with regard to their longer-term sustainability and impacts with respect to potential climate change and sea level rise scenarios. With specific reference to the Coorong South Lagoon, this includes the tidal and morphological responses and the salinity regime likely to be achieved along the Coorong and within the North and South Lagoons.
- Further investigations would need to consider how maintaining/improving Murray Mouth openness impacts nutrient concentrations and export potential for the Coorong.
- Further investigations would be required to understand the engineering feasibility of options such as the Murray Mouth training walls, particularly in the context of constructability given the challenges with access and availability of suitable materials for construction.
- Detailed ecological studies would be required to understand all ecological impacts (short and long-term) associate with the options, both within the construction footprint, as well as broader ecological implications.

- Further engineering and ecological investigations would need to be followed by a benefit-cost assessment of alternatives to determine whether the current dredging scenario is still the best option for long-term management. Testing of different options for management of the Murray Mouth should also be considered in conjunction with other management options, including those considered within this report.
- With specific reference to the training wall option, further modelling and consideration of the long-term impacts on longshore sand movement is needed to determine sand bypassing needs.
- Extensive community and indigenous consultation is required to understand the level of support or otherwise.

3 Option 2 – Lake Albert – Coorong Connector

The concept of a connecting pipe or channel between Lake Albert and the Coorong has been investigated a number of times since the 1980's to varying degrees of detail and with a range of different objectives in mind.

The initial concept of a Lake Albert – Coorong Connector was documented in 1983 as part of an investigation into the possibility of constructing a channel from Lake Albert to the Coorong to enable Lake Albert salinity to be reduced by flushing flows from the less-saline Lake Alexandrina (Ebsary 1983).

During the height of the millennium drought a similar concept for a connector was investigated to supply water to Lake Albert from the Coorong to mitigate the exposure of acid sulphate soils caused by critically low water levels within the lake (Department for Environment and Heritage, 2010d). This option was considered temporary.

The salinity within Lake Albert peaked in early 2010 at over 10 times the long-term average of 1500 EC to just over 20,000 EC units. Whilst the millennium drought ended in late 2010, slow recovery of salinity within the lake led to the concept of an interconnecting pipe or channel between Lake Albert and the Coorong being revisited in 2013, again as a means of flushing water through the otherwise terminal lake. The connector, investigated in detail during the Lake Albert Scoping Study, part of the Coorong, Lower Lakes and Murray Mouth (CLLMM) Recovery Program, was specifically aimed at long-term management of Lake Albert water quality (including salinity reduction to long-term averages) under different climate scenarios. Whilst not intended as a direct benefit to the Coorong at the time, the concept of a connector between Lake Albert and the Coorong may be applied to water quality improvement and water level management within the Coorong through the provision of additional and a more direct flow path to the Coorong, compared to tidal or barrage flows.

3.1 Options Description

Options investigated over the past 15 years have included both channels and pipes to connect the Coorong to Lake Albert. In general the options have included the ability to supply up to 1 GL/day either to Lake Albert from the Coorong (Tonkin Consulting 2008) or from Lake Albert to the Coorong (Department of Environment, Water and Natural Resources 2014). The former was intended as a temporary, emergency measure to prevent acidification of Lake Albert, whilst the latter was considered as a long-term option to improve flushing of the lake and export of salt.

Initial feasibility assessments for a connection between Lake Albert and the Coorong completed in 2006 focussed on a channel connector. In 2009, further work was completed based upon a pumped option, which included a pump station, multiple large diameter pipes and inlet and discharge structures. (Tonkin Consulting 2008). Three pumps run in parallel using diesel generator sets and electric motors were proposed to drive the water between the Coorong and Lake Albert (Tonkin Consulting 2008). Seven individual 1 MW shipping container sized generators were to provide power to the pumps, within a confined area surrounded by a noise mound and fencing. The pump option was considered as a short-term option, expected to operate for a two-year period. Whilst this option was based upon flow from the Coorong to Lake Albert, the infrastructure requirements and associated impacts are considered similar to what would be required to achieve flow in the opposite direction.

More recent work completed as part of the Lake Albert Scoping Study focussed on a long-term option for exchange of water between Lake Albert and the Coorong, intended to increase flushing of Lake Albert through lake water level cycling rather than providing any benefit of increased flows to the Coorong. The study determined that a channel connector with barrage control was preferred over a pipeline due to construction cost, maintenance and overall footprint. The preferred alignment ran from Bascombe Bay in Lake Albert through the peninsula to the Coorong. It was anticipated that dredging would be required 200 m into Lake Albert and 700 m into the Coorong to achieve the preferred 1 GL/day flow or up to 300 GL/year.

The preferred option comprised a 1.7 km trapezoidal channel with a 13 m base width and 1V:4H side slopes. The maximum depth of cut through the highest point of the alignment was 9.4 m.

Regulating structures were proposed at the upstream and downstream end of the channel to allow for flow management and control. These were envisaged to include manually operated penstock gates.

Construction of the channel would require disposal of approximately 250, 000 m^3 of spoil material. Disposal sites were not considered in detail, however, it was noted that 'side casting' may be the preferred disposal method due to reduced costs.

Figure 3 shows a cross section view of the open channel concept investigated in 2013, whilst Figure 4 shows the alignment options explored in detail as part of the 2008 and 2013 studies.

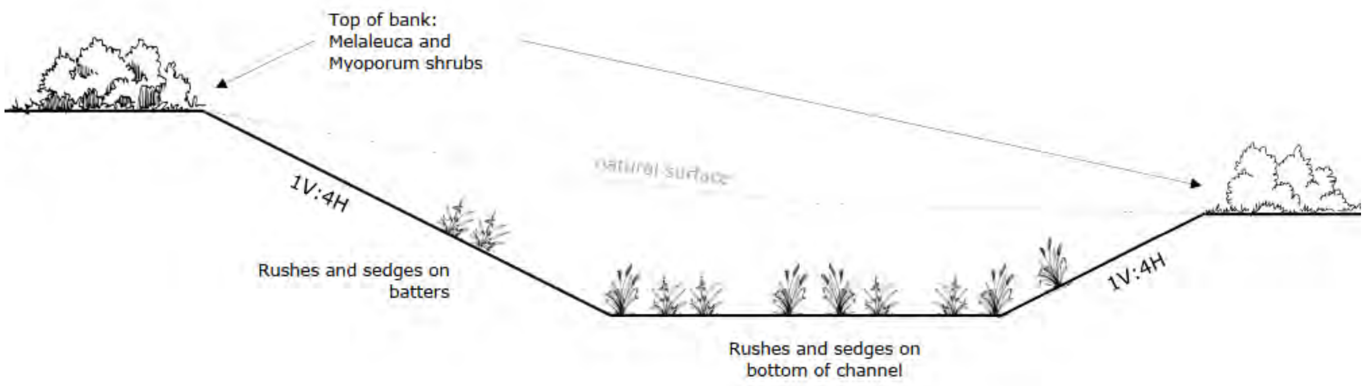

Figure 3 Schematic cross section of Lake Albert – Coorong Connector

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COORONG INFRASTRUCTURE INVESTIGATIONS
LAKE ALBERT–COORONG CONNECTOR
2008 AND 2013 OPTIONS

Figure 4

3.1.1 Previous Assessments

Prefeasibility investigations into a Lake Albert – Coorong Interconnector commenced in 2006, although the concept had been considered as early as 1983 (Ebsary 1983). The outcomes sought from the connector have varied over time.

Further feasibility investigations into a pumped connection between the Coorong and Lake Albert were undertaken for SA Water in 2008, considered as a temporary option to offset evaporative losses within the lake during the lake as a means of preventing and reducing lake body acidification. Options for connection of the lake to the ocean were also considered. These investigations included an assessment of various route options, selection of a preferred route and development of concepts and cost estimates. Whilst focussed on a different objective (supply of water to Lake Albert, rather than flushing water from Lake Albert) many of the considerations, infrastructure requirements and impacts are considered relevant to a pumped option from Lake Albert to the Coorong.

Five years later, a range of investigations were undertaken as part of the Lake Albert Scoping Study, completed throughout 2013 which considered a range of infrastructure and options for salinity reduction within Lake Albert, one of which included a connection between Lake Albert and the Coorong.

Whist the focus of this work was on Lake Albert, many of the environmental, social and cultural implications are common to an option based on providing additional water to the Coorong.

The scoping study included:

- review of existing literature
- A study of community requirements
- Detailed hydrodynamic modelling
- On-ground investigations, including geotechnical, ecological, topographical
- Acid sulphate soil investigations
- Engineering feasibility investigations
- Cost-benefit assessment.

More recent modelling was undertaken in 2017 (BMT WMB 2017) to investigate a Lake Albert – Coorong Connector as a means of increasing water levels in the Coorong South Lagoon, as well as to control salinity during summer and autumn when salinity levels are typically at their highest levels.

3.1.2 Outcomes of Previous Community Consultations

A Ngarrindjeri Position Paper for the Lake Albert Scoping Study was prepared by the Ngarrindjeri Regional Authority in 2013. Key feedback provided included:

- "*the waters of the River Murray should be allowed to flow to the sea to ensure a healthy Ngarrindjeri Ruwe/Ruwar (country, body, spirit) and that this a right of the Ngarrindjeri under their native title claim*
- *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,*
- *any future developments, explorations or projects in the area need to include appropriate resourcing to enable meaningful Ngarrindjeri participation in a manner which is consistent with their cultural principles…*"

It is noted that this position related to a management action which aimed to achieve different outcomes to those that would be achieved by a connector specifically aimed at providing flow from Lake Albert to support the health of the Coorong.

Existing documentation on the Lake Albert Scoping Study indicates that consultation with a range of stakeholders did occur in 2013, however full details of this consultation are not known at this time. It is understood that a community reference group was formed during the study.

The Lake Albert Scoping Study Options report notes that of all management options identified at that time, the Coorong Connector was the second most popular, with 63% support and 16% opposed. A key issue discussed was the environmental impact of the Connector on the Coorong. The community agreed at that time that an environmental impact study would need to be completed.

3.2 Potential Benefits

3.2.1 Environmental

Modelling completed as part of the 2013 Lake Albert Scoping Study indicated that a Lake Albert – Coorong connector would be likely to reduce salinity within Lake Albert to that similar to Lake Alexandrina within 6-12 months of operation and would also assist in the reduction of salinity within the Coorong. Whilst this was considered an effective means of reducing lake salinity (and the only effective infrastructure solution), it was concluded at the time that the lake would likely return to historic salinity levels through operational lakes cycling before it would be possible to construct a connector.

More recent modelling completed in 2017 concluded that a Lake Albert Connector would provide a positive salinity impact to the mid- and southern Coorong. Any increase in fresh water volume in this section of the system would penetrate further south and take longer to drain through the Murray Mouth (BMT WBM 2017 – Technical memo). The sensitivity of this management option to a prolonged dry period is unknown. Further, the modelling assumed a relatively high average flow rate of 1 GL/day, consistent with previous investigations, which was feasible with the proposed trapezoidal channel when the water level difference between Lake Albert and the Coorong was large enough. With lower water level differences between the lake and Coorong the preferred long-term flow rate may not be achieved and may therefore not provide the same benefit.

3.2.2 Social and Cultural

Previous work on the Lake Albert Connector concept has focussed on benefits to Lake Albert, rather than the Coorong. In the literature, no specific social or cultural benefits were identified that are specifically relevant to the Coorong.

3.2.3 Economic

Previous work on the Lake Albert Connector concept have primarily focussed on benefits to Lake Albert, rather than the Coorong. The Lake Albert Scoping study noted the following economic benefits:

- Increased productivity to existing irrigators
- Increased productivity of agricultural output due to changes in landuse from dryland to irrigated dairy

No assessment has been made as to whether these economic benefits are still of relevance given the current proposal and status of Lake Albert. Further, no assessment of economic benefits specific to the Coorong have been made.

Intuitively, as with other options, any improvement to Coorong water quality may have economic benefits associated with commercial fishing and recreational tourism although these economic benefits have not been quantified, which represents a knowledge gap.

3.3 Potential Impacts

3.3.1 Environmental

Potential environmental impacts which require consideration have been identified as:

- Coorong water quality: Within the Coorong itself, the environmental impacts of discharging Lake Albert water into the Coorong, including impacts on water quality parameters other than salinity, including turbidity and nutrient concentrations, have not been quantified to date.
- Ecology: Whilst not quantified or detailed in the literature, impacts on ecological communities within the construction footprint, whether this is a pipe or channel, will occur. No details of ecological studies or impacts on species of state or national significance are available.
  Significant potential environmental impacts were noted in the 2009 investigations into temporary pumping options (Tonkin Consulting 2008). The construction footprint would be significant, particularly the burying of the rising main and the potential for significant scouring at both the inlet and outlet and the construction of the pump station.
- Dredging / water quality impacts: For the channel option, in addition to the channel's construction footprint, some excavation/dredging of sediment in Lake Albert and the Coorong would be required at the inlet and outlet, which presents a risk of exposing and mobilising potential acid sulfate soils. This may also be the case for the pumped option.
- Noise: For a pumping option, running of diesel generators would impact on local receptors and require consideration in the design phase.
- CO2 emissions: For a pumping option, running of diesel generators would contribute to greenhouse gas emissions. No emissions calculations have been provided.

3.3.2 Social and Cultural

The preferred channel alignment identified during the 2013 study passes through three properties with different titles, including Aboriginal Trust land. There will likely be similar impacts on land regardless of the alignment option chosen. Land acquisition and/or easements would be required for the length of the channel/ pipe and spoil disposal sites.

It is not known whether any specific archaeological or anthropological studies have been undertaken to confirm specific cultural impacts. At the time of the Lake Albert Scoping Study there was no Ngarrindjeri support for any form of engineering intervention, including construction of a Coorong connector.

3.3.3 Economic

No specific economic impacts have been identified in relation to this option. This represents a knowledge gap.

3.4 Estimated Cost

All costs provided below are quoted in either 2008 or 2013 dollars, as noted. The Reserve Bank of Australia Inflation Calculator indicates a change in cost between 2008 and 2019 of 25.5% at an average inflation rate of 2.1% and a change in cost between 2013 and 2019 of 11.2% at an average annual inflation rate of 1.8%.

3.4.1 Capital Costs

The total cost for the temporary pumped solution proposed in 2008 was around $21m (2008 AUD) (Tonkin Consulting, 2008).

The pre-feasibility cost estimate for the barrage-controlled channel connected investigated in 2013 was $19m (2013 AUD). An economic assessment was undertaken for this option, with a reported benefit-cost ratio of 0.3 to 0.4. It was noted that the economic feasibility would be heavily influenced by an increase in regional irrigation and in the absence of an this, further social and cultural benefits would need to be identified.

The cost-benefit for an option to supply water from Lake Albert to the Coorong for the purpose of improving the Coorong is expected to be different due to the different range of costs and benefits expected.

3.4.2 Operational Costs

Operational costs associated with a pumped option vs. a channel option will vary significantly.

Ongoing operation and maintenance activities for a connecting channel will be required including removal of sediment build up, regulating structure operation etc. Automation of the regulators could be considered to reduce on-ground operation requirements but would increase the capital costs of implementation.

Preliminary, high level operating costs for the channel option were apparently developed as part of the Engineering Feasibility Study completed in 2014. These were reported at $1.6m (AUD 2014). It is not clear whether this is an annual cost, or total cost over the estimated life of the project.

No operational costs for the pumped option have been provided, although this will be highly dependent upon the pumping rate and duration.

3.5 Current Knowledge Gaps

The following knowledge gaps and necessary further work has been identified. This list should not be considered exhaustive, but represents some of the key issues:

- Whilst a number of investigations on a Lake Albert – Coorong Connector were undertaken as part of the Lake Albert Scoping study, these were undertaken with a specific focus on Lake Albert, rather than the advantages and disadvantages for the Coorong. Details on any associated impacts, positive or negative, on the Coorong, and specifically the South Lagoon, are therefore not available.
- Further definition is required on the focus of this potential management option; specifically, whether it is intended as a short-term or long-term management action. This may drive the selection of the most appropriate infrastructure options, for example a channel connection or piped connection.
- The Lake Albert Scoping study noted that construction of a Coorong Connector may have unknown effects on the Coorong ecology in terms of salinity, turbidity and water level. Whilst some preliminary modelling has now been completed on salinity and water level implications, the broader impacts to ecology and other water quality parameters (e.g. nutrient concentrations and export) have not been quantified.
- Details of consultation and engagement activities completed as part of the 2013 Lake Albert Scoping Study have not been provided, although there appeared to be general community support for a Coorong Connector as a means of addressing salinity within Lake Albert. Similar support was not gained from the Ngarrindjeri people. Regardless of the support or lack thereof at the time, there is a clear need for further consultation and engagement to understand the current support for such a proposal, with its shifted focus to the Coorong South Lagoon.
- It is understood that no detailed consideration of land tenure or access has been previously been given. This is of importance to any chosen alignment, but also to inform disposal options for an open channel solution.
- If considered further, more detailed planning, design and impact assessment with regard to their longer-term sustainability and impacts with respect to potential climate change, and in particular sea level rise, scenarios would be required.
- Updated engineering and ecological feasibility investigations would be required to progress this option. This may include consideration of the impacts to regional groundwater resources should the channel option intercept the seasonal groundwater table, and a detailed assessment of spoil disposal options, including the ecological impacts of disposal.

4 Option 3 – Improvements to North Lagoon / South Lagoon Connectivity

Previous investigations for options to improve North / South Lagoon connectivity have examined the possibility of increasing flowrates between the North and South Lagoon of the Coorong (Department for Environment and Heritage 2010b) through channel excavation or dredging. The aim of this investigated option was to improve ecological conditions by reducing salinities in the South Lagoon through improved water exchange with the less saline North Lagoon.

This option was considered as a complementary option in combination with the South Lagoon Salinity Reduction Scheme (SLSRS); an option to reduce salinities in the South Lagoon by pumping the South Lagoon to the Southern Ocean (Department for Environment and Heritage 2010b).

4.1 Options Description

A concept design studied targeted excavation of 'Hell's Gate', the narrowest section of the Coorong separating the North and South lagoons (Department for Environment and Heritage 2010b). This involved deepening the link between the North and South Lagoons to maintain the exchange of flows where historically physical separation would occur throughout summer. The concept investigated consisted of an excavation approximately 6 km either side of Parnka Point, with a sill level of -0.8 mAHD.

The general zone considered for dredging is shown in Figure 5. It is understood that dredging is not required for the full length, but rather in selected zones where hydraulic connectivity is reduced.

4.1.1 Previous Assessments

In 2010, a feasibility study was undertaken to determine the effectiveness of dredging 'Hell's Gate', nominally the constriction between the Needles and Parnka Point (Department for Environment and Heritage 2010b). This option included the excavation of approximately 441,000 m^3 of material to form a channel 20m wide and approx. 6 km either side of Parnka Point through Hell's Gate, with a sill level of -0.8 mAHD.

The idea for the channel arose from manipulation of modelling results that found by increasing the transmission efficiency between the North and South Lagoon, in conjunction with SLSRS pumping out of the south lagoon, salinity decreased and remained mostly within the target range for ecological health, even with zero barrage flows (Lester et al.). The modelling assumed that the dredging was undertaken each side of Parnka Point (refer Figure 5) in conjunction with pumping from the south lagoon and in the absence of barrage flows.

Alternative 2-dimensional hydrodynamic modelling undertaken by BMT (Department for Environment and Heritage 2010b) with quite different results. It was found that dredging Parnka Point in combination with pumping resulted in very little difference in resulting salinity compared with pumping alone. It was noted, however, that modelled simulation periods did not continue beyond the cessation of pumping, and that salinity may be lower than the pumped only case after pumping is discontinued due to increased mixing.

The results of the 2-dimensional modelling was at odds with the modelling undertaken by Lester et al., despite both models calibrating well against previous conditions. Some differences between the model operating rules are noted, most importantly the adopted pumping rate.

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DEPARTMENT FOR ENVIRONMENT AND WATER

COORONG INFRASTRUCTURE INVESTIGATIONS
IMPROVEMENTS TO THE NORTH LAGOON/
SOUTH LAGOON CONNECTIVITY

Figure 5

4.1.2 Outcomes of Previous Consultations

No known previous consultations have been undertaken.

4.2 Potential Benefits

4.2.1 Environmental

Whilst the model had conflicting results, it was suggested that increased flows from the North Lagoon into the South Lagoon enabled by the excavation of Hells gate would have two key positive effects.

Firstly, it would reduce salinity and increase water levels in the South Lagoon over the long term (Department for Environment and Heritage 2010b). Lower salinities would help sustain the ecosystem of the South Lagoon, particularly the Ruppia/Chironomid/Hardyhead ecosystem and associated biota such as migratory birds. Higher water levels would particularly help *Ruppia tuberosa*, as it requires specific water levels over different parts of its lifecycle.

Secondly, increased water exchange with the North Lagoon could also serve to mitigate pumping effects of the SLSRS, which may otherwise reduce water levels in the South Lagoon, thereby reducing the risk of exposure of acid sulphate soils (Department for Environment and Heritage 2010b).

In comparison to the no-dredge option, it was anticipated that increasing the transmission efficiency between the north and south lagoon through dredging would:

- prevent 'spikes' of high salinity in the South Lagoon during summer
- maintain a lower salinity in the South Lagoon throughout the year
- maintain lower water temperatures in the South Lagoon
- prevent excessive declines in water level in the South lagoon during summer.

4.2.2 Social and Cultural

No known social or cultural benefits were highlighted. This represents a potential knowledge gap.

4.2.3 Economic.

No known economic benefits were highlighted. This represents a potential knowledge gap.

4.3 Potential Impacts

4.3.1 Environmental

Several potential environmental impacts exist (Department for Environment and Heritage 2010b). Perhaps the most important environmental impact is the turbidity plume created by dredging activities within the works zone (refer Figure 5). This increased turbidity could cause gill clogging in fish, reduced light penetration, and smothering of the lagoon floor habitat. It is suggested that these effects could be mitigated through use of silt curtains, dependent upon the dredging methodology implemented.

Another impact is habitat disturbance - the length and width of the channel, and its significant depth, would disturb a large area both for creation of the channel and disposal of the spoil excavated (Department for Environment and Heritage 2010b). Assuming the bed material creates a submerged area of spoil with equivalent area, a conservative estimate of total 'footprint' of the channel would be 48 ha. However, the sections of the Coorong which would be excavated had little remaining ecology – the aquatic plants which formerly occupied this area of the Coorong were mostly absent as of 2010, along with associated invertebrates, fish and waterbirds. Current information on aquatic ecology in this area has not been reviewed. Off-site disposal of spoil has not been investigated.

Finally, excavation of Hell's Gate would inherently modify the hydrodynamics of the Coorong (Department for Environment and Heritage 2010b). Part of what makes the Coorong unique is the salinity gradient from the Murray Mouth to the South Lagoon. While increasing transmission efficiency between the North and South Lagoon is good in drought conditions where the South Lagoon is very hypermarine, under normal conditions there is potential that ecological character could be altered due a reduction in the range of salinity conditions experienced. This includes shortening, or completely removing the period when the water levels in the South Lagoon fall below that in the North Lagoon, and with increased connectivity lower salinities. The ecological implications of this have not been documented which represents a knowledge gap.

4.3.2 Social and Cultural

It was noted that aboriginal heritage issues are central to the design and implementation if excavation was to go ahead (Department for Environment and Heritage 2010b). Actions which affect the physical body of the Coorong could be contentious with the Ngarrindjeri community, and would require a full approvals and consent process.

4.3.3 Economic

No known economic impacts were highlighted. This represents a potential knowledge gap.

4.4 Estimated Cost

4.4.1 Capital Costs

An approximate cost of dredging was $7.12m (AUD 2010). The Reserve Bank of Australia Inflation Calculator indicates a change in cost between 2010 and 2019 of 19.8% at an average inflation rate of 2.0%.

4.4.2 Operational Costs

No ongoing costs are expected once construction is completed. However, the need for repeat dredging represents a knowledge gap, and is in part dependent on other actions that may reduce deposition.

4.5 Current Knowledge Gaps

The option of dredging between the north and south lagoons of the Coorong has previously been considered in conjunction with other management options, principally pumping from the south lagoon to the Southern Ocean. No known modelling has been undertaken to determine the effect of this option alone on salinity or water levels with the south lagoon, nor the impacts of this option when considered in conjunction with any other management option.

Current knowledge gaps include:

- A detailed assessment of environmental impacts associated with dredging
- Potential constructability challenges, including those relating to the dredging methodology, disposal of spoil and access for plant and equipment
- Aboriginal cultural heritage impacts, including acceptance or otherwise of the management action
- Community and stakeholder perception or acceptance of the management action
- Effects on long term ecological character of the Coorong
- An appreciation of the cost vs. benefit of dredging as a management option
- Long-term effectiveness of dredging as a management solution in the context of predicted sea level rise and other climate change effects. The need for repeat or ongoing dredging has also not been identified.

5 Option 4 – South East Flows Augmentation

The South East Flows Augmentation (SEFA) seeks to reduce salinity in the South Lagoon of the Coorong through diversion of drainage flows which are currently discharged into the sea, routing them into the South Lagoon of the Coorong, via Salt Creek. By increasing freshwater flows into the South Lagoon, salinity is reduced as freshwater flows dilute the hypersaline waters.

At least as early as 2008, the South East Flows Restoration Project (SEFRP) was discussed as part of the Coorong, Lower Lakes and Murray Mouth Recovery Project. Following completion of feasibility investigations and a formal business case, funding was approved for detailed design and construction with construction occurring between March 2017 and May 2019. Key construction activities included construction of 13km of new floodway running north from Blackford Weir, upgrade of approximately 80 km of existing channel north of the newly constructed floodway and upgrade of approximately 15 km of the Northern Bakers Range floodway.

The South East Flows Augmentation can be viewed as an extension of the South East Flows Restoration Project, diverting additional surface water flows from the South East into the South Lagoon of the Coorong.

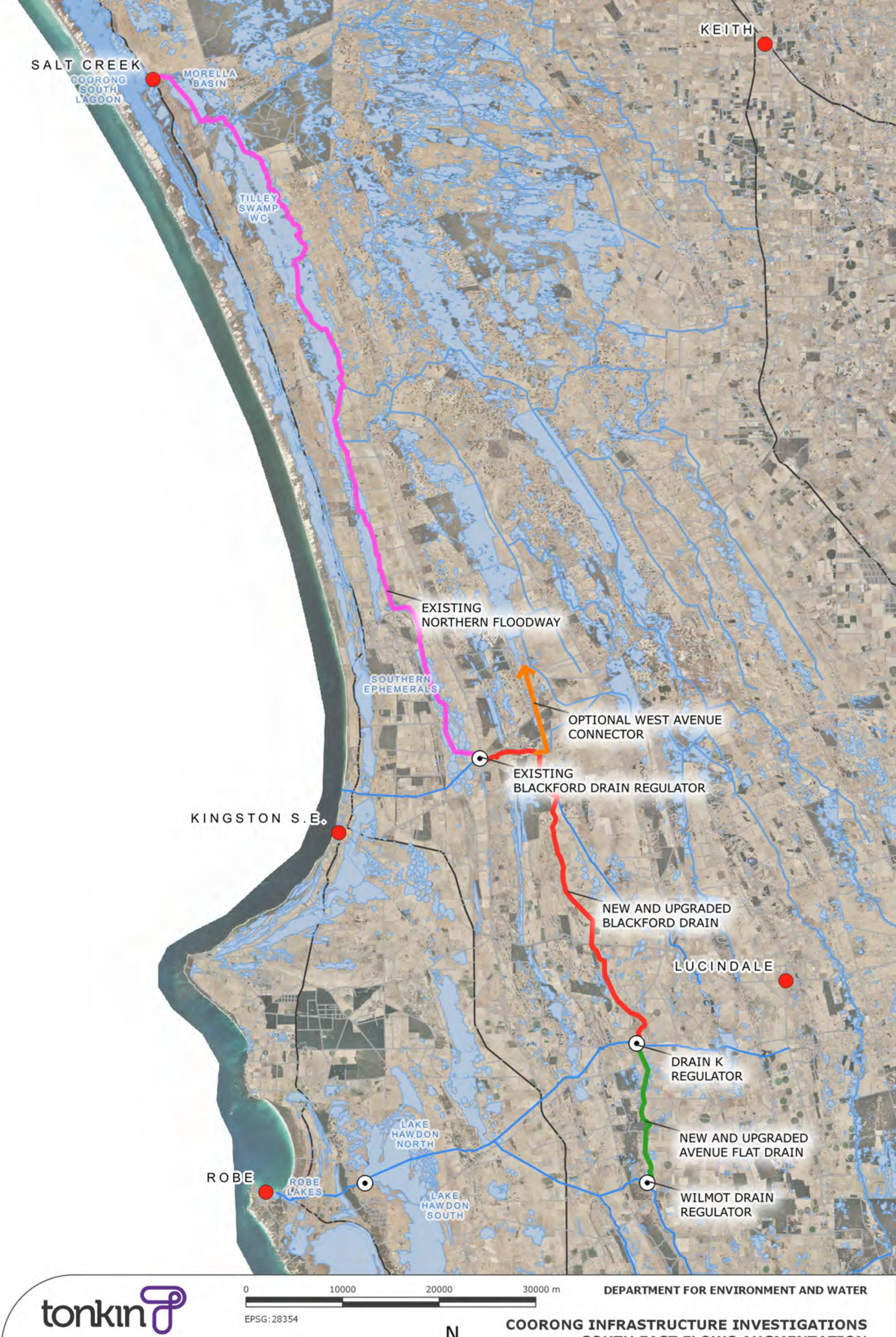
5.1 Option Description

The SEFA includes an extension to the existing South East Flows Restoration Project through 'harvesting' water from drainage systems between Blackford Drain and Wilmot Drain. The solution aims to utilise existing drainage infrastructure in so far is possible, with some new and upgraded infrastructure required. Key infrastructure would include:

- SEFA floodway following the Blackford Drain and Avenue Flat Drain alignments:
  - upgrade of the Blackford Drain to provide an additional 300 ML/d capacity, capped at 600 ML/d
  - upgrade of the Avenue Flat drain to provide an additional 150 ML/d, capped at 300 ML/d
  - construction of short sections of new floodway to connect Blackford Drain to Drain K and Avenue Flat Drain to Wilmot Drain
  - new and upgraded occupational and road crossings for access
- new regulators within the Drain K and Wilmot Drains to enable water to be diverted north into the SEFA floodway
- a fish exclusion structure within Blackford Drain to prevent upstream migration of pest fish species from Blackford Drain into the Drain L system
- a new regulator within Drain L downstream of Lake Hawdon North for environmental flow management

Further to the primary SEFA floodway and associated infrastructure an opportunity exists to construct an additional floodway which would connect SEFA and the West Avenue Watercourse, diverting water through wetlands en-route to an alternative pathway to the South Lagoon. This outcome emerged as a result of community consultation, particularly with the South East Water Conservation and Drainage Board.

The indicative alignment for SEFA investigated in 2016 is shown in Figure 6. Conceptual cross sections of the floodway, based on the as constructed arrangement of the SEFRP, are shown in Figure 7.



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DEPARTMENT FOR ENVIRONMENT AND WATER

COORONG INFRASTRUCTURE INVESTIGATIONS
SOUTH EAST FLOWS AUGMENTATION
2017 INDICATIVE ALIGNMENT

Figure 6

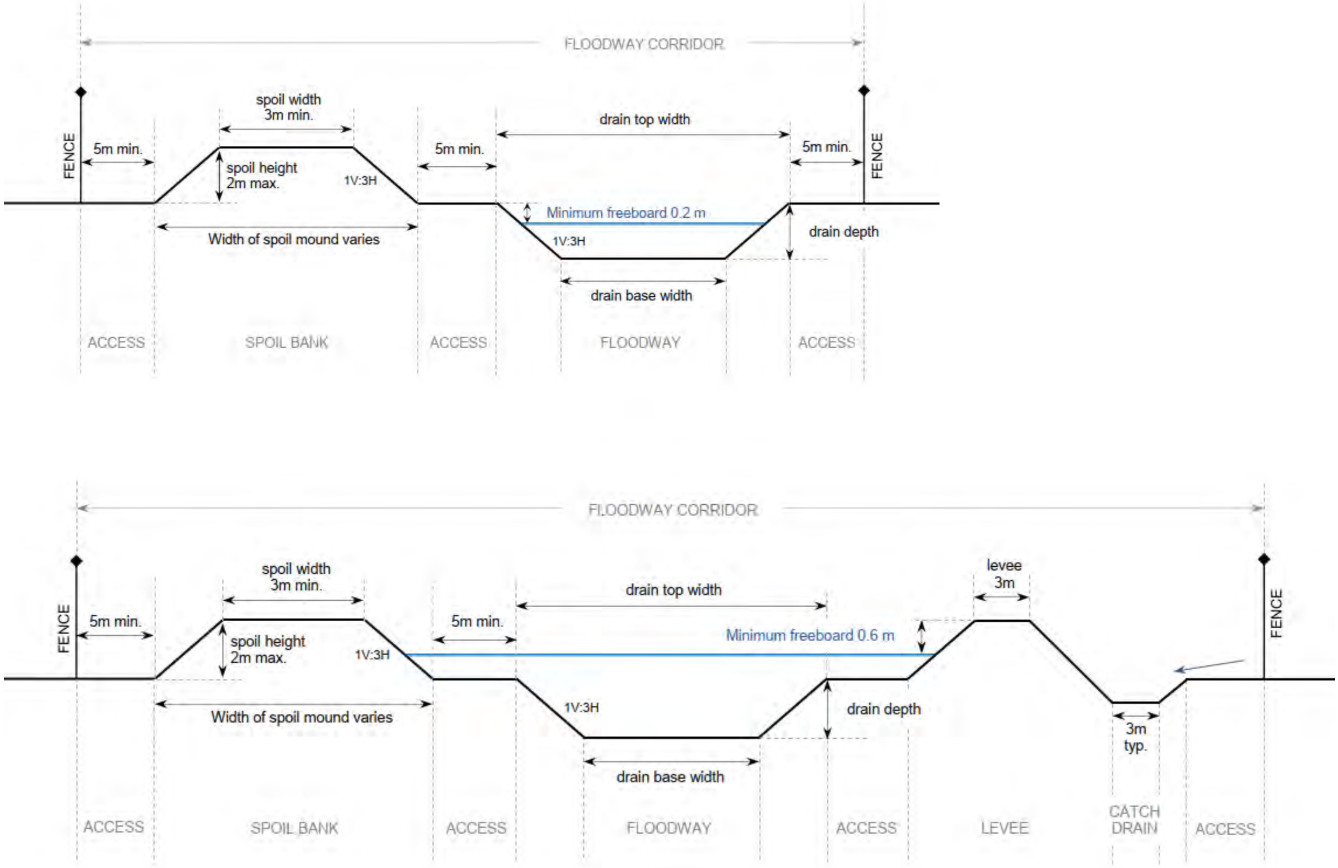

Figure 7 Conceptual floodway arrangement based on adopted SEFRP Northern Floodway

5.1.1 Previous Assessments

Investigations into the feasibility of the South East Flows Augmentation Project were undertaken as part of the broader *Coorong Investigations Project* throughout 2017.Unlike past investigations there is no intention to connect to Drain M further south of the project area.

Key investigations included:

- Hydrological investigations: to determine surface water availability within the Blackford, Drain L and Wilmot Drain catchments and to inform the diversion rules to maintain environmental water requirements for key south east wetlands, including Lake Hawdon North (Whiting 2017a, 2017b).
- Engineering investigations: including modelling of existing drainage networks and preliminary design of infrastructure requirements to support implementation of SEFA (Tonkin 2017a, 2017b)
- Consideration of pest fish species management: including an assessment of the risk of Eastern Gambusia invasion of the Upper Drain L catchment and development of a pest fish barrier concept to manage pest fish migration from Blackford Drain to Drain L (Berghuis 2017, Whiterod & Gannon 2017).
- Hydrodynamic modelling: to investigate the impacts of SEFA (and other management options) on flows and salinity within the Coorong South Lagoon (Sims 2017, BMT WBM 2017a).
- Preliminary ecological response modelling: to assess the benefits or negative impacts that SEFA may have on salinity or water levels within the South Lagoon.

- Coupled hydrodynamic and biogeochemical / ecological modelling: to predict the habitat extent of the waterbird food source *Ruppia tuberosa* under SEFA conditions (Hipsey et al 2017).
- Economic Analysis: including a cost-benefit analysis and estimation of regional economic impacts for input to the Business Case (Econsearch 2017)
- Water Quality: Assessment and modelling of the effects of south east drainage flow releases on Coorong Water Quality (Moseley et al. 2017)

The Coorong Investigations Project Feasibility Assessment Report (Department of Environment, Water and Natural Resources 2017a) concluded that SEFA was feasible from a construction perspective and would deliver additional median annual yields of approximately 15.6 GL in a median year to the Coorong South Lagoon.

5.1.2 Outcomes of Previous Community Consultations

It is generally accepted that while the south east community are understanding of the international value of the Coorong, they also place a high value on wetlands in the South East region. With SEFA harnessing a portion of the last reliable divertible water in the Upper South East, community feedback has indicated that this water should be integrated as much as possible with the existing wetlands in the South East. Without this integration, SEFA is vulnerable to the perception that water in the South East was being sacrificed to solve overallocation problems caused upstream.

Community stakeholders consulted during the 2017 Coorong Investigations included the South East Water Conservation and Drainage Board, South East Aboriginal People Focus Group and Ngarrindjeri people represented by the Ngarrindjeri Regional Authority. No individual landholder consultation has been undertaken along the proposed alignments to date.

Both the South East Aboriginal People Focus Group and Ngarrindjeri Regional Authority were supportive of SEFA, taking the view that increased environmental flows to the Coorong were appreciated as they worked towards restoring the Coorong to its historical state.

The South East Water Conservation and Drainage Board provided critical review of the proposal, but conditionally supported SEFA provided that:

- The West Avenue Watercourse connector is constructed as part of the project to ensure that wetland health is maintained in the South East
- The Lake Hawdon North regulator is constructed and operated to divert a minimum of 100 ML/day through the Robe Lakes system before diversion into the Coorong
- The quality of water diverted is high enough (particularly salinity) to flow through the Blackford Drainage system, particularly in the context of diversions through West Avenue Watercourse.
- The impact of deepening sections of existing drains is evaluated to ensure that no negative impacts to surface water on farming land are experienced
- The design of the floodway is able to prevent pest fish species from moving upstream to areas not currently invested.

5.2 Potential Benefits

5.2.1 Environmental

The SEFA seeks to deliver additional fresh water to the Coorong South Lagoon to primarily assist with salinity management, which is expected to lead to a range of environmental benefits. This water is currently discharged to the sea near Kingston and SEFA has the potential to retain water in the regional SE landscape for the benefit of agriculture, groundwater recharge and the environment.

Long-term catchment modelling has estimated that the contribution from the south east drainage network (prior to SEFRP construction) to the Coorong South Lagoon via Salt Creek is in the order of 29.4 GL/year, and the now complete SEFRP is capable of delivering an additional 25.9 GL/year in a median year. SEFA is estimated to be capable of delivering an additional 15.6 GL/year in a median year (Whiting 2017a).

Modelling undertaken as part of the 2017 Coorong Investigations found that an increase in flows into the Coorong South Lagoon would cause a drop in the salinity of the Coorong as a whole. With only SEFRP flows (approx. 55.6 GL/year total inflow, median year), modelling found that salinities could drop to an average yearly maximum of around 90 g/L, the upper end of the ecologically desirable range. With flows from both SEFRP and SEFA (approx. 71.2 GL/year total inflow), salinities could drop to a maximum of around 80 g/L, more comfortably within the ecologically desirable range.

The modelling indicates that SEFRP has the potential to decrease salinity in the South Lagoon, with positive impacts expected on local ecology and a number of significant bird species. If SEFA was constructed, it could enable salinity to be reduced further in the South Lagoon, with a resulting increase in ecological health. SEFRP and SEFA both have the ability to be managed such that water is only supplied to the Coorong when it is needed.

Positive impacts to nutrient concentrations and export related to the current South East flows have been reported in Mosley et al (2017).

Some additional benefits may be experienced outside of the South Lagoon, particularly increased environmental flows with fresher water through a number of wetlands, in particular the Taratap Watercourse and Tilley Swamp Watercourse. With the inclusion of the West Avenue connector, significant environmental benefits could be achieved through additional environmental water delivery to the West Avenue watercourse when the needs of the Coorong have been met. The SEFA proposal also includes a regulating structure within Drain L to enable environmental water management within Lake Hawdon North to offset reduced drainage flows. The ability to better manage water within Lake Hawdon and the Robe Lakes is expected to have significant environmental benefits.

5.2.2 Social and Cultural

Positive social and cultural effects noted include the restoration of some environmental flows which the Coorong historically enjoyed, a positive result for the South East aboriginal community.

The Ngarrindjeri people have traditional ties to the South East region and in particular, to the Coorong South Lagoon and the associated Ephemeral Lakes and wetlands. Members of the South East Aboriginal Focus Group have indicated their support for the restoration of flows through West Avenue Watercourse and Tilley Swamp Watercourse to the Coorong via this project as important to their cultural wellbeing. They see the revival of the Coorong and some of the South East wetlands would benefit future generations through strengthening and revitalising the foundation of Indigenous knowledge (Econsearch 2017).

The capability for prudent management of local groundwater in a drying landscape made possible by the new infrastructure, including regulating structures, would provide positive social benefits to en-route landholders.

5.2.3 Economic

The economic analysis of SEFA was presented in terms of three evaluation criteria: net present value (NPV), benefit cost ratio (BCR) and internal rate of return (IRR). According to all three evaluation criteria, SEFA is a worthwhile investment.

SEFA has an estimated NPV of $11.95m (2017 AUD), which indicates that, relative to the base case (do nothing) SEFA will generate a net benefit to the community of $11.95m over 20 years. If the NPV is greater than zero the investment is considered worthwhile (Econsearch 2017).

The BCR of SEFA is 1.4, which in a broad sense means that for each dollar invested $1.40 will be returned over the life of the project. For a project to be viable, the BCR must be greater than 1.0 (Econsearch 2017).

In summary, the net benefits of investing in SEFA outweigh the net benefits of no investment (base case).

5.3 Potential Impacts

5.3.1 Environmental

Potential environmental impacts which require consideration in progressing the SEFA have been identified as:

- Pest fish migration: The pest fish species Eastern Gambusia, is considered one of the worst alien fish species in the world (Whiterod & Gannon 2017). Whilst this fish has not been detected within the Blackford Drain to date, it has the potential to migrate to this catchment through hydrologic connectivity to Drain M under REFLOWS diversion scenarios along the Bakers Range watercourse. Gambusia is known to occur within Drain M.
  Whilst the Drain L catchment was previously thought to be free of alien fish species, studies in 2017 found gambusia in some locations in relatively small numbers (Whiterod & Gannon 2017). Although no longer gambusia free, connectivity of Blackford drain to Drain L via SEFA potentially provides a mechanism for further gambusia invasion to the Drain L catchment, although the risk is considered small. The concept developed for SEFA includes a pest fish exclusion structure, designed to prevent upstream migration of gambusia under most flow scenarios.
- Reduced environmental flows to Lake Hawdon and Robe Lakes: Diversion of flows from Wilmot Drain, Drain K/L and Blackford Drain will reduce flows to downstream ecosystems. This is of importance to the Drain L catchment, and in particular Lake Hawdon North and the Robe Lakes, a group of coastal wetlands with high ecological significance. The SEFA concept includes a regulating structure to hold water within Lake Hawdon North to replicate, and potentially restore, flooding conditions with lower flows and enable environmental release to the Robe Lakes.
- Localised groundwater impacts: Deepening of drainage channels in the upper regions of the Blackford Drain and Avenue Flat drain has the potential to lower local groundwater levels over summer months if the floodway invert intercepts the local water table. The preliminary design includes provision to manage local groundwater levels through the use of small regulating structures installed at occupational crossings.
- Impacts on native vegetation through construction of new floodways and infrastructure.
- Water quality: There has been some concern in the scientific community that increased flow from the South East drainage network will contribute additional nutrients to the Coorong South Lagoon and provide a more beneficial environment for algae growth. However, a Mosley et al. (2019) analysis of water quality data targeting South East flows operations concluded that higher salinity was associated with a higher degree of eutrophication in the Coorong, with a large increase in total nutrient concentrations observed as salinity increased above marine values. External nutrient loads from Salt Creek were estimated to be low relative to standing nutrient stocks in the South Lagoon. Mosley et al (2019) also concluded that increasing inflows to the Coorong will, in the long-term, lead to a reduction in Coorong eutrophication.

5.3.2 Social and Cultural

No specific social and cultural impacts have been noted in the literature reviewed, although there will be some inherent impacts associated with construction through private and public land, such as severance of landholdings. These issues can be addressed as part of detailed design. There are likely to be concerns of the broader community regarding the loss of a fresh water resource from the region for the betterment of other industries and environments outside the region (M deJong pers. comm.). These impacts are likely to be similar to those successfully managed throughout the SEFRP.

5.3.3 Economic

Whilst funding for capital investment for the project may be secured, annual costs associated with operations and maintenance of infrastructure will remain with the South East Water Conservation and Drainage Board.

A number of new structures are proposed under the current concept, including several new large-scale regulating structures. These are anticipated to be similar to the new regulator built on Blackford Drain as part of South East Flows Restoration Project, which can be operated remotely saving on operational costs.

As a result of the land acquisition required for the SEFA there will be some minor loss of regional economic activity from a reduction in productive farm land (Econsearch 2017).

5.4 Costs

All costs quoted below are in 2017 dollars.

The Reserve Bank of Australia Inflation Calculator indicates a change in cost between 2017 and 2019 of 3.6% at an average inflation rate of 1.8%.

5.4.1 Capital Costs

Estimated capital cost estimates were prepared following completion of the preliminary design of SEFA in 2017. These formed the basis of the economic assessment and cost benefit ratio calculation, which provided input to the SEFA business case.

Estimated capital costs of the SEFA project are approximately $40.1m (AUD 2017) inclusive of project delivery costs including design, land acquisition, environmental and cultural heritage management and project management.

SEFA is estimated to provide a median 15.6 GL of water to the Coorong, equating to $2,567/ML, comparable to the unit cost of SEFRP. The Volume Weighted Average Price of SA Murray Class 3a entitlements in 2017 was $2,922/ML. At the accepted irrigation efficiency multiplier of 2.5x, this equates to $7,305/ML (Econsearch 2017).

5.4.2 Operational Costs

Estimated ongoing maintenance and operational costs for the SEFA project are estimated to be approximately $319k/year over and above existing O&M costs of the South Eastern Water Conservation and Drainage Board (Econsearch 2017).

5.5 Further work and current knowledge gaps

Identified knowledge gaps and further work required includes:

- Site investigations (survey and geotechnical) to confirm design requirements.
- Optimisation of the alignment to minimise native vegetation impacts and address landholder preferences.
- Detailed landholder consultation to ascertain requirements for local drainage, groundwater management and other site-specific issues.
- Broader community engagement to assess the appetite for large scale alteration to water management in the region.
- Further understanding of the positive and negative ecological response of the Coorong to additional freshwater flows, including effects on water quality.
- Further investigations into potential cultural heritage constraints and development of an engagement strategy with SEAFG which includes involvement of the Aboriginal peoples of the region.

- Further understanding of filamentous green algae and why blooms are occurring annually after the Millennium Drought. Specifically, there is a need to better understand:
  - the spatial scale of the filamentous green algae problem in the Coorong
  - the nutrient sources (River Murray, Coorong, South East) that are causing the blooms to occur more consistently since the Millennium Drought, as well as the intra-Coorong cycling of nutrients.

6 Option 5 – Coorong South Lagoon Regulator Structure

The abundance of *Ruppia tuberosa*, a key aquatic plant species within the Coorong, has been in decline since the 1980s and 1990s, likely a result of changes in salinity and water levels (Paton et al. 2015). Throughout the millennium drought, between 2003 and 2010 a combination of high salinity and reduced water levels saw the species all but disappear from the South Lagoon. Recovery of the species has been slow, even since the reestablishment of suitable salinities following the breaking of the drought.

It is believed that two factors are limiting the recovery of the key aquatic species in the southern Coorong: a severely depleted seed bank throughout much of the Coorong South Lagoon; and low water levels in spring and summer (October to February) that prevent the remaining plants from completing their reproductive cycle.

The construction of a potential water regulating structure within the southern lagoon of the Coorong aims to maintain water levels in the southern lagoon throughout spring and summer at a level sufficient to enable Ruppia to reproduce by flowering and setting seed.

6.1 Option Description

The concept of a regulating structure across the Coorong was initially presented as temporary, low level structure to maintain water levels within the South Lagoon throughout spring and into summer, with overtopping in winter. This solution offers little flexibility and was considered unlikely to be suitable for long-term deployment.

As part of the Coorong Investigations project completed in 2017, a range of investigations were undertaken looking at construction of a permanent regulating structure across the Coorong to maintain water levels in the South Lagoon when levels drop in the North Lagoon through the spring and summer periods. In addition to permanent options, a temporary option was also considered. The range of options explored included:

- locations at Parnka Point and the Needles
- regulator crest heights ranging from 0.3 mAHD to 1.0 mAHD
- fixed weir and operable structures, with gates that could be opened and closed
- alternative construction forms including concrete, plastipile or temporary forms such as an AquaDam.

The permanent solutions were intended to include operable gates such that through-flow could occur during times when water levels are naturally high enough but be fully or partially closed to hold water within the south lagoon when required.

The temporary Aquadam solution was intended to be a temporary solution that could be deployed short-term with limited environmental footprint.

Four options were shortlisted as part of the engineering feasibility investigations completed:

- A fixed height, operable concrete and earthen embankment structure at Parnka Point: a long-term solution with a 50+ year design life, although the design life of the regulator gates will be highly dependent on the material from which the gates are manufactured.
- A fixed height, operable plastipile and earthen embankment structure at Parnka Point: Similar to the above but with plastipile support structures. Whilst potentially not as susceptible to corrosion as a concrete and steel structure, the design life of plastipile products is untested.
- A fixed height, operable concrete and earthen embankment structure at the Needles: a long-term solution with a 50+ year design life, although the design life of the regulator gates will be highly dependent on the material from which the gates are manufactured. The poor site access and ground conditions at The Needles is likely to make construction expensive and challenging.

- A temporary, inflatable Aquadam structure at the Needles: consisting of yearly deployment and removal of an inflatable AquaDam structure. This represents a much more temporary solution, with the AquaDam installed around the start of September and removed around the end of January.

The two alternative regulator locations investigated in 2016 are shown on Figure 8.

6.1.1 Previous Assessments

Investigations into the feasibility of the Coorong Regulating Structure were undertaken as part of the broader *Coorong Investigations Project* throughout 2017.

Key investigations included:

- Engineering feasibility investigations: including an assessment of potential locations, completion of limited survey, definition of functional and performance requirements, identification of options and development of a shortlist of four options. For each shortlisted option, conceptual designs were developed along with indicative cost estimates (Tonkin 2017).
- Hydrodynamic modelling: to investigate the impacts of a regulating structure on water levels, flows and salinity within the Coorong South Lagoon in the short and long-term (Sims 2017, BMT WBM 2017).
- Preliminary ecological response modelling: to assess the benefits or negative impacts that a regulating structure may have on salinity or water levels within the South Lagoon.
- Coupled hydrodynamic and biogeochemical / ecological modelling: to predict the habitat extent of the waterbird food source *Ruppia tuberosa* under regulated water level conditions (Hipsey, Busch and Aldridge 2017). The modelling looked at the effect of regulator location, height and gate operation, both with and without augmented freshwater flows from Salt Creek.

The DEW high-level feasibility assessment found that, in accordance with Tonkin's engineering feasibility assessment; construction was feasible.

A permanent or semi-permanent non-gated regulating structure was generally not preferred as the reduced mixing between the north and south lagoon was expected to cause negative salinity and water level impacts. A gated regulator was preferred as it was considered likely to maintain spring water levels without impacting autumn water levels, along with only moderate salinity increases.

6.1.2 Outcomes of Previous Community Consultations

No known previous consultations with community stakeholders have been undertaken.

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DEPARTMENT FOR ENVIRONMENT AND WATER

COORONG INFRASTRUCTURE INVESTIGATIONS
SOUTH LAGOON REGULATOR STRUCTURE LOCATIONS INVESTIGATED 2017

Figure 8

An elevation view of the regulator structure is shown in Figure 9.

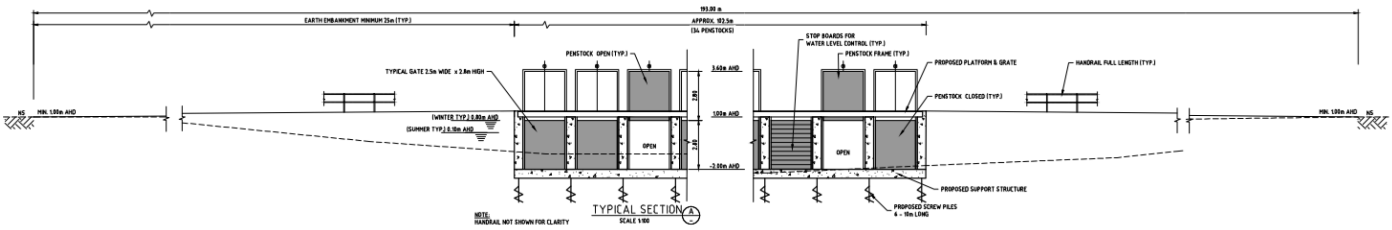

Figure 9 Typical detail of regulator structure

6.2 Potential Benefits

6.2.1 Environmental

Ideal environmental outcomes of flow regulator structures between the North and South Lagoons is higher water levels ideally leading to higher survival and recruitment rates of *Ruppia tuberosa* over its entire lifecycle. Increased water levels are potentially beneficial to survival of *Ruppia tuberosa*, but the effects of increased salinity and eutrophication should be considered.

Modelling completed with the specific aim of assessing effects on water level and salinity found that in general, the construction of a regulator structure would increase water levels over the critical spring / summer period with an increase in salinity which was lower when augmented south east drainage flows were present and higher when they were not.

In general, much higher levels were maintained much longer with 1.0 mAHD structures compared with 0.3 mAHD and 0.6 mAHD structures, effectively mitigating early falls in water levels during spring and maintaining an elevated water level (>0.1 mAHD) through January with an increase in salinity. The conclusion of the options assessment was that most of the considered options would be effective at increasing the water level in the South Lagoon, albeit with an increase in salinity which depended on both the additional south east drainage flows available and the height of the finished structure.

Modelling performed to evaluate the survival probability of Ruppia over different lifecycle stages and response to differing water levels and salinity under base case and regulated water level conditions produced mixed results. While survival rates of the adult lifecycle stage were found to sometimes increase, on average the overall probability of seed bank replenishment had mixed results with impacts in some years and benefits in others. It was noted that with optimisation of gate operating rules, benefits could be increased. It should be noted that the modelling only considered salinity and water level effects on Ruppia, effects of other factors such as depth variations in temperature, interactions with algae, or impact on other biotic groups, were not considered.

6.2.2 Social and Cultural

No specific social or cultural benefits have been identified in the work completed to date. This represents a potential knowledge gap.

6.2.3 Economic

No specific economic benefits have been highlighted, as no detailed economic analyses have been completed for the option of constructing a regulating structure. This represents a potential knowledge gap. With improved ecological health of the Coorong it is expected that this may lead to additional tourism with associated economic benefit.

6.3 Potential Impacts

6.3.1 Environmental

The modelling indicated that regardless of structure size and additional flow availability, some increases in salinity could be expected with the increases in water level generated by the regulator. While it is noted that the increases were not enough to push salinities outside of the desirable range, and that effects were generally small, higher salinities could have other negative ecological effects. A key finding of the modelling undertaken was that the increases in salinity caused by construction of flow regulator structures would be more than offset by the reduction in salinity from increased inflows from SEFRP alone or SEFRP and SEFA.

The modelling indicated little difference in results for regulators positions at Parnka Point or the Needles.

No specific assessment of other potential environmental impacts has been undertaken to date, although the engineering feasibility report did highlight potential environmental impacts associated with construction. These include:

- Restricted access, particularly at the Needles, which would necessitate disturbance to create suitable access for construction vehicles.
- Creation of a 'mudwave' during construction, where very soft bed materials are pushed to the surface following placement of earthen and concrete structures.
- Disturbance to local areas at the regulator location, most notable at the Needles location where the structure will span Snake Island.

6.3.2 Social and Cultural

No known social or cultural impacts were highlighted as part of the works completed to date, although the Coorong South Lagoon is a known area of great cultural significance.

The Needles regulator location would also have some impact on private property.

Construction of a permanent structure across the lagoon would also limit boat passage.

This represents a potential knowledge gap.

6.3.3 Economic

No known economic impacts have been highlighted, as no detailed economic analyses have been completed for the option of constructing a regulating structure. This represents a potential knowledge gap.

As this option involves the construction of new infrastructure, either permanent or temporary, there will be associated operating and maintenance costs, although these have not been quantified to date and will be dependent upon the specific option selected.

6.4 Estimated Cost

All costs quoted below are in 2017 dollars.

The Reserve Bank of Australia Inflation Calculator indicates a change in cost between 2017 and 2019 of 3.6% at an average inflation rate of 1.8%.

6.4.1 Capital Costs

Indicative capital costs for each of the options developed to concept stage by Tonkin were estimated at:

- Parnka Point embankment, concrete supports: ~$18.8m (AUD 2017)
- Parnka Point embankment, Plastipile supports: ~$15.7m (AUD 2017)

- The Needles embankment, concrete supports: ~$34.0m (AUD 2017)
- AquaDam: costs were considered in the context of annual operating costs, with the purchase cost spread over the life of the product (assumed to be two years).

6.4.2 Operational Costs

Operational costs for the permanent options were not considered as part of the feasibility assessment, however high ongoing costs are expected due to the adverse conditions presented by the hypermarine state of the South Lagoon.

Operational costs for the AquaDam option were estimated at ~$1.44m (AUD 2017) per year assuming the barrier could be used for two years before replacement. Being able to use the barriers more or less than twice per replacement would decrease or increase the operating cost of the AquaDam option.

The recovery of the Ruppia grasses is likely to take several years of successful water level management to produce measurable improvements. Therefore, if Aqua Dam units were to be utilised for 10 years the cost of this option would be close to $15M in aggregate spent.

6.5 Current Knowledge Gaps

Identified knowledge gaps and further work required includes:

- Cultural heritage surveys and consultation with SEAFG and the Aboriginal peoples of the region to understand archaeological or anthropological constraints to building and maintaining a regulating structure at either Parnka Point or the Needles (or alternative location)
- An understanding of how changes in operating rules could increase or decrease the modelled survivability of Ruppia. Optimisations to operating rules could increase survivability but it remains unclear which what operating rules should be used and why.
- Further understanding of the positive and negative ecological response of the Coorong to changes in water levels and salinity.
- Economic feasibility, including benefit cost ratio, net present value and internal rate of return
- An understanding of broader community and stakeholder acceptance of a regulating structure, including potential impacts on boating and other recreational uses.
- Site investigations (survey and geotechnical) to confirm design requirements.
- Further investigations into potential cultural heritage constraints and development of an engagement strategy with SEAFG which includes involvement of the Aboriginal peoples of the region.

7 Option 6 – Temporary pumping from the Coorong South Lagoon to the Southern Ocean (salinity reset)

The Coorong South Lagoon Pumping Project, also known as the South Lagoon Salinity Reduction Scheme (SLSRS) looked to reduce salinity in the South Lagoon of the Coorong by pumping the hypermarine (i.e. saltier than sea water) water in the South Lagoon direct to the Southern Ocean via a temporary pipe through the costal dunes (Department for Environment and Heritage 2010c). The SLSRS was considered in direct response to the millennium drought which caused salinities within the south lagoon to reach critical levels. The scheme was intended to 'reset' salinity in the South Lagoon through export of salt and drawing in lower salinity water from the south east drainage schemes and through the Murray Mouth. It was surmised that if salinity could be reduced and connectivity maintained between the Coorong and the sea in conjunction with an effective Basin Plan, the ecosystem formerly present in the South Lagoon would re-establish, and the Coorong and Murray Mouth ecosystem would be primed to respond favourably when barrage flows return.

7.1 Option Description

In 2010, detailed design of the South Lagoon pumping project commenced via an Early Contractor Involvement (ECI) procurement process with design consultants working alongside a construction contractor to develop, cost and build/operate the infrastructure. The project did not progress to construction.

Following earlier work to investigate alternative pumping options, a solution based on an average pumping rate of 250 ML/d was designed and documented. The pump station, pipeline and associated infrastructure was required to have a design life of nominally 4 years, as it was considered that target salinity levels could be achieved within a timeframe of 2-4 years. It was intended that the infrastructure be decommissioned after this time.

During the design process, 30 individual dune crossing location options for the pipeline were identified and assessed, with selection criteria including:

- the required length of pipeline
- maximum height through the dunes
- expected quantity of earthworks
- required length of cable to supply power to the pump station
- pump power consumption
- proximity to the preferred zone of extraction
- vegetation and habitat impacts
- proximity to local communities
- sites of potential Aboriginal significance
- water depth within the lagoon
- access across the lagoon to a site for support facilities and the Princes Highway.

The preferred dune crossing location for the pipeline was approximately 3 km west of Policeman Point just south of Princes Soak. This locality provided a short dune crossing and close access to water depth within the Coorong, thus providing a relatively short pipeline length of 1.3 km. The indicative alignment and position of infrastructure investigated in 2010 is shown in Figure 10.


YOUNGHUSBAND PENINSULA
PRINCES HIGHWAY
Coorong South Lagoon
EASTERN GROIN BOAT RAMP & CHANNEL
CONSTRUCTION & OPERATIONAL COMPOUND
SUBMERGED ELECTRICAL CABLING
E
PUMP STATION
BEACH TRAFFIC DIVERSION TRACK
Pumping direction
PIPE OUTLET
2010 PIPELINE ALIGNMENT
Policeman Point
tonkin
0
300
600
900 m
EPSG:28354
Job Number: 20200306
Filename: 20200306GQ001RevB
Revision: B
Date: 2020-04-03
Drawn: Sarah Murphy
Data Acknowledgement:
Base data from Data SA, 2017
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DEPARTMENT FOR ENVIRONMENT AND WATER
COORONG INFRASTRUCTURE INVESTIGATIONS
SOUTH LAGOON–SOUTHERN OCEAN
2010 TEMPORARY PUMPING OPTION
Figure 10

In addition to the pipeline, additional construction and operational infrastructure is required, including a pump station, cabling, operational compound, fuel storage, Princess Highway modifications and ocean outfall. Diesel generator set was the preferred means of power generation for the pump.

7.1.1 Previous Assessments

The selection of the preferred pumping rate was based on the outcomes of feasibility investigations and modelling undertaken throughout 2009 for the SA Murray Darling Basin NRM Board (Aurecon 2009, BMT WBM 2009). The outcomes of these assessments were summarised in the Technical Feasibility Assessment – Pumping hypermarine water out of the Southern Lagoon of the Coorong by the Department for Environment and Heritage (now DEW) in 2010.

Previous assessments considered three potential pump rates over three time periods, 150 ML/day for 18 to 36 months, 250 ML/day for 18 to 36 months and 450 ML/day for 3 to 4 months once per year over 3 years (Department for Environment and Heritage 2010c). Modelling indicated that the 150ML/day option would not decrease salinity in the South Lagoon over time, only maintain current levels. Expert opinion of marine scientists was that large pulse events of hypermarine water would have more negative effects in the ocean receiving environment than lower volume continuous discharge.

In 2010 the Department of Environment and Natural Resources (DENR) through SA Water initiated an Early Contractor Involvement (ECI) process to secure the services of a Contractor to design and construct the pumping solution. The ECI process involved the formulation of various options, development of a preferred concept design and an estimated price for detail design, construction, operation and maintenance of the solution. The project did not proceed to construction, although the design process did proceed to selection of a preferred concept and documentation of the concept.

A range of site investigations were undertaken as part of the ECI project including survey, geotechnical investigations, consultation with aboriginal groups and environmental studies.

7.1.2 Outcomes of Previous Consultations

It is understood that consultations have been undertaken, particularly throughout the ECI design phase, however the details of this consultation, along with outcomes, are have not been cited.

The ECI design report notes that the site inspections and subsequent discussions with stakeholders attempted to identify and incorporate allowance for the requirements of other stakeholder groups and the risks associated with such requirements. These discussions included government agencies such as EPA, National Parks, DPTI, local community groups such as commercial fishers and nearby residents.

7.2 Potential Benefits

7.2.1 Environmental

Salinity is one of two key abiotic drivers of ecosystem health in the Coorong (Brookes et al. 2009), the other being water level. The target salinity range for the South Lagoon to maintain a healthy ecosystem is a maximum of 100 g/L in summer and a maximum of 60 g/L in winter (Lester et al. 2009b). This salinity range best supports an ecosystem characterised by the aquatic plant *Ruppia tuberosa*, chironomid larvae as the dominant macroinvertebrate, and the small-mouthed hardyhead fish. It is this ecosystem that supports the productive mudflats of the South Lagoon that are a key component of the ecological character of the Coorong, contributing to its status as a wetland of international importance (Phillips and Muller 2006).

Modelling showed that the salinity levels in the South Lagoon were expected to converge to near target levels within three years of pumping for the preferred 250 ML/day option (Department for Environment and Heritage 2010c). This reduced salinity was expected to result in a significant increase in the ecological health of the South Lagoon; an increase in the ruppia / chironomid / hardyhead ecosystem, and a subsequent increase in the abundance of larger fauna which feed on the elements of that ecosystem.

7.2.2 Social and Cultural

No specific social or cultural benefits have been identified. This represents a potential knowledge gap.

7.2.3 Economic

No specific economic benefits have been highlighted. This represents a potential knowledge gap.

7.3 Potential Impacts

7.3.1 Environmental

- Noise: The proposed Coorong South Lagoon Pumping operation was located approximately 3 to 4 km south-west of one receptor township, two farmhouses and nearby smaller houses which dot the immediate Coorong area namely, within and surrounding Carinya, Orlunda Downs and Policeman Point (a township in direct line of sight of the proposed operation). Given the proximity of the proposed pump station to these residences, and considering the key topographical features of the area, an emphasis on the mitigation of noise impacts was a key design consideration.
- CO2 emissions: The running of diesel generators to power the pumps would contribute a significant amount of CO_2 to the atmosphere (Department for Environment and Heritage 2010c). Greenhouse gas emissions associated with operation of the generators were calculated at between 13,870 tonnes and 36,987 tonnes over the (temporary) lifespan of the project.
- Threatened species: several nationally threatened flora and fauna species were noted by Aurecon as potentially present on and near the lagoon where pumping infrastructure would exist (Department for Environment and Heritage 2010c). However, it was noted that existing cleared sites existed on the eastern side of the Coorong which were likely suitable for the generators without additional clearance.
- Vegetation clearance: The pipeline would require at least partial burial which would require grading of a trench through the dunes along with some associated vegetation clearance. The trench was estimated at around 10m wide with the pipe to be left in place in the case that future pumping of the South Lagoon was required.
- Marine impacts: The discharge of hypermarine water from the Coorong into the Southern Ocean was expected to have little effect on nationally significant ecology in the Southern Ocean, although some effects on ecology *not* considered nationally significant were expected (particularly the Goolwa Cockle) (Department for Environment and Heritage 2010c). While the discharge was expected to be between 4 and 5 times more saline than seawater, modelling suggested that a salinity increase of only around 5% would be experienced 2 km out into the Southern Ocean and would not be detectable against the background.
- Acid Sulphate Soils: The pumping out of the South Lagoon was expected to drop water levels up to 0.2 m below those that occur naturally (Department for Environment and Heritage 2010c). Two potential effects were noted: exposure of acid sulphate soils causing acidification of the South Lagoon, and reduction in *Ruppia tuberosa* due to increased mudflat exposure.
  The potential for acid sulphate soils to acidify the South Lagoon was reviewed by the CSIRO in 2008 and was considered low to moderate at the time (Department for Environment and Heritage 2010c). Further, exposure of the soils could be managed through a decrease in pump rate, although some efficiency in removal of the hypermarine water in the South Lagoon would be lost. Water quality and water level monitoring was proposed to assess and mitigate exposure of acid sulphate soils throughout the project.

The position of experts at the time was that the negative ecological impacts in the short term would be significantly outweighed by the positive ecological benefits in the long term (Department for Environment and Heritage 2010c).

7.3.2 Social and Cultural

It was recognised there was requirement for consultation and approval of the Ngarrindjeri people prior to and throughout the ECI process.

The ECI design report notes that archaeological investigations and consultation with the local Aboriginal community indicated a preference for the alignment option selected, as the alternative alignments were expected to have higher potential for encountering Aboriginal artefacts.

No details of the extent or nature of consultation with Aboriginal groups or other stakeholders (including landholders) cited, although anecdotal reports suggest that representatives were involved in site walkovers when assessing alignment options.

7.3.3 Economic

No known economic impacts have been identified at this time. This represents a potential knowledge gap.

7.4 Estimated Cost

Early cost estimates prepared in 2009 in advance of the ECI process ranged from $20M for the 'best case scenario of pumping for 18 months, to $33M for the more conservative scenario of pumping for 4 years (Department for Environment and Heritage 2010c). The costs were based upon pumping 24 hours a day, 7 days per week.

The $20M-$33M costings presented above comprise:

- Approximately $15M-$18M capital cost investment (purchase and installation of equipment)
- Approximately $5M-$15M operations and maintenance costs (including fuel and monitoring)

Firm details of costings developed during the ECI phase of the project, which were based upon the design developed and costed by the construction contractor, are not available, however personnel communications with project staff have indicated the project was costed at $17.5m (AUD 2010), similar to the earlier estimates.

Costs quoted are in 2010 dollars. The Reserve Bank of Australia Inflation Calculator indicates a change in cost between 2010 and 2019 of 19.8% at an average inflation rate of 2.0%.

7.5 Current Knowledge Gaps

The following knowledge gaps and necessary further work has been identified. This list should not be considered exhaustive, but represents some of the key issues:

- Additional work may have been undertaken throughout 2010 as part of the ECI process, however details of activities such as landholder, community, stakeholder and aboriginal consultation have not been found. Further work is therefore needed to confirm the cultural and social impacts associated with the project. Given the passage of time since completion of the designs, past outcomes may no longer be of relevance.
- No record of the capital and operating costs of the final solution chosen have been found, nor any assessment of the benefit-cost ratio or other economic assessment.
- With 10 years having passed since the end of the millennium drought, a contemporary understanding of the benefits of a temporary pumping solution for salinity reset also needs to be understood.

8 Option 7 – Permanent connection between the Coorong South Lagoon and Southern Ocean

The option of a connecting pipe or channel between the Coorong South Lagoon and the Southern Ocean arose from the idea of managing salinities in the South Lagoon through either introducing flows of lower salinity marine water or exporting flows of hypermarine water in the South Lagoon (Department for Environment and Heritage 2010a).

The similarity between this option and the 'Coorong South Lagoon Pumping Project' investigated as part of the Coorong South Lagoon Salinity Reduction Scheme (SLSRS) is noted. For pumping of water from the South Lagoon to the ocean this option is effectively an ongoing (as opposed to temporary) SLSRS. In general, assessments made regarding the SLSRS are valid for this option also.

Less investigative work has been completed on an option to pump water from the Southern Ocean into the South Lagoon, however many of the construction impacts and infrastructure requirements will be similar in nature.

8.1 Option Description

Explored options included:

- 150 ML/day pumping out of the South Lagoon
- 150 ML/day pumping out of the South Lagoon in addition to deepening the channel at Hell's Gate
- pumping 150 ML/day into the South Lagoon from the Southern Ocean (Department for Environment and Heritage 2010a).

At the time, the preferred option after investigation was the combination of pumping out of the South Lagoon and deepening of the channel at Hell's Gate.

A pumping option would require:

- Power supply
- A pumping station including pump(s), switching gear, controls and a shed
- Pipe(s) across the dunes
- Intake and outlet facilities.

The infrastructure is likely to be similar to that discussed for Option 6, although may be more permanent in nature.

8.1.1 Previous Assessments

Formal assessments considering the specific option of a permanent pipe connecting the South Lagoon of the Coorong with the Southern Ocean were undertaken as part of the 2009 study investigating options for maintaining an open Murray Mouth (BMT WBM 2009).

Modelling considered a connector between the South Lagoon and Southern Ocean, either allowing flow from the lagoon to the ocean or conversely from the ocean to the lagoon (BMT WBM 2009). All options assumed that the existing Murray Mouth dredging regime continued.

Additional investigations associated with a temporary pumping options from the South Lagoon to the ocean were undertaken as part of the Coorong South Lagoon Salinity Reduction Scheme discussed in the preceding section. These investigations explored options of 150 ML/day as well as 250 ML/day and 450 ML/day.

8.1.2 Outcomes of Previous Community Consultations

No known previous community or indigenous consultations for a permanent pumping option have been explored. Some consultation has been undertaken for the South Lagoon Salinity Reduction Scheme but not for a permanent option. Consultations undertaken for that scheme may be relevant to this option.

8.2 Potential Benefits

8.2.1 Environmental

Investigations into a permanent connection between the South Lagoon and the Southern Ocean focussed on the impacts on the key indicators of salinity and water level.

Modelling indicated that both options which include pumping out of the South Lagoon significantly reduce salinity in both the North and South Lagoons, even as far north as Tauwitchere. The option that includes pumping of seawater into the South Lagoon would decrease salinity in the South Lagoon but significantly increase it along the North Lagoon to and beyond Tauwitchere.

Pumping of seawater into the South Lagoon tends to increase water levels in the South Lagoon, forcing water into the North Lagoon. Pumping water out of the South Lagoon tends to lower water levels, with the effect more marked when dredging at Parnka Point is not undertaken in conjunction.

8.2.2 Social and Cultural

No specific social or cultural benefits have been identified. This represents a potential knowledge gap.

8.2.3 Economic

No specific economic benefits have been highlighted. This represents a potential knowledge gap.

8.3 Potential Impacts

8.3.1 Environmental

In 2010, DEH recognised that there was potential for environmental impacts if the South Lagoon Salinity Reduction Scheme (SLSRS) was implemented. This option is very similar in that installation of pumping infrastructure across the dunes separating the South Lagoon and the Southern Ocean was considered. The impacts given below are applicable to those of the South Lagoon Salinity Reduction Scheme but are likely relevant to the option of permanent pumping also.

- Noise: A pumping operation is likely to be located close to receptors which dot the immediate Coorong area. Proximity of a pump station to receptors, and considering the key topographical features of the area, an emphasis on the mitigation of noise impacts would be a key design consideration.
- CO2 emissions: The running of diesel generators to power the pumps would contribute a significant amount of CO_2 to the atmosphere (Department for Environment and Heritage 2010c).
- Threatened species: several nationally threatened flora and fauna species were noted by Aurecon as potentially present on and near the lagoon where pumping infrastructure would exist (Department for Environment and Heritage 2010c). However, it was noted that existing cleared sites existed on the eastern side of the Coorong which were likely suitable for the generators without additional clearance.
- Vegetation clearance: The pipeline and pump station would require at least partial burial which would require grading of a trench through the dunes along with some associated vegetation clearance. The trench may be around 10 m wide.
- Marine impacts: The discharge of hypermarine water from the Coorong into the Southern Ocean was expected to have little effect on nationally significant ecology in the Southern Ocean, although some effects on ecology *not* considered nationally significant were expected (Department for Environment and Heritage 2010c). While the discharge was expected to be between 4 and 5 times more saline than seawater, modelling suggested that a salinity increase of only around 5% would be experienced 2 km out into the Southern Ocean and would not be detectable against the background.

- Marine impacts: Construction of a marine in take or outfall structure will have localised effects on marine and beach ecology, including disturbance created during construction.
- Acid Sulphate Soils: The pumping out of the South Lagoon was expected to drop water levels up to 0.2 m below those that occur naturally (Department for Environment and Heritage 2010c). Two potential effects were noted: exposure of acid sulphate soils causing acidification of the South Lagoon, and reduction in *Ruppia tuberosa* due to increased mudflat exposure.
  The potential for acid sulphate soils to acidify the South Lagoon was reviewed by the CSIRO in 2008 and was considered low to moderate at the time (Department for Environment and Heritage 2010c). Further, exposure of the soils could be managed through a decrease in pump rate, although some efficiency in removal of the hypermarine water in the South Lagoon would be lost. Water quality and water level monitoring was proposed to assess and mitigate exposure of acid sulphate soils throughout the project.
- Salinity of the North Lagoon: For the option including pumping into the South Lagoon from the ocean, salinity was expected to increase within the North Lagoon due to the forcing of marine water in a northerly direction.
- Modification of salinity gradient: The salinity gradient from the Murray Mouth to the South Lagoon is one of the ecological characters of the site. Sea water entering the south lagoon may disrupt this gradient, resulting in a (relatively) fresher zone in the South Lagoon. The ecological impacts of this are largely unknown.

8.3.2 Social and Cultural

In 2010, DEH recognised that there was potential for environmental impacts if the South Lagoon Salinity Reduction Scheme (SLSRS) was implemented. This option is very similar in that installation of pumping infrastructure across the dunes separating the South Lagoon and the Southern Ocean was considered. The social and cultural impacts are therefore expected to be very similar to those associated with the Coorong Pumping project. It was recognised there was requirement for consultation and approval of the Ngarrindjeri people.

The design report for the South Lagoon pumping project (Tonkin 2010) notes that archaeological investigations and consultation with the local Aboriginal community indicated a preference for the alignment option selected, as the alternative alignments were expected to have higher potential for encountering Aboriginal artefacts.

No details of the extent or nature of consultation with Aboriginal groups or other stakeholders (including landholders) is available, although anecdotal reports suggest that representatives were involved in site walkovers when assessing alignment options.

8.3.3 Economic

No known economic impacts have been highlighted other than ongoing operational and maintenance costs associated with pumping infrastructure. This represents a potential knowledge gap.

8.4 Estimated Cost

All costs provided below are quoted in 2009 dollars. The Reserve Bank of Australia Inflation Calculator indicates a change in cost between 2009 and 2019 of 23.3% at an average inflation rate of 2.1%.

8.4.1 Capital Costs

Capital costs estimated for temporary 150 ML/day option were around $9.8m (2009 AUD) by Tonkin, (2009). Capital costs for a permanent solution ranged from approximately $7m for a pump out facility to approximately $10m for a pump in facility (BMT WBM 2009).

8.4.2 Operational Costs

The estimated yearly operational costs for the permanent pumping option were estimated at $0.75m (AUD, 2009) (BMT WBM 2009). Yearly operational costs for the temporary option were estimated at around $3.6m (AUD 2009) (Tonkin 2009), almost all of which was fuel supply costs to run pumps. Assumptions were made regarding energy supply in the permanent case which were investigated and found untenable in the feasibility assessment undertaken for the temporary option in 2010; particularly, that connection to the grid would be economically feasible (Department for Environment and Heritage 2010c). An estimate for the cost to connect to (at the time) ETSA infrastructure indicated this would not be the case as over 45 km of new major transmission infrastructure would be required.

The NPV for the permanent solution (including the assumed mains power supply) ranged between $10m and $13m for the pump out solution and $13m and $16m for the pump in solution depending on the frequency of pumping required. These NPV estimates are expected to more than double if the annual operating costs are in the order of millions due to fuel supply costs.

8.5 Current Knowledge Gaps

The following knowledge gaps and necessary further work has been identified. This list should not be considered exhaustive, but represents some of the key issues:

- Details of activities such as landholder, community, stakeholder and aboriginal consultation have not been sourced, although it is noted that consultation may have occurred for the temporary pumping solution as part of the Coorong Pumping Project design process. Regardless, further work is needed to confirm the cultural and social impacts associated with the project, whether temporary or permanent. Given the passage of time since past investigations, past outcomes may no longer be of relevance anyway.
- No reliable estimates capital or operating costs are available as options did not progress to detailed feasibility or design stages. If considered further, an assessment of the benefit-cost ratio or alternative economic assessment will be required.
- Further confirmation of impacts of any connection to the Southern Ocean, whether this be pumping in or out of the South Lagoon, are required as it may not be possible to achieve both key objectives of salinity and water level management with this option without creating adverse impacts on the North Lagoon.
- A detailed assessment of the physical impacts of ocean intake or outfall structures needs to be undertaken.
- If considered further, more detailed planning, design and impact assessment with regard to longer-term sustainability and impacts with respect to potential climate change and sea level rise scenarios would be required.

9 Business as Usual

The business as usual option represents a continuation of current operating procedures and infrastructure. In particular, this includes:

- Maintenance of current dredged channel dimensions (dredging has operated continuously since 2015 continuously, with a short break during the 2016/17 high flow event)
- Existing barrage operations which includes the use of the prototype decision support tool for optimised water releases over the barrages to improve north and south lagoon salinity levels.
- Maintenance and operation of the South East Flows Restoration Project (SEFRP) in conjunction with normal south east drainage flows, as completed in 2019.

9.1 Options Description

The business as usual case represents the status quo, with no further engineering intervention.

Current dredging operations have been in place since 20142015, maintaining the openness of the Murray Mouth (Department for Environment and Water n.d.-b). At times since commencement, one to two dredges have been utilised when required to maintain the same mouth openness, showing that there is operational flexibility depending on requirements during certain times of the year.

South East drainage discharges to the Coorong have been increasing over time as drainage systems constructed under the Upper South East Dryland Salinity and Flood Management Plan have been progressively completed. A boost to these flows was enabled through completion of the South East Flows Restoration Project in 2019, which will enable supply of additional freshwater flows from drainage in the South East to the southern extremity of the South Lagoon Via salt creek. Key construction activities enabled diversion of fresh water from the Blackford Drain near Kingston northwards to the Coorong South Lagoon. The scheme includes the operational flexibility to divert water into and store within key wetlands of the south east, including Tilley Swamp, for optimal release.

9.1.1 Previous Assessments

Whilst no explicit previous assessments have been undertaken for a 'business as usual' case per se, the current state of the Coorong, and in particular the South Lagoon is well documented and has been the subject of numerous studies and investigations over the past several decades.

Recognising the current limitations in effective management of water with the current infrastructure and challenges associated with a changing climate in the future, there have been extensive investigations into engineering interventions and long-term management actions aimed at addressing the effects of altered south east drainage practices, water over-allocation across the Murray-Darling Basin and the effects of drought. Each of these investigations has generally defined the need for intervention and the consequences of not acting.

9.1.2 Outcomes of Previous Community Consultations

In 2018, the Coorong Summit brought together a broad range of community, scientific, First Nations and industry perspectives and interests to consolidate current understanding of the site and the key processes driving its ecological condition. This included investigating the current drivers for water quality, including nutrification, hyper-salinity and the processes driving the ecological condition of iconic species such as Ruppia, benthic macroinvertebrates and migratory bird species. The summit was also an opportunity to scope a vision for the site's potential future, develop objectives and targets for future management, as well as identify challenges to achieving this vision.

The Summit's vision for the site's future was:

"*We want the Coorong to return to being a beautiful landscape teeming with abundant and diverse populations of waterbirds, fish and plants. We want the Coorong to support the values of the Traditional*

Owners and be an icon for South Australia and its visitors through supporting a strong tourism industry. We want management of the Coorong to not be rigid and must allow for variability in environmental and river operations conditions. It must also be managed at an ecosystem scale including the Murray Mouth, Lower Lakes and surrounding wetlands and more broadly and importantly within the Murray-Darling Basin."

This vision is unlikely to be fully achieved by the business as usual option but elements can be achieved by business as usual.

9.2 Potential Benefits

9.2.1 Environmental

Business as usual operations imply that potential environmental impacts are not introduced, but conversely additional environmental benefits are also not introduced. Potential environmental impacts avoided included, as identified for the management options considered in this report include:

- GHG emissions from construction or operations
- Displacement of or damage to ecosystems or habitat associated with construction
- Scouring / erosion caused by construction and artificial flowrates associated with suction or discharge of pumping mains
- Increases in turbidity due to dredging and other construction activities
- Migration of pest fish to new areas
- Reduction in environmental flows to south east wetlands
- Increases in salinity associated with flow regulation within the South Lagoon
- Impacts on water quality due to additional south east drainage flows
- Discharge of hypermarine water into Southern Ocean
- Potential for exposure of acid sulphate soils

This list is not exhaustive.

These represent potential environmental 'benefits' insofar as they are impacts not experienced with the business as usual option.

9.2.2 Social and Cultural

Business as usual operations imply that potential social and cultural impacts are not introduced.

9.2.3 Economic

Business as usual operations imply that potential economic impacts are not introduced. In particular, no additional capital or operational expenditure which associated with any of the options will be required.

9.3 Potential Impacts

9.3.1 Environmental

The Healthy Coorong Healthy Basin Action Plan notes that "*several critical components, processes and services that define the ecological character of the Coorong are at risk of exceeding their limits of acceptable change. Although the key ecological features of the Coorong that make it a unique and valuable place are still present, the system is in a vulnerable state, with little capacity to absorb continued and cumulative environmental stress. For the Basin Plan to succeed, the Coorong must be returned to a healthy and resilient condition.*"

The risk of a business as usual option is that under continued climatic stress the ecological character of the Coorong South Lagoon will continue to decline due to increasing salinity levels and low water levels at critical times of the year. With these factors leading to reduced availability of food resources, reductions in the abundance of some waterbirds, including migratory shorebirds may continue.

9.3.2 Social and Cultural

The Coorong is of enormous cultural significance to the Ngarrindjeri people. The southern part of the Coorong South Lagoon is also culturally significant to the First Peoples of the South East and is part of their Traditional Country. Whilst the business as usual case will not introduce any new cultural impacts associated with infrastructure works or revised management actions, further decline in the ecological character of the South Lagoon may adversely impact cultural values.

Failing to maintain a healthy Coorong not only has implications for First Nations people, it also has consequences to the wider public who utilise the region for a wide range of activities including birdwatching, commercial and recreational fishing, canoeing, four-wheel-driving and camping.

9.3.3 Economic

Business as usual operations imply that potential economic benefits are not being realised.

The Healthy Coorong Healthy Basin Action Plan notes that the nearly 28,000 people who live in the Coorong, Lower Lakes and Murray Mouth region mainly work in agriculture, viticulture, fishing, manufacturing and tourism, with the majority of industries relying on a healthy wetland system to thrive.

9.4 Estimated Cost

9.4.1 Capital Costs

The capital costs of business as usual are zero.

9.4.2 Operational Costs

Existing operational costs will continue. These operational costs include the operational costs for the dredging operations, and operations and maintenance of SEFRP.

10 Summary

A review of existing literature relating major infrastructure and management options that have been identified over the past two decades, aimed at improving the delivery of water to the Coorong and the ability to manage it for ecological benefit, has been undertaken. The objectives of each option investigated has often varied but have generally aimed to address two key biotic indicators of salinity and water level. In more recent times nutrient loads have emerged as a key ecological indicator of concern with further work needed to understand nutrient dynamics within the Coorong and its impacts.

Investigations have been undertaken to varying levels of detail, with some investigated at a high level only (Murray Mouth options, permanent Southern Ocean connection, North Lagoon – South Lagoon dredging), some the subject of detailed feasibility assessments (Lake Albert – Coorong Connector, South Lagoon Regulating Structure) and some proceeding to business case and/or detailed design (South East Flows Augmentation, temporary South Lagoon pumping option). Despite the level of investigation, none have proceeded to construction, either fully or partially.

The table below summarises the key focus areas for each of the options investigated, whether a detailed feasibility study has ever been undertaken, and the indicative capital cost of implementation reported in the literature.

The capital costs reported are not necessarily intended to provide a reliable estimate of costs to implement but do demonstrate that all options investigated previously will require a significant capital investment, along with ongoing operational and maintenance costs. O&M costs are expected to vary between several hundred thousand dollars per year to several million dollars per year, depending on the option.

Costs within this report have not been updated to present day figures, however in each case, an indication of potential cost increase since the estimates were prepared has been given based on the Reserve Bank of Australia Inflation Calculator. These values are shown in brackets in the table below. It is noted that these potential cost increases do not take into account changes in technology, construction methodologies or materials and construction costs that may have varied in response to economic factors other than standard inflation.

	Option	Primary objective	Detailed feasibility assessment?	Indicative capital costs (+ inflation estimate)[1]
1	Options for maintain an open Murray Mouth (dredging, sand fluidisation, training walls)	Improved connectivity and water exchange between the ocean and Coorong	No	Training Walls: $50m (2009) (+23%)
2	Lake Albert – Coorong Connector	Salinity and water level management within Lake Albert	Yes (channel only)	$20m (2013) (+11.2%)
3	Dredging between the North Lagoon and South Lagoon to improve connectivity (not a standalone solution)	Salinity and water level management within the Coorong South Lagoon	No	$7m (2010) (+19.8%)

	Option	Primary objective	Detailed feasibility assessment?	Indicative capital costs (+ inflation estimate)[1]
4	South East Flows Augmentation	Salinity and water level management within the Coorong South Lagoon	Yes	$40m (2017) (+3.6%)
5	South Lagoon Regulating Structure	Water level management within the Coorong South Lagoon	Yes	$15m-$35m (2017) (+3.6%)
6	Temporary Pumping from the South Lagoon to the Southern Ocean	Salinity management within the Coorong South Lagoon	Yes	$10m (2009) (+23%)
7	Permanent Connection between the South Lagoon and Southern Ocean	Salinity management within the Coorong South Lagoon	No	$10m-$16m (2009) (+23%)

Environmental, social, cultural and economic risks and benefits vary between options. In general, all options achieve salinity reduction within the South Lagoon and the associated ecological benefits, albeit to a varying degree. Benefits relating to water levels within the South Lagoon are more variable. The risks or benefits to nutrient loads, cycling and filamentous green algal growth is less well defined as this has emerged as a key indicator of ecological health in more recent years.

All options will result in some degree of environmental, social and cultural impact, with the magnitude dependent upon the option and the mitigation measures put in place during design and construction.

Knowledge gaps and the requirement for further work varies between options, however the following are applicable to all options:

- Consideration of long-term sustainability and impacts with respect to sea level rise scenarios and other potential climate change impacts including changing rainfall and temperature patterns.
- Further understanding of the positive and negative ecological response of the Coorong to changes in water levels and salinity and the timescale over which these changes are expected, with specific reference to the South Lagoon.
- Further understanding of filamentous green algae and why blooms are occurring annually after the Millennium Drought. Specifically, there is a need to better understand:
  - the spatial scale of the filamentous green algae problem in the Coorong
  - the nutrient sources (River Murray, Coorong, South East) that are causing the blooms to occur more consistently since the Millennium Drought, as well as the intra-Coorong cycling of nutrients.
- An understanding of community and stakeholder acceptance, gained through a detailed stakeholder and community engagement process.
- Further investigations into potential cultural heritage constraints and development of an engagement strategy with First Nations people, which includes involvement of the Aboriginal peoples of the region.
- Detailed economic analyses, including and understanding of the whole of life costs and benefits, expressed as a benefit-cost ratio, net present value or other measure.
- Detailed planning, design and impact assessment.

Appendix A – References

Aurecon. (2009). *Preliminary Hydrodynamic Modelling Report, Coorong Temporary Saline Water Discharge*. SA Murray-Darling Basin NRM Board.

Berghius, A. P. (2017). Pest Fish Barrier Concept for Blackford Drain Catchment. Aquatic Biopassage Services.

BMT WBM. (2009a). *Coorong Model Upgerade and Simulations of Proposed Pumping from the Southern Lagoon*. SA Murray-Darling Basin NRM Board.

BMT WBM. (2009b). *Review of Schemes for Maintaining an Open Murray Mouth*. Department for Environment and Heritage.

BMT WBM. (2017a). *Coorong Options Assessment*. Department of Environment, Water and Natural Resources.

BMT WBM. (2017b). *RE: Lake Albert Connector Simulations*. Department of Water, Environment and Natural Resources.

Brookes, J. D., Lamontagne, S., Aldridge, K. T., Benger, S., Bisset, A., Bucater, L., Cheshire, A. C., Cook, P. L. M., Deegan, B. M., Dittman, S., Fairweather, P. G., Fernandes, M. B., Ford, P. W., Geddes, M. C., Gillanders, B. M., Grigg, N. J., Haese, R. R., Krull, E., Langley, R. A., … Ye, Q. (2009). *An Ecosystem Assessment Framework to Guide Mangement of the Coorong. Final Report of the CLLAMMecology Research Cluster.* CSIRO Water for a Healthy Country National Research Flagship, Canberra ACT.

Department for Environment and Heritage. (2010a). *Managing Salinity in the Coorong—Maintaining an Open Murray Mouth*. Department for Environment and Heritage.

Department for Environment and Heritage. (2010b). *Increasing Transmission Flows in the Coorong: Targeted Excavation of Hell's Gate*. Department for Environment and Heritage.

Department for Environment and Heritage. (2010c). *Managing Salinity in the Coorong—Pumping Hypersaline Water out of the Southern Lagoon*. Department for Environment and Heritage.

Department for Environment and Heritage. (2010d). *Managing Water Levels in Lake Albert to Prevent Acidification*. Department for Environment and Heritage.

Department for Environment and Water (2019a) Healthy Coorong Healthy Basin: 4. Long Term Operational Infrastructure Project Proposal. Government of South Australia, 28 March 2019.

Department for Environment and Water (2019b) Project Coorong - Healthy Coorong Healthy Basin Action Plan. Government of South Australia.

Department for Environment and Water. (n.d.). *Keeping the Murray Mouth open*. Retrieved June 3, 2020, from https://www.naturalresources.sa.gov.au/samurraydarlingbasin/projects/all-projects-map/keeping-the-murray-mouth-open

Department of Environment, Water and Natural Resources (2014) Lake Albert Scoping Study Options Paper, Government of South Australia, August 2014.

Department of Environment, Water and Natural Resources. (2017a). *Coorong Investigations Study: Feasibility Assessment Report*. Department of Environment, Water and Natural Resources.

Department of Environment, Water and Natural Resources. (2017b). *South East Flows Augmentation Buisness Case*.

Ebsary, R. M. (1983). *Lake Albert Salinity Study*. South Australian Department of Environment and Planning.

Econsearch. (2017). E*conomic Analysis of the Proposed South East Flows Restoration Project Augmentation*. Department of Environment, Water and Natural Resources.

Fulton C and Brookes J (2017) *Preliminary assessment of potential ecological benefits or negative impacts of a Coorong regulator and augmentation of South East flows to the Coorong,*

Hipsey, M. R., Busch, B. D., & Aldridge, K. T. (2017). Coorong Investigations Project: Ruppia habitat changes in response to augmented South East Flows scenarios and a regulating structure. Department of Environment, Water and Natural Resources.

Lester, R., Webester, I., Fairweather, P., & Langley, R. (2009). *Predicting the ecosystem response of the Coorong to the South Lagoon Salinity Reduction Scheme*. SA Murray-Darling Basin NRM Board.

Lester, R., Webester, I., Fairweather, P., & Langley, R. (2009). *Understanding and Quantifying the Ecological Benefit of Dredging the Murray Mouth*. Flinders University.

Mosley L.M., and Hipsey M. (2019). Health Coorong Healthy Basin - Water quality in the Coorong, 2019 Monitoring Report. Report to the Department for Environment and Water. School of Biological Sciences, University of Adelaide.

Mosley, Luke & Hamilton, Ben & Busch, Brendan & Hipsey, Matthew & Taylor, Ben. (2017). Assessment and modelling of the effects of the 2013-2016 Morella Basin Releases on Coorong Water Quality.

Ngarrindjeri Regional Authority. (2013). N*garrindjeri Position Paper—Lake Albert Scoping Study.*

Paton, D. C., Paton, F. L., & Bailey, C. P. (2015). *Ecological Character Description for Ruppia tuberosa in the Coorong*. University of Adelaide. https://data.environment.sa.gov.au/Content/Publications/CLLMM_220_ECD%20for%20Ruppia%20Tuberosa_2015.pdf

Phillips, W., & Muller, K. (2006). Ecological Character of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance. Department for Environment and Heritage.

Sims, C. (2017). *Long term Coorong hydrodynamic modelling—Coorong Investigations Project*. Department of Environment, Water and Natural Resources.

Tonkin Consulting (2008). Lake Albert Investigation—Evaporation Offeset Pumping Pre-Feasbitility Investigation. SA Water.

Tonkin Consulting (2009). *Coorong Temporary Pumping Review*. South Australian Murray Darling Basin NRM Board.

Tonkin Consulting (2010). *ECI Design Report—Coorong South Lagoon Pumping Project*.

Tonkin Consulting (2017a). *SEFRP Augmentation: Pre-feasibility design and costings*. Department of Water, Environment and Natural Resources.

Tonkin Consulting (2017b). *SEFRP Augmentation: Preliminary Design Report*. Department of Water, Environment and Natural Resources.

Tonkin Consulting (2017c). *Coorong Investigations Project—Engineering Feasibility: Coorong Regulating Structure*. Department of Environment, Water and Natural Resources.

Whiterod, N., & Gannon, R. (2017). Assessing the risks of Eastern Gambusia invasion in Drain L catchment associated with SSEFRP augmentation. Department of Environment, Water and Natural Resources.

Whiting, J. (2017a). *Augmenting the South East Flows Restoration Project—Hydrological Modelling—Stage 1 review*. Department of Environment, Water and Natural Resources.

Whiting, J. (2017b). *SEFRP Augmentation—Hydrological analysis Stage 2: Development of Source model*. Department of Environment, Water and Natural Resources.

WMB and L&T. (2004). *Murray River Mouth—Review of Alternative Schemes*. The Department of Water, Land and Biodiversity Conservation.