MURRAY FUTURES

Lower Lakes & Coorong Recovery

1. Managing Salinity in the Coorong – pumping hypersaline water out of the Southern Lagoon

Technical Feasibility Assessment

Version 13 February 2010

Government of South Australia

WATER FOR GOOD

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1 PROJECT CONTEXT AND SCOPE

1.1 Managing salinity in the Coorong

This Technical Feasibility Assessment addresses one of three complementary projects developed for managing salinity in the Coorong, collectively referred to as the Coorong Salinity Management Strategy (CSMS). This document covers the pumping of hypermarine water from the southern Coorong into the Southern Ocean, a project referred to as the South Lagoon Salinity Reduction Scheme (SLSRS). The other two projects of the CSMS are the maintenance of an open Murray Mouth and the Coorong South Lagoon Flow Restoration Project (CSLFRP).

The aims of CSMS are to reduce salinity in the South Lagoon, to slow or prevent future increase in salinity and to maintain connectivity between the Coorong and the sea. If these aims are achieved in combination with an effective Basin Plan, it is anticipated that the ecosystem formerly present in the South Lagoon will re-establish there, and the Coorong and Murray Mouth ecosystem will be primed to respond favourably when barrage flows return. Taken in isolation, none of the three projects are likely to achieve the aims of the CSMS. For example, despite an open Murray Mouth being maintained through continuous dredging since October 2002, salinities in the South Lagoon have risen dramatically and key components of the former ecosystem have largely disappeared (Brookes *et al.* 2009). Similarly, the CSLFRP and SLSRS would be ineffective at reducing Coorong salinity if the Murray Mouth was closed (Lester *et al.* 2009a).

Salinity is one of two key abiotic drivers of ecosystem health in the Coorong (Brookes *et al.* 2009), the other being water level. Salinity has been increasing in the Coorong for a number of years, and particularly since 2002 (Figure 1), corresponding with a period of greatly reduced flows from the River Murray into the Coorong at the barrages. The target salinity range for the South Lagoon to maintain a healthy ecosystem is a maximum of 139,000 EC (100 g/L) in summer and a minimum of 87,000 EC (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 benthic macroinvertebrate, and the small-mouthed hardyhead fish (*Atherinosoma microstoma*). 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). These mudflats have historically provided feeding habitat for endemic and migratory shorebirds, many of which are protected under international agreements, including the Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

Salinity Units

In this report salinity is expressed as electrical conductivity (EC). The units of EC are microsiemens per centimetre ($\mu S.cm^{-1}$). Alternative units for salinity are grams per litre (g/L) and parts per thousand of total dissolved solids (ppt TDS). 1 g/L = 1 ppt/TDS. For conversion between EC and g/L this paper uses the formulae provided by Williams (1986):

For salinity <3000 mg/L (EC <5500 $\mu S.cm^{-1}$):
Salinity = 0.68EC (units: salinity mg/L, EC $\mu S.cm^{-1}$)

For salinity >3000 mg/L (EC>5500 $\mu S.cm^{-1}$):
Salinity = $0.466EC^{1.0878}$ (units: salinity g/L, EC $mS.cm^{-1}$).

The Ruppia/chironomid/hardyhead system dominated the South Lagoon as recently as 1999 (Brookes *et al.* 2009). Since 2002 the target maximum salinity in the South Lagoon has generally been exceeded throughout the entire year, and salinities have occasionally peaked at close to double the target level (Figure 1). As a consequence of excessive salinity, coupled with inappropriate water levels, the ecosystem of the South Lagoon has undergone a dramatic shift.

The Ruppia/chironomid/hardyhead system is now virtually absent from the South Lagoon and has contracted northward to be confined to a small area of the North Lagoon (Brookes *et al.* 2009). Aquatic plants and fish are now largely absent from the South Lagoon. Many of the characteristic waterbirds of the Coorong, including those protected under international agreements, have declined dramatically in number in the South Lagoon (Brookes *et al.* 2009).

Abundances of brine shrimp (*Parartemia zietziana*), banded stilt (*Cladorhynchus leucocephalus*) and chestnut teal (*Anas castanea*), species indicative of increased salinity, have increased dramatically in the South Lagoon since 2004 (Rogers and Paton 2009). Expansion of the remnant Ruppia/chironomid/hardyhead system further northwards into the greater North Lagoon appears to be prevented by salinities being too low. At salinities below 87,000 EC, the *Ruppia tuberosa* beds become smothered by filamentous algae and the Ruppia/chironomid/hardyhead system fails to establish.

Preservation of the remnant Ruppia/chironomid/hardyhead system present in the North Lagoon is critically important because it provides the only remaining source area from which future expansion and re-establishment throughout the South Lagoon can occur (Paton *et al.* 2009). The remnant habitat is extremely vulnerable to degradation or loss due to exposure to inappropriate salinity caused by wind seiche and other short-term or seasonal factors. If lost completely from the Coorong, re-establishment of the habitat would be extremely difficult or impossible to achieve, thus highlighting the urgency of reducing Coorong salinity via the SLSRS.

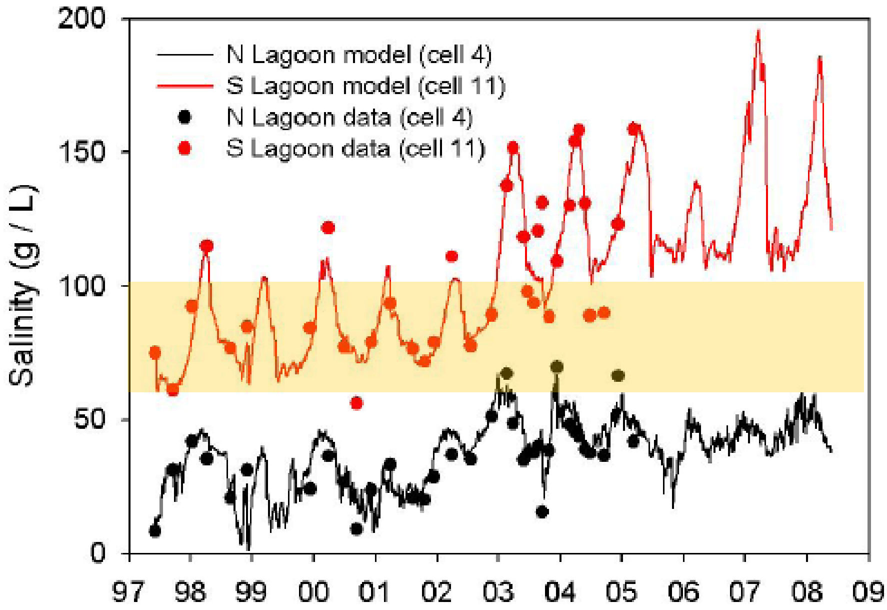

Figure 1. Salinity (modelled and actual) in the South Lagoon (red line, points) and North Lagoon (black line, points) of the Coorong from mid 1997 to mid 2008 (source: Lester *et al.* 2009b). Note cell 4 refers to the area of the North Lagoon in the vicinity of Mark Point and cell 11 to the area of the South Lagoon in the vicinity of Woods Well. The orange band represents the target salinity range for ecosystem health.

1.2 Project scope

The salt load of the Coorong South Lagoon is now so high that a major flood in the River Murray, with barrage flows in excess of 10,000 GL, is required to restore target salinities (Paton *et al.* 2009). A flow at the barrages of this magnitude is unlikely to occur for at least several years.

The South Lagoon Salinity Reduction Scheme is a one-off suite of engineering interventions aimed at reducing the salinity of the Coorong by moving salt out of the system. It is anticipated that the project will facilitate the ecological recovery of the South Lagoon by reducing salinities to within target levels for the Ruppia/chironomid/hardyhead ecosystem.

The project is based on the active pumping of hypermarine water out of the South Lagoon, piped across Younghusband Peninsula, to an ocean outfall. Related interventions that may make salinity management more sustainable (in the absence of flows over the Barrages), are under investigation. These include the option of dredging the natural channel between the North and South Lagoons to increase its transmission efficiency. If it were to proceed, dredging would be a future initiative after pumping begins, and is currently at concept stage only.

Pumping will export salt from the system, draw lower salinity marine water in through the Murray Mouth and thus reduce salinity throughout much of the North and South Lagoons of the Coorong (BMT WBM 2009b, Lester *et al.* 2009b). The project is currently at the concept design stage. All components of the project are subject to further feasibility assessment, which will influence the final detailed design. However, modelling has indicated the project does have the potential to reduce salinity and provide ecological benefits for the Coorong South Lagoon (BMT WBM 2009b, Lester *et al.* 2009b), and that these benefits are predicted at this stage to be ultimately possible without dredging (i.e. with pumping alone). The project scope includes further feasibility assessments and the researching and preparation of documents required for Commonwealth and State-level approvals.

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2 APPROACH

2.1 Alternative approaches

In the absence of sufficient flows over the barrages to flush the salt from the Coorong South Lagoon, some form of engineering intervention is required to export salt from the system. An alternative to the active pumping of water out of the South Lagoon is a passive, gravity-reliant approach. This would involve construction of a permanent pipeline between the South Lagoon and the ocean through the Younghusband Peninsula. Flow of hypermarine water (water of salinity greater than seawater) from the Coorong into the sea would occur when the difference in head levels permitted. Figure 2 illustrates the concept.

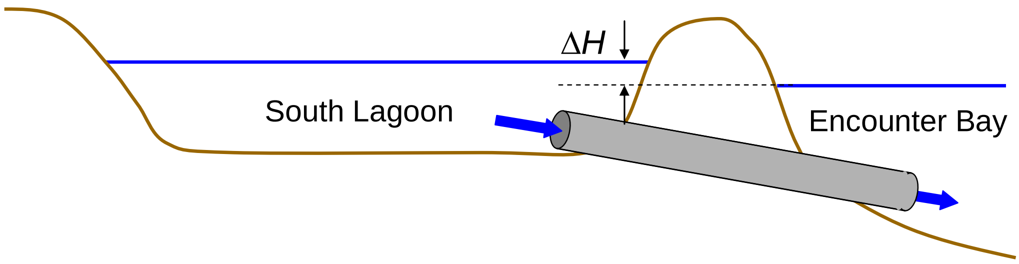

Figure 2. Schematic cross section of the South Lagoon showing a pipe connection to the sea.

A proposal to develop this idea further was submitted to the SA Murray-Darling Basin Natural Resources Management Board (SAMDBNRMB) by CSIRO (Webster 2009). The concept was modelled and discounted due to relative inefficiency and estimated costs. Other pumping locations in the South Lagoon were also assessed and were also discounted due primarily to modelled inefficiency.

During the extensive assessment process many different rates and durations of pumping have been considered including:

- pumping at 150 ML/day for 18 to 36 months
- pumping at 250 ML/day for 18 to 36 months
- pumping at 450 ML/day for 3 to 4 months once per year for 3 years.

The 450 ML/day option is likely to be about twice as expensive as the other options (Tonkin Consulting 2009) and the expert opinion of marine scientists on the project steering committee concluded that this large pulse event would be more detrimental to the ocean receiving environment then a lower volume continuous discharge. The option has therefore been ruled out.

Two-dimensional hydrodynamic modelling suggests that pumping at 150 ML/day would fail to reduce South Lagoon salinity to target levels (BMT WBM 2009b); it would merely maintain current levels (Figure 3). Modelling of pumping at a rate of 250 ML/day indicates that in the third year of pumping the target salinity levels are approached at Policeman Point (BMT WBM 2009b) (Figure 3), although definitive timelines against the targets are subject to many external factors. Based on cost and effectiveness of salinity reduction, a pumping rate of 250 ML/day is the preferred option. Note that while the modelling presented in Figure 3 is suitable for a comparison of different pumping and dredging options, updated modelling has been completed for the preferred option (Figure 4) with a revised initial salinity.

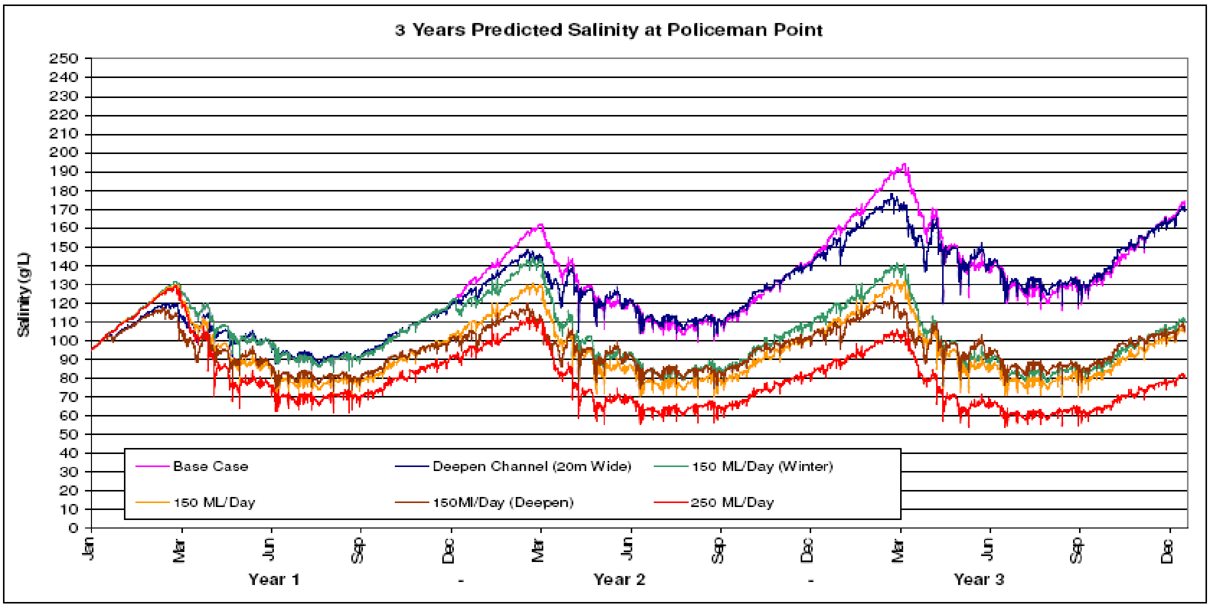

Figure 3. Modelled salinity in the South Lagoon under six intervention scenarios.
Note salinity levels at starting point are artificially low in comparison with predicted levels at actual commencement of the project in late 2010.

2.2 Pumping at 250 ML/day

Revised modelling of pumping at a rate of 250 ML/day (BMT WBM 2009a) indicates that in the third year of pumping the target salinity levels are not quite achieved at Policeman Point (Figure 4). Confidence in this modelling is reasonable, although some uncertainties remain, particularly in relation to the transmission efficiency of Hell's Gate, the narrowing between the North and South Lagoons. Recent bathymetric survey of the area improved the predictive power of the 2D hydrodynamic model. Due to model uncertainties, the necessary duration of the pumping program cannot currently be determined with absolute precision. However, 36-48 months is likely to be adequate. It is important to note that there is good agreement between the 2D model created by BMT WBM (BMT WBM 2009a) and the 1D model created by CSIRO (Webster 2005) regarding the predicted salinity reduction of the SLSRS.

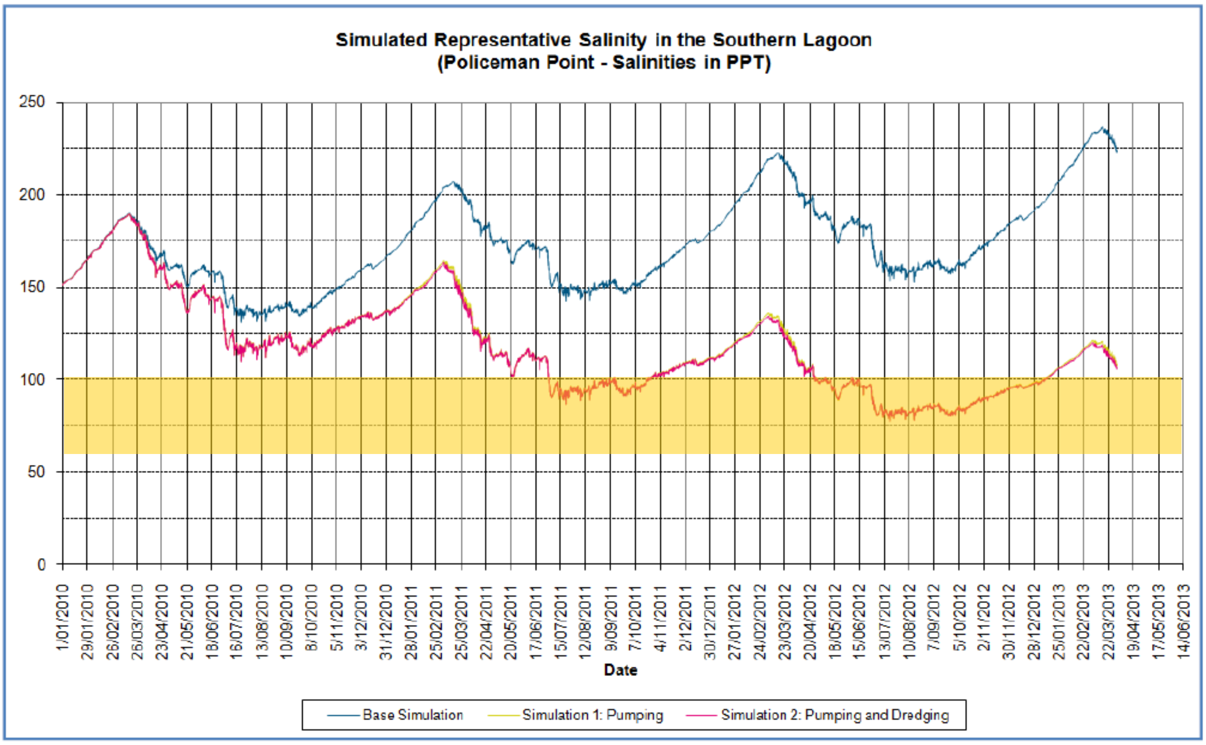

Figure 4. Revised modelled salinity in the South Lagoon under intervention scenarios (note initial salinity is higher than for figure 3, and is therefore more realistic). Base case (blue line) is the 'do nothing' scenario. 250 ML/day (orange line) is the preferred option (source: BMT WBM 2009a). The orange band represents the target salinity range for ecosystem health.

Based on early market discussions and an early engineering review (Tonkin Consulting 2009), the following concept has been proposed as a possible solution. A generator and associated fuel supply will be placed on the eastern side of the Coorong South Lagoon in the vicinity of Woods Well (Figure 5) on land. A barge carrying one or more pumps will be moored in the South Lagoon approximately 1450 m from the generator. A submerged electric cable will connect the pump to the generator. A temporary pipeline will be constructed from the pump to the eastern shoreline of Younghusband Peninsula, over the peninsula's sand dunes to an outfall on the ocean beach, a total distance of approximately 2450m. Two possible designs for the ocean outfall have been proposed (Tonkin Consulting 2009). The first is a discharge to the back of the beach onto a rock apron. The second option is a buried pipe discharging directly below the low tide mark. This option is currently preferred and forms the basis of the discharge modelling and assessments. Preliminary designs of pumping and discharge infrastructure have been prepared by Tonkin Consulting (2009). Detailed design of the intake and pumping infrastructure is currently being prepared by SA Water. The suite of possible options will be further considered during this process and by an Early Contractor Involvement procurement model.

One of the other options is the possibility of constructing a temporary causeway out to one of the Coorong islands or to a platform in the lagoon to provide for safe and effective pump maintenance access irrespective of seasonal water levels. This would potentially reduce operational costs and minimise risks associated with access to pumping equipment. This option would only be investigated further if final feasibility showed significant difficulty in routinely accessing a platform for maintenance and initial placement due to naturally shallow waters between the pump location and the eastern shore. Connecting the pumps to the main electrical grid network was investigated to reduce the need for generators and fuel but was discounted due to high capital costs (circa $16M), as indicated by the South Australian grid provider.

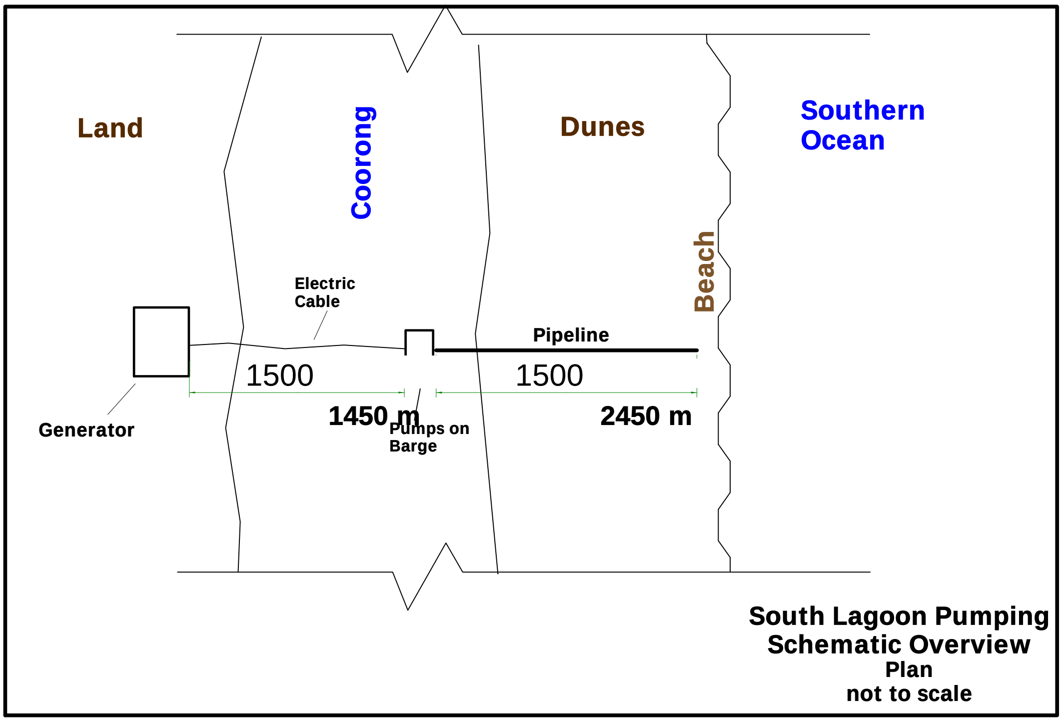

Figure 5. Schematic diagram of possible pumping infrastructure for the SLSRS.

The proposed location of pumping and outfall infrastructure is shown in Figure 6. This information is subject to further refinement during the detailed design phase, which will include flora, fauna and cultural heritage assessments of the project area. Final location selection for infrastructure will be based on a number of criteria, including:

- avoidance/minimisation of the area of native vegetation required to be cleared or disturbed;
- avoidance/minimisation of threatened species impacts;
- avoidance/minimisation of cultural heritage impacts;
- accessibility for infrastructure construction, operation and maintenance (see Tonkin Consulting 2009);
- minimisation of earthworks for pipeline trenching;
- transport of barrages to mooring locations; and
- optimal salinity reduction throughout the South Lagoon.

Options under consideration to transport plant and equipment to the ocean outfall location include a barge or pontoon system at Parnka Point, approximately 16 km north of the proposed outfall site. Parnka Point is the narrowest point of the Coorong with existing tracks on either side. The existing road from the Princes Highway to Parnka Point is suitable for heavy traffic. From the lagoon side of Younghusband Peninsula to the ocean beach an existing track may need to be widened and potentially stabilised to facilitate access of construction equipment (Tonkin Consulting 2009). Another option involves access via Tea Tree Crossing, a public road approximately 20 km south of the proposed outfall location, which is navigable seasonally subject to lagoon water levels. The ocean beach will be used as a transport route to the outfall site under both the Parnka Point and Tea Tree Crossing options. The ocean beach will not require surfacing with imported materials. The possible access routes to the outfall site are shown in Figure 7.

Figure 6. Proposed location of pumping infrastructure (source: Tonkin Consulting 2009)].

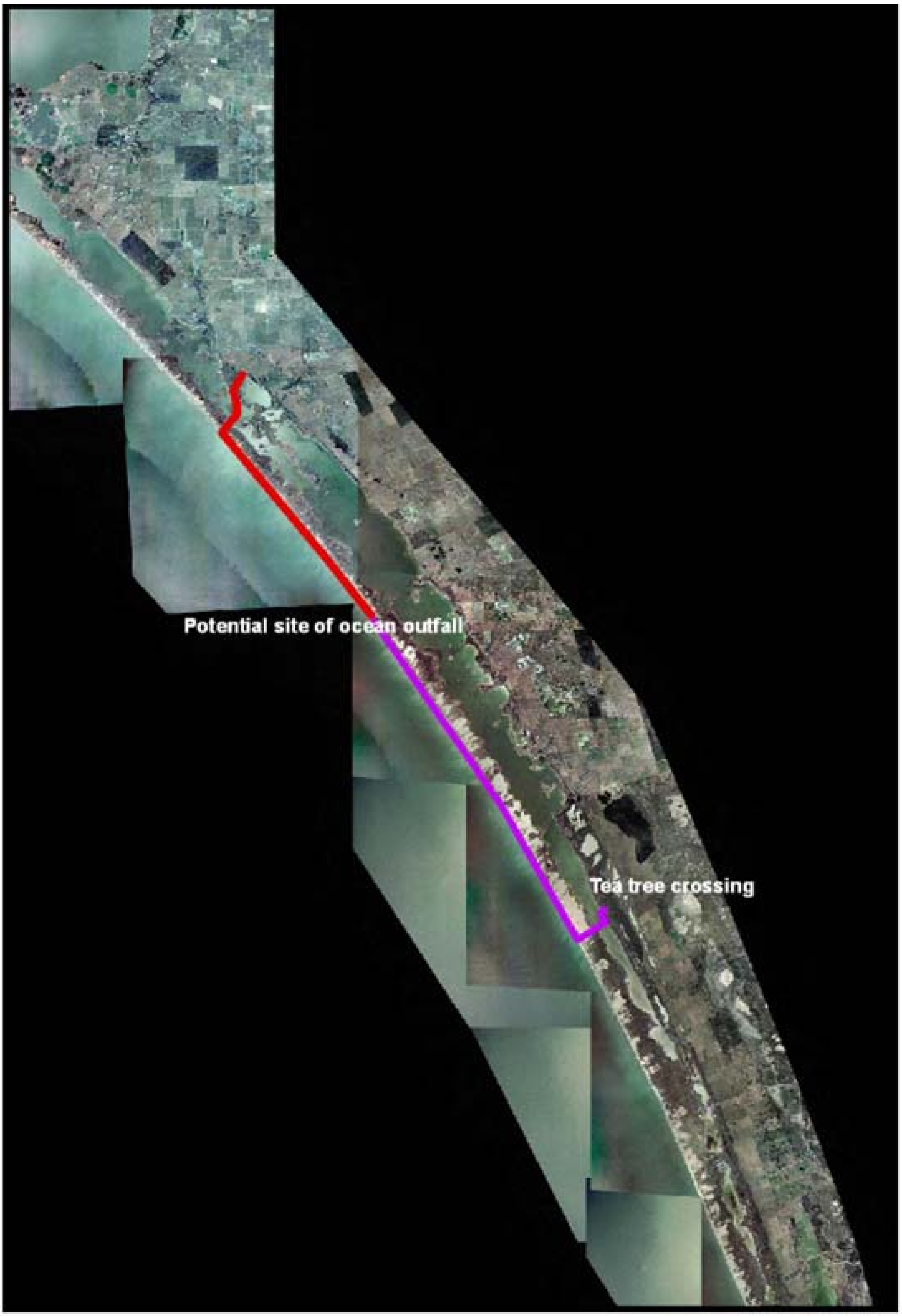

Figure 7. Proposed access routes to outfall location (source: Tonkin Consulting 2009).

2.3 Increasing transmission efficiency between lagoons (a potential future sub-project)

As mentioned in section 1.2, early investigations and modelling have been conducted on the potential requirements of, or benefits associated with, increasing the efficiency of water transmission between the North and South Lagoons, and whether the pumping project would require additional actions such as dredging at specific points (Lester *et al.* 2009b). Bathymetric and geotechnical survey work (SA Water 2009) of the narrowing between the North and South Lagoons has been completed, with the data held by the South Australian Government Department of Water, Land and Biodiversity Conservation (DWLBC). This will enable refinement of the hydrodynamic modelling of the Coorong and inform a decision on dredging between the two Lagoons.

It is currently predicted that the pumping of the South Lagoon will achieve the desired outcome in terms of progress against salinity targets in the absence of a dredging program, with such a program potentially providing benefits in maintaining salinity levels within the appropriate range with subsequent benefits in long-term ecological maintenance.

Parnka Point is regarded as the boundary between the North and South Lagoons of the Coorong. The constriction of the Coorong waterbody between the Needles and Parnka Point is known as Hell's Gate. In this vicinity the Coorong is both narrow and, in places, extremely shallow. The movement of water between the North and South Lagoons is restricted at Hell's Gate, which can lead to differences in both water quality and water level between the two lagoons. From January through April, when mean sea level, and thus water levels throughout the Coorong, attain their seasonal low, the North and South Lagoons can become hydraulically separated. Webster (2005) suggested that hydraulic separation occurs at water levels of 0.0 mAHD. Under these conditions the South Lagoon becomes an isolated waterbody. During summer and into autumn evaporation greatly exceeds precipitation in this region. Because evaporative losses cannot be replaced water levels in the South Lagoon can fall well below those of the North Lagoon. Additionally, due to the process of evapoconcentration (water lost via evaporation but salts left behind) salinity in the South Lagoon can increase dramatically during such events.

Targeted excavation between the North and South Lagoons through Hell's Gate is proposed as a potential means to increase the transmission efficiency between the two lagoons. It is anticipated this will (Lester *et al.* 2009b):

- 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; and
- prevent excessive declines in water level in the South Lagoon during summer.

In order to understand the full potential need for increased transmission flow and the full benefits and risks, further feasibility assessment and modelling that incoroporates real pumping progress data shall be developed. Detailed flow measurements are required at Parnka Point once pumping commences. This data can then be used to further improve existing model confidence and allow the benefits of the added value projects such as targeted excavation and the installation of temporary regulators to hold up spring water levels, to be further assessed. It is currently envisaged that at least 12 months flow measurement is required, which considering salinity is going to be the limiting factor during this period does not further delay any further possible realised benefits from limited excavation.

Modelling will entail the undertaking of 3D modelling in the Coorong to assess the short term salinity benefits of undertaking the action. Additionally 1-d Modelling over longer timescales linked to MSN BigMod and hydraulic modelling from the proposed USE scheme will be required to examine interactions between the actions and environmental flows over the barrages delivered through the Basin Plan. Further interpretation using the ecosystem states model will also examine the environmental benefits linked to the hydrological effects. This combined program of modelling will assist in determining the likely benefits of the program and its justification through a cost benefit analysis or multi criteria assessment prior to its implementation.

To assist in establishing a budget and to enable comparisons between construction options, the preliminary cost estimates for the project are provided in Table 1.

Table 1. Preliminary cost estimates for the TEHG

Cost components	Estimated Total
Investigations and detailed viability assessment and 3d modelling requirements	350,000

Direct excavation cost (based on the removal of 441,000 cubic metres of material)	4,853,414
Cultural survey	20,000
Monitors (2x for 3 months)	70,000
Additional approvals	100,000
Direct cost of excess volume removal (based on removing 20,000 cubic metres of calcrete)	600,000
Sub total before contingency	5,643,414
Contingency at 20 per cent	1,128,683
Total estimated cost including contingency	**7,122,097**

The costs shown above indicate the possible costs for targeted excavation to be carried out only once. After completion of the project its success can be evaluated to determine if further excavation is warranted, and how frequently. The costs are preliminary estimates and final tenders for work will be required.

3 LOCATION

The proposed location of pumping infrastructure is indicated in Figure 6. Aerial views of the general area are shown in Figure 8.

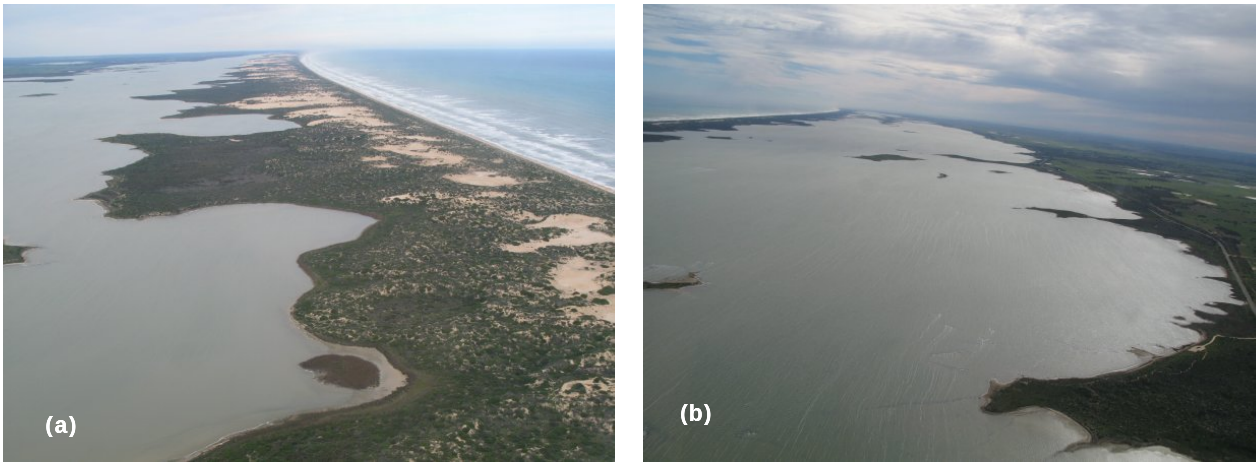

Figure 8. Aerial views of potential pumping infrastructure locations on (a) Younghusband Peninsula and (b) the eastern side of the South Lagoon.

4 INPUTS AND COSTS

4.1 Investigations to date

A summary of the feasibility investigations for the SLSRS completed to date, their providers and costs is provided in Table 2. These studies have been subject to peer review and scrutiny by relevant experts who are represented on the project steering group. Investigations are on-going.

Table 2. Summary of SLSRS feasibility investigations completed to date

Service Description	Provider
Hydrodynamic 1D Coorong Study Low resolution	CSIRO
Ecological Response model	Flinders Uni
Flow Through cell boat survey	DWLBC
Bathymetry Surveys	SA Surveys
Bathymetry Surveys	SA Water
Bathymetry Surveys 2nd round SA Water	SA Water
Bathymetry Surveys SA Surveys	SA Surveys
Hoverservices for Bathymetry	Hoverservices
Stage 1 Outcomes and Knowledge gaps	Aurecon
Variation no 1 additional reporting and split report	Aurecon
Marine Receptor and habit mapping	DEH Marine/SARDI
Ecological asset inventory and salinity tolerances	SARDI
Engineering and costing Review	Tonkin
Variation no 1 Additional engineering studies	Tonkin
Goolwa Cockle distribution and abundance study	SARDI/Adelaide Uni
Salinity tolerances for Goolwa Cockles	SARDI
Sitting fees	Various
Coastal hydrodynamic studies (stage 1)	Aurecon
Coastal hydrodynamic studies (stage 2)	Aurecon
Coastal hydrodynamic studies (stage 3)	Aurecon
Initial modelling of South Lagoon salinity under various pumping options	BMT WBM
Revised modelling of South Lagoon salinity under preferred pumping option	BMT WBM
Total (based on quotations and expectations)	**$546,000**

4.2 Project cost estimates

Due to the uncertainty surrounding the required duration of pumping, costings have been prepared for 'best case' (i.e. shortest likely duration) and 'worst case' (longest likely duration) scenarios (Table 3). Costings are based on advice from Tonkin Consulting (2009) and include market approaches made by Tonkin Consulting to garner approximate pricing for essential components. These prices are indicative only, as due to the complex nature of the site and specialist equipment requirements coupled with tendering seeking innovation in delivery, the final accurate costings will be available following final detailed design in the first half of 2010. Full costing breakdowns across years shall be available at that stage. The early costing estimates from Tonkin Consulting assume the following:

- pumping will occur at rate of 250 ML/day for 24 hours per day, 7 days per week, which equates to a duration of 78 weeks (18 months) to pump the entire volume of the South Lagoon (137 GL);
- costs include both commissioning and decommissioning;
- the project will obtain fuel (diesel) for $0.85/L;
- the scour prevention apron on the ocean beach will be constructed of rock (rather than A Jacks);

- the pipeline across the Younghusband Peninsula will be trenched and left in place following completion of pumping;
- purchase (rather than hire) of both pumps and transformers, which may require a long lead time. The purchase option has been assumed because the high salinity of the South Lagoon necessitates the use of specialised pumps that may be difficult to hire. Purchase is likely to be more expensive than hire; therefore the assumption of purchase is conservative. Note that the hire option may be possible and has lead time of 4 months (Glynn Ricketts, SAMDBNRMB, pers. com. 4/9/09); and
- planning and approvals for early works.

Table 3. SLSRS Costings (adapted from Tonkin Consulting 2009)

PROJECT COMPONENT	**PUMPING OPTION**	
	250 ML/day for 18 months (best case)	**250 ML/day for 4 years**
Early site works	$700,000.00	$700,000.00
Detailed Design	$500,000.00	$500,000.00
Hire Equipment (genset (generators), cables, pontoons)	$1,711,680.00	$4,490,680.00
Outlet Works (includes track upgrades)	$701,023.00	$701,023.00
Electrical and Controls (transformers, cables etc.)	$1,335,000.00	$1,335,000.00
Mechanical (pumps etc.)	$1,938,323.62	$1,938,323.62
Piping	$6,211,570.00	$6,211,570.00
Miscellaneous (includes security)	$100,000.00	$100,000.00
SUB TOTAL	$13,197,596.62	$15,276,596.62
Contingencies (20%)	$1,499,519.32	$3,055,319.33
Operation and Maintenance (includes fuel @ $0.85/L)	$4,800,000.00	$12,937,329.60
Monitoring (see section 11.2)	$586,500.00	$1,564,000.00
TOTAL + Contingencies (ex.GST)	**$20,083,615**	**$32,833,245**
Potential Transmission Efficiency at Hells Gate (TEHG)		
Modelling, Investigations, Feasibility	$350,000	$350,000
Design and Construction	$5,644,097	$5,644,097
Contingency	$1,128,000	$1,128,000
Total	**$7,122,097**	**$7,122,097**

The costings in Table 3 may change during the detailed design phase. Additionally, the preliminary costing for potential dredging at Hells gate (Parnka Point) has been added. Note that cost estimates for the pumping project exclude (Tonkin Consulting 2009):

a) government charges and levies;
b) repair and re-making the outfall in the event of a storm event;
c) security costs other than fencing;
d) detailed engineering and documentation, surveys, project management and related costs;

e) costs associated with storing and mothballing the equipment at the conclusion of the first pumping exercise; and

f) all exclusions noted in the genset and barge supplier proposals (see: Tonkin Consulting 2009).

5 DURATION AND TIMELINES

Lead time for the procurement of particular items will influence the commencement of the pumping program. Items that must be procured, for which there are long lead times, include purpose selected pumps and the system transformers. Based on the early feasibility assessment, which proposed utilising electric pumping fed by diesel generators, procurement of suitable transformers is fundamental to the operation and at this point these are a critical lead item. However, it may be possible to use hired pumps and transformers and decrease the lead time to approximately 4 months (SAMDBNRMB, pers. com., 4/9/09).

Modelling indicates that commencement of pumping in summer provides the greatest salinity reduction benefits (BMT WBM 2009b). Depending on conditions, continuous pumping for approximately 3-4 years is required to achieve salinity targets (BMT WBM 2009a). However, the actual duration of pumping will depend upon a number of factors including seasonal conditions, any inflows, outfall parameters, and progress against salinity targets. Pumping will be planned to be completed within the shortest duration possible against salinity targets.

The duration of the approvals process will depend on the level of assessment required by the Department of the Environment, Water, Heritage and the Arts (DEWHA) in relation to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The actual start date for pumping will be determined by a combination of logistics, market response, approvals and seasonal conditions. The following timeline is proposed :

Submission of EPBC Act referral	Late February 2010
DEWHA response (4 weeks)	Late March 2010
If deemed not a controlled action:	
Commence procurement	April 2010
Commence pumping	Winter/Spring 2010
Decommission	Late2014
If deemed a controlled action but requiring lowest level of assessment (2 months):	
Commence procurement (non-referred aspects)	Mid June 2010
Commence construction (referred aspects approved)	Winter/Spring2010
Commence pumping	Spring/Summer 2010
Cease pumping and decommission	April 2014
If deemed a controlled action and requiring high level of assessment (EIS: 18 months):	
Commence EIS	Early April 2010
Commence procurement (non-referred aspects)	April 2010
Commence construction (referred aspects approved)	October 2011
Commence pumping	Summer 2011
Decommission	April 2015

6 ECOLOGICAL BENEFITS OF IMPLEMENTATION

In summary, the anticipated ecological benefits of the South Lagoon Salinity Reduction Scheme are the restoration of the Ruppia/chironomid/hardyhead ecosystem of the South Lagoon and an increased abundance of the higher biota (e.g. waterbirds) it supports. The likely impacts under a 'do nothing' scenario will be avoided. Under a 'do nothing' scenario the following outcomes are likely (Paton *et al.* 2009):

- Total loss from the entire Coorong of the Ruppia/chironomid/hardyhead ecosystem that formerly dominated the South Lagoon;
- Local extinction of the fairy tern (*Sterna nereis*);
- Limited benefit, or exacerbation of degradation, when freshwater inflows at the barrages return and/or increased inflows from the South East drainage network are made available. Such inflows would have ecological benefits under more typical salinity conditions;
- Further declines in the abundance of most waterbird species; and
- The ecological character of the Coorong is at imminent risk of irreversible change. Re-establishment of the Ruppia/chironomid/hardyhead ecosystem could be extremely difficult or impossible if it is allowed to disappear completely. The ecological benefits of implementation, i.e. the risks of the 'do nothing' scenario that would be avoided, are discussed in further detail in Paton et al. (2009), Paton et al.(2008), Lester et al. (2009b), CLLAMMecology (2008) and Brookes et al. (in review).

7 ECOLOGICAL RISKS OF IMPLEMENTATION

A Draft EPBC Act Referral has been prepared for the SLSRS (DEH 2009) and is due for finalisation and lodgement in early 2010. The referral outlines the potential impacts of the SLSRS upon matters of national environmental significance (NES) and strategies to avoid and minimise those impacts. Impacts can be categorised as follows:

- Impacts of the pumping infrastructure 'footprint';
- Impacts of hypermarine discharge into the Southern Ocean; and
- Impacts of pumping upon the Coorong waterbody;

Potential impacts are not limited to matters of NES. The following sections provide a brief overview of all potential impacts.

7.1 Pumping infrastructure footprint

There are several nationally threatened species of flora and fauna potentially present in the riparian and terrestrial areas where vegetation clearance or disturbance will be required for the temporary placement of pumping infrastructure (Aurecon 2009a). There are existing cleared areas on the eastern side of the Coorong that appear suitable for the placement of generators without the need for additional clearance.

The pipeline will need to be at least partially buried for stabilisation and to minimise undulations (Tonkin Consulting 2009). This may necessitate the grading of a trench through the dunes and some vegetation clearance. The pipeline footprint is anticipated to be up to 10m wide (Aurecon 2009b). Following completion of the project it is anticipated that the pipeline will be left in place in case it is required in the future (Tonkin Consulting 2009) and if deemed that the disturbance associated with removal is excessive.

A flora and fauna survey of the riparian and terrestrial habitats in the project area will be undertaken. This will inform the final location of pumping infrastructure such that impacts to threatened species and native vegetation are avoided or minimised. Areas cleared of vegetation for the SLSRS are anticipated to regenerate naturally following the completion of the project. Efforts to promote natural regeneration and manage weeds will be addressed in the Environmental Management Plan.

There are naturally unvegetated areas within the project footprint that, despite their lack of vegetation, provide habitat for fauna. For example, the ocean beach, which will be subjected to additional vehicle traffic during construction and maintenance, provides habitat for threatened species such as Hooded Plover (Baker-Gabb and Weston 2006) and other shorebirds. It should be noted that the Younghusband Peninsula's ocean beach is currently accessible to vehicles (NPWS 1990) and the project represents a temporary increase in traffic. The relatively short section (~16 km) of the ocean beach that will be subject to increased traffic and the temporary nature of the increase suggests impacts to beach fauna are unlikely to be significant. The risk of any disturbance will be further reduced in the project Environmental Management Plan.

7.2 Hypermarine discharge

Preliminary hydrodynamic modelling of the dispersal of the plume of hypermarine water that will be discharged into the Southern Ocean has been undertaken (Aurecon 2009b). The discharge water is anticipated to have salinity four/five times that of seawater at the commencement of pumping. Modelling suggests that a salinity of ≥ 3800 EC (2 g/L) above background level (53,000 – 54,390 EC (35–36 g/L)) is unlikely to be detectable further than 2km from the outfall, due to the dispersal capacity of the receiving environment (Aurecon 2009b).

The Draft EPBC Act Referral examines the potential impact of the plume upon matters of NES in the marine environment. It concludes that significant impacts are unlikely (DEH 2009). Additional studies have been commissioned in relation to the impact of hypermarine discharge on environmental matters not protected under the EPBC Act. These include an investigation of the salinity tolerances of the Goolwa Cockle (*Donax deltoides*) (Wiltshire *et al.* 2009), an assessment of the distribution and abundance of Goolwa Cockle in the vicinity of the ocean outfall (Gorman *et al.* 2009) and further work that utilises the findings of the Adelaide desalination plant Environmental Impact Assessment upon various components of the marine ecosystem (Aurecon 2009b).

7.3 Coorong waterbody

The purpose of reducing salinity in the Coorong is for ecological restoration. Expert opinion has concluded that the significant positive outcomes for the project more than compensate for some anticipated short term adverse impacts.

Matters of NES protected under the EPBC Act that occur within the Coorong waterbody and could be potentially impacted by the South Lagoon Salinity Reduction Scheme include:

- the ecological character of one wetland of international importance (The Coorong, Lakes Alexandrina and Albert)
- a number of threatened species
- a number of threatened ecological communities
- a number of migratory species.

The Draft EPBC Act Referral for the project (DEH 2009) addresses avoidance and mitigation of impacts to these matters of NES. Additional detail can also be found in Aurecon (2009a). In summary, no significantly negative impacts upon matters of NES in the Coorong waterbody are likely to occur as a consequence of the SLSRS, provided several simple mitigation measures are enacted.

An ecological risk of the project is that pumping will have a negative impact on the ecological character of the South Lagoon by lowering water levels. Low water levels have two potentially negative impacts: acidification of the Coorong waterbody, and ecologically inappropriate exposure duration impacting lifecycles of key species of mudflats.

A review of the acid sulfate soil (ASS) risks in the Coorong has been undertaken by the CSIRO (CSIRO 2008). The risk of acidification of the Coorong if water levels drop and soils become exposed is considered low to moderate. Pumping may lower water levels up to 0.2m below those that occur naturally (BMT WBM 2009b) (Figure 9). Acidification of the Coorong waterbody due to the SLSRS is very unlikely. In the unlikely event that an acidification event appears imminent due to pumping, the rate of pumping can be adjusted to prevent further exposure of ASS. Water quality and water level monitoring is proposed in order to assess and mitigate any exposure of acid sulphate soils.

Maintenance of appropriate water levels in spring and early summer has historically been important to ensure that mudflats remain inundated for long enough to permit *Ruppia tuberosa* to complete its lifecycle prior to summer mudflat exposure (Phillips and Muller 2006). However, given the Ruppia/chironomid/hardyhead ecosystem is now absent from the entire South Lagoon (Brookes *et al.* 2009), the requirement that appropriate water levels be maintained to support this system is no longer valid. In fact, the seasonal disconnection that occurs between the North and South Lagoons (Figure 10) may enable more efficient export of salt from the system by pumping during summer because fresher water from the North Lagoon will not be drawn in to dilute it.

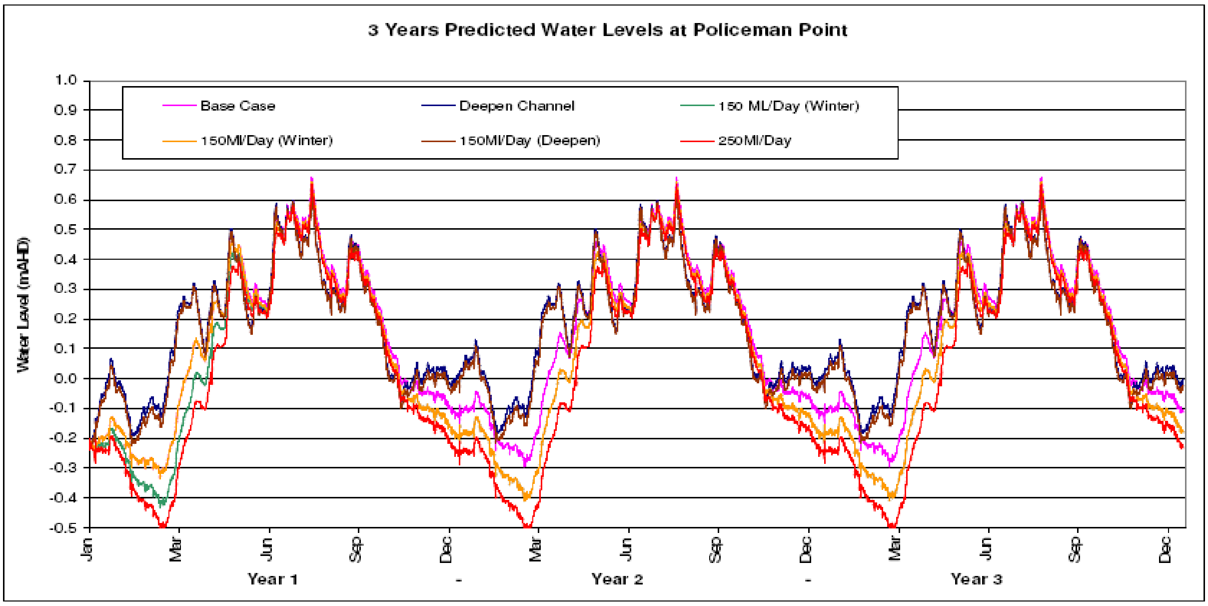

Figure 9. Modelled water level in the South Lagoon under six intervention scenarios. Base case (pink line) is the 'do nothing' scenario. 250 ML/day (red line) is the preferred option (source: BMT WBM 2009b).

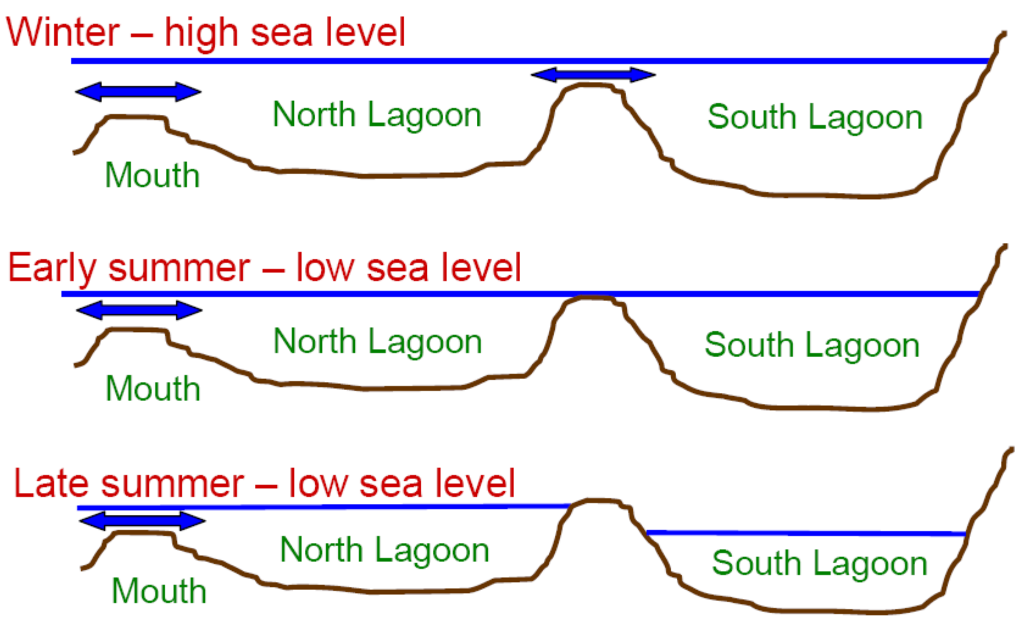

Figure 10. Seasonal connection and disconnection between the Coorong North and South Lagoons (source: Lester *et al.* 2009b).

8 PROJECT RISKS

All project risks are of a non-ecological nature. Project risks documented in this Technical Feasibility Assessment report will be included in the Coorong, Lower Lakes and Murray Mouth (CLLMM) project risk register, with mitigation strategies included as appropriate.

8.1 Governance

Poorly defined roles and responsibilities of agencies and agency staff could undermine good governance of the project and lead to a poor outcome. Given the potential for involvement of several agencies in the governance of the South Lagoon Salinity Reduction Scheme, a clear definition of roles and responsibilities for all involved is critical to avoid governance gaps and/or duplication.

8.2 Procurement delays

Long lead times for some infrastructure components required for the SLSRS have the potential to delay the project, which could lead to increased project costs. The longer the commencement of the pumping is delayed, the higher the salt-load of the Coorong will become. This will then mean that pumping would need to be carried out for longer to meet salinity targets, resulting in higher costs. Additionally, delaying pumping and the corresponding increase in salinity could reduce the effectiveness of the ecosystem restoration objectives of the project, especially as the remnant Ruppia/chironomid/hardyhead ecosystem could be lost from the North Lagoon, making re-establishment of this system in the South Lagoon more difficult.

A timely approach to procurement and the preferential procurement of items and contractors with short lead times would help avoid this risk.

8.3 Mouth dredging impacts

The South Australian Government has extensively modelled the morphology and hydrology of the Murray Mouth. Pumping 250 ML/day from the South Lagoon will not significantly affect current dredging operations. Natural events, such as high tides, strong winds and storms result in far more sand influx and tidal exchange than any measurable effect of pumping. The target tidal prism is not expected to be affected by pumping.

9 GREENHOUSE GAS IMPLICATIONS

Over the long-term, the Scheme aims to increase the biosequestration performance of the Coorong South Lagoon compared with the current scenario of system decline, as well as seeking to reduce the greenhouse emissions from degradation of ecological processes. Improved biosequestration against the current trajectory of system decline is an additional outcome of the project, beyond the improved ecological function and system recovery.

The SLSRS will generate greenhouse gases during its installation, operation and decommissioning. Greenhouse gases will be generated by commissioning, maintaining and decommissioning pumping infrastructure, and operating pumping infrastructure.

Greenhouse gas emissions associated with commissioning, maintaining and decommissioning pumping infrastructure are difficult to calculate because they depend upon factors not yet determined, such as source location for infrastructure components and location of contractors. Calculation of emissions from these aspects of the project will only be possible when the detailed design and procurement process is under way.

Greenhouse gas emissions associated with the operation of pumping infrastructure (i.e. operation of generators) have been calculated based upon the fuel use estimates provided by Tonkin Consulting (2009). Conversion of diesel use to CO_2 emissions assumes the combustion of 1 litre of diesel releases 2621.8764 g of CO_2 (US EPA 2005).

Table 4. Estimated CO_2 emissions from operation of SLSRS pumping infrastructure

Pumping Option	Diesel Use Per Week (L)	Total Diesel Use (L)	Total CO_2 Emissions (tonnes)
250 ML/day for 18 months	67,822	5,290,116	13,870
250 ML/day for 4 years	67,822	14,106,976	36,987

The use of grid power for the project was investigated with ETSA Utilities. It was determined that major new transmission infrastructure would be required, covering a distance in excess of 45 km from the nearest source, which would be cost-prohibitive. Further, any emissions reduction through the use of grid power or green power would be countered by the additional embodied emissions associated with significant new infrastructure.

10 APPROVALS

A comprehensive review of state and federal legislation has been undertaken. All requirements and needs for approval will be addressed when developing plans and implementing actions.

Key relevant legislation is summarised in the following sections.

10.1 Aboriginal Heritage Act 1988

Proposed works will need to be done in a way that does not infringe the provisions of the South Australia Aboriginal Heritage Act 1988. Under Section 23 of the Act it is an offence to damage, disturb or interfere with a site or object of significance to Aboriginal tradition, archaeology, anthropology or history (or Aboriginal remains) without authorisation from the Minister. The Act also provides that before the Minister gives any authorisation under the Act, they must consult with, among others, the traditional owners for the area. The proposed works are located within the traditional lands of the Ngarrindjeri people.

The Kungun Ngarrindjeri Yunnan (Listening to Ngarrindjeri People Talking) Agreement (KNYA) between the Ngarrindjeri People and four State Government Ministers (The Minister for Environment and Conservation, the Minister for Aboriginal Affairs and Reconciliation, the Minister for the River Murray and the Minister for Agriculture, Food and Fisheries) was executed on 6 June 2009.

The KNYA establishes the means whereby the Ngarrindjeri People, through the Ngarrindjeri Regional Authority are able to coordinate 'activities and resources of the Ngarrindjeri community and high level interactions with the State Government of South Australia'. The Agreement indicates the Ministers' desire for a new relationship 'based upon mutual respect and trust acknowledging that Ngarrindjeri consider protection and maintenance of culture and cultural sites upon its land and waters central in every respect to Ngarrindjeri community well being and existence'.

To fulfil it's obligations to the KNYA and the Ngarrindjeri Regional Authority, the SLSRS team will need to consult with the NRA and seek appropriate approvals for this project to commence. In addition to risk managing Aboriginal heritage issues via the KNYA process, this project will require approvals as required by the *Aboriginal Heritage Act 1988*. Advice will also be required as to any potential implications in relation to the *Native Title Act (C'th) 1993*.

The CLLMM projects team have developed a draft Aboriginal Heritage Process to assist project managers in their interactions with Aboriginal heritage issues.

10.2 Coast Protection Act 1972

An Act to make provision for the conservation and protection of the beaches and coast of this State; and for other purposes. Notify Coast Protection Board of works. Proposals may involve development along the coast; the policies of the Coast Protection Board are relevant.

10.3 Crown Lands Act 1929

An Act relating to Crown lands. This Act has a particular influence on coastal and river management, as generally the first 30 to 50 metres of adjacent land is held under this Act. A licence to occupy Crown Lands may be required. Note that this Act will be repealed with the commencement of the *Crown Land Management Act 2009* in the near future.

10.4 Development Act 1993

The *Development Act 1993* (the Development Act) is administered by the South Australian Minister for Urban Development and Planning. No development may be undertaken unless approved or exempted in accordance with the Act. Subject to the Development Act, no development may be undertaken unless the development is an 'approved development.' Section 4 of the Act defines 'development' as a number of activities including: 'an act or activity in relation to land (other than an act or activity that constitutes the continuation of an existing use of land) declared by regulation to constitute development, (including development on or under water) but does not include an act or activity that is excluded by regulation from the ambit of this definition' (Section 4, (h)). The construction of a pipeline is considered "development" under the Development Act.

Infrastructure that is erected as part of this proposal may be exempted under Schedule 14(1)(d) of the *Development Regulations 2008*. This provision includes an exemption for 'temporary' development which is required in an emergency situation in order to—

(iii) maintain essential public services; or

(iv) prevent a health or safety hazard; or

(v) protect the environment where authority to undertake the development is given by or under another Act.

The proposed works may fall within this exempted category and consequently approval under the Development Act is not required. In addition, the access roads as per the Act are not considered to be forms of development and therefore would not require approval under the Act.

10.5 Environment Protection Act 1993, Environment Protection (Water Quality) Policy 2003

The *Environment Protection Act 1993*, under Section 25, does impose a general environmental duty, which requires that a person must not undertake an activity that pollutes or might pollute the environment, unless taking all reasonable and practical measures to prevent or minimise any resultant harm. In the context of the Act 'pollute' includes discharging, disturbing or depositing pollutants or failing to prevent the discharge, deposition or disturbance or escape of pollutants. In addition, the Environment Protection (Water Quality) Policy 2003 (the WQEPP) sets out water quality criteria for protection of waters within South Australia. The Policy includes matters the EPA must take into account when making decisions relating to environmental authorisations, development applications referred to the EPA and other specified matters. This Policy also makes it an offence to deposit listed pollutants (including soil and gravel) into waters without authorisation.

The SLSRS is likely to require a license under the EP Act. Because the water discharged to the marine environment is unlikely to meet the water quality requirements of the WQEPP an exemption to this policy may be required from the EPA. The EPA can grant an exemption under the condition that that all reasonable and practicable measures to reduce potential harm by the operation are maintained. An exemption would be required from the following clauses of the Water Quality EPP to permit the deposition of salt in State waters:

1. Clause 12h – increase in turbidity or sediment levels; and
2. Clause 17(3) – deposition of a listed pollutant (Part 2 Schedule 4, soil / clay / gravel / sand) into waters.

The required applications for Works Approval and an application for exemption from the WQEPP will need to be submitted to the EPA. On receipt of this application a decision can be made by the EPA based on the merits of the application and the benefits to the South Lagoon of the Coorong.

10.6 Environment Protection and Biodiversity Conservation Act 1999 (Cwth)

If an action is likely to have a significant impact on a matter of National Environmental Significance (NES), the SA Government may require an environmental approval from the Australian Government Minister for the Environment, Heritage and the Arts under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). An EPBC Act referral is currently being prepared for the SLSRS.

10.7 Environment Protection (Sea Dumping) Act 1984 (Cwth)

Relates to the dumping of any wastes or other matter dumped into coastal waters from any vessel, aircraft or platform.

10.8 Fisheries Management Act 2007

No formal approvals required. However notification is advisable.

10.9 Harbors and Navigation Act 1993

Ministerial approval is required for infrastructure (*e.g.* pipes, electrical cables, floating barge) in River Murray waters and requirement for navigation aids.

10.10 Marine Parks Act 2007

Two marine parks (Marine park 18 Upper South East marine park and Marine Park 15 Encounter Marine Park are in the general vicinity of the CLLMM area. No requirements at this time. Management zones and special purpose areas have not yet been defined for the proposed marine parks. Notification of action recommended.

10.11 Murray-Darling Basin Act 2008

Approval from the Murray-Darling Basin Authority under part 58 and 59 of the Murray-Darling Basin agreement is required. Under part 58 a general scheme of work must be approved by the Authority, which may require amendments to the scheme of work to be undertaken. This may include directives regarding the efficient construction, operation, maintenance and required performance of any works as instructed under clause 61. A general description of the measure, including implementation and cost arrangements must be submitted to and approved by the authority under part 59, also subject to Authority directives under clause 61.

10.12 National Parks and Wildlife Act 1972

An Act to provide for the establishment and management of reserves for public benefit and enjoyment; to provide for the conservation of wildlife in a natural environment; and for other purposes. The project area is within the Coorong National Park. Permission from the Director NPWS is required for access, the disturbance of any soils, destruction of vegetation. The Coorong National Park management plan 1991 contains further relevant information.

10.13 Native Title Act 1993 (Cwth)

The proposed works are within the area of the Ngarrindjeri and Others Native Title Claim (SC98/4). See: http://www.nntt.gov.au/Applications-And-Determinations/Search-Applications/Pages/Application.aspx?tribunal_file_no=SC98/4

Whilst a determination of native title has not been made in this claim the South Australian Government is in active negotiations with Ngarrindjeri to resolve it. The Act protects any native title rights and interests that exist pending a native title determination and these rights may only be affected in ways prescribed by the Act. The proposed works is expected to be a valid future act permitted by Section 24 KA of the Act. However notification under the Act is required.

10.14 Native Vegetation Act 1991

In South Australia native vegetation is protected by the *Native Vegetation Act 1991 (NV Act)*. The NV Act requires that clearance of native vegetation can only occur in accordance with Part 5 of the Act, subject to the consent of the Native Vegetation Council (NVC) (or delegate), if the vegetation is of a prescribed class or in prescribed circumstances. This protection includes scattered native trees. In most cases the removal of those trees requires the consent of the NVC. Under the NV Act, clearance of vegetation is required to be offset through the implementation of a significant environmental benefit (SEB). The NVC has developed an interim policy to guide the development of an SEB considered suitable in offsetting proposed impacts to vegetation. The construction of a pipeline and access tracks that require the clearance of native vegetation is likely to require consent from NVC.

10.15 Natural Resources Management Act 2004

The *Natural Resources Management Act 2004* (the NRM Act) sets out a detailed scheme for the sustainable management and protection of natural resources including water. Among other things it regulates ‘water affecting activities’ and the allocation, taking and use of water. A permit is required to undertake a water affecting activity. Water affecting activities under section 127 of the Act include the erection or construction of structures that are expected to collect or divert water flowing in a prescribed watercourse. The River Murray Prescribed Watercourse consists of the River Murray channel and associated watercourses as described in the Water Allocation Plan for the River Murray Prescribed Watercourse.

11 ENVIRONMENTAL MANAGEMENT PLAN STATUS

11.1 Environmental Management Plan

An Environmental Management Plan (EMP) will be required for the implementation of the SLSRS. An EMP will be prepared when the design and operational details of the project are finalised.

11.2 Monitoring

The monitoring program has two parts: Coorong monitoring, and marine monitoring. Monitoring includes hydrometric, water quality and biological parameters. The results from the proposed program will inform an operational response plan in relation to any pumping regime.

11.2.1 Coorong monitoring

A Coorong monitoring framework has been designed specifically to detect hydrometric, water quality and biological responses to the SLSRS (SAMDBNRMB 2009). Hydrological parameters to be monitored are:

- water depth
- water velocity
- flow direction.

Water quality parameters to be monitored are:

- electrical conductivity (EC)
- acidity (pH)
- alkalinity
- turbidity
- dissolved oxygen (DO)
- temperature.

Biological parameters to be monitored are:

- *Ruppia tuberosa* winter cover
- abundance of *Ruppia tuberosa* above-ground biomass (shoots)
- abundance of *Ruppia tuberosa* propagules (seeds, turions)
- abundance of *Tanytarsus barbitarsis* (Chironomidae) larvae
- abundance of Smallmouth Hardyhead (*Atherinosoma microstoma*)
- abundance of aquatic birds
- abundance of *Parartemia zietziana* (brine-shrimp).

This program complies with existing hydrological and water quality monitoring undertaken for the Upper South East Dryland Salinity and Flood Management Program, DEH surface water monitoring (quarterly) and the DWLBC surface water monitoring program, which includes telemetered data with a live link to the internet (see http://data.rivermurray.sa.gov.au/).

Biological parameters have been identified due to their relevance as key performance indicators of successful ecosystem restoration of the Coorong. With the exception of brine-shrimp, this list complements and supports existing monitoring undertaken by the University of Adelaide on behalf of various agencies (EPA, DWLBC, SAMDBNRMB/TLM).

An annual Coorong monitoring budget has been calculated. Costs have been minimised by integrating the required work into existing monitoring programs for the Coorong. Monitoring for the South Lagoon Salinity Reduction Scheme simply increases the frequency of measurement and number of sites for some parameters, and adds an additional biological parameter. Monitoring will include refuge monitoring for recolonisation from the North lagoon. Further information is provided in SAMDBNRMB (2009).

11.2.2 Marine monitoring

A marine monitoring program is currently under development. The scope of the program will in part be influenced by any approval conditions imposed on the project under relevant legislation. It is anticipated to include:

- weekly water quality monitoring of the outfall plume via grab samples collected from shore
- quarterly water sampling from a boat in the near shore high energy surf zone, if weekly triggers are breached for key determinants
- studies of benthic biota to compare plume impact against baseline status within the predicted impact zone
- annual marine habitat assessment
- chlorophyll a and salinity studies using remote sensing techniques.

In addition to the proposed marine monitoring, ongoing quarterly monitoring of Goolwa Cockles on the Coorong beach, undertaken by SARDI, is anticipated to continue and will inform the project.

12 REFERENCES

Aurecon (2009a). *Data Collation, Review and Preliminary Ecological Assessment, Coorong Temporary Saline Water Discharge (DRAFT). Report prepared for the SA Murray-Darling Basin NRM Board*. Aurecon Australia Pty Ltd, Adelaide, South Australia.

Aurecon (2009b). *Preliminary Hydrodynamic Modelling Report, Coorong Temporary Saline Water Discharge (DRAFT). Report prepared for the SA Murray-Darling Basin NRM Board*. Aurecon Australia Pty Ltd, Adelaide, South Australia.

Baker-Gabb, D. and Weston, M. (2006). *South Australian Recovery Plan for the Hooded Plover (Thinornis rubricollis) (DRAFT)*. Department for Environment and Heritage, Adelaide, South Australia.

BMT WBM (2009a). *Coorong Model Upgrade and Simulations of Proposed Pumping from the Southern Lagoon. Report prepared for the South Australian Murray-Darling Basin Natural Resources Management Board*. BMT WBM Pty Ltd, Broadmeadow, NSW.

BMT WBM (2009b). *Coorong Salinity Modelling (update six out of six scenarios modelled)*. BMT WBM Pty Ltd, Broadmeadow, NSW.

Brookes, J. D., Lamontagne, S., Aldridge, K. T., Benger, S., Bissett, A., Bucater, L., Cheshire, A. C., Cook, P. L. M., Deegan, B. M., Dittmann, 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., Lester, R. E., Loo, M., Munro, A. R., Noell, C. J., Nayar, S., Paton, D. C., Revill, A. T., Rogers, D. J., Rolston, A., Sharma, S. K., Short, D. A., Tanner, J. E., Webster, I. T., Wellman, N. R., and Ye, Q. (2009). *An Ecosystem Assessment Framework to Guide Management of the Coorong. Final Report of the CLLAMMecology Research Cluster*. CSIRO Water for a Healthy Country National Research Flagship, Canberra, ACT.

Brookes, Justin D. , Rogers, Daniel J. , Aldridge, Kane T. , Deegan, Brian , Hipsey, Matthew R. , Paton, David C. , Ganf, George G. , Rolston, Alec , Webster, Ian , and Noell, Craig (in review). Managing the Lower Lakes and Coorong *Marine and Freshwater Research*

CLLAMMecology (2008). *Response of the Coorong Ecosystems to Alternative Murray-Darling Flow Scenarios. A report prepared for the South Australian Murray Darling Basin Natural Resource Management Board by members of the CLLAMMecology Research Cluster*. Coorong, Lower Lakes and Murray Mouth Ecology Research Cluster, Adelaide, South Australia.

CSIRO (2008). *Risk assessment of Acid Sulfate Soil in Ramsar wetlands of the Murray Darling Basin: Coorong. Unpublished report*. Commonwealth Scientific and Industrial Research Organisation, Adelaide, South Australia.

DEH (2009). *Referral of Proposed Action - Coorong South Lagoon Salinity Reduction Strategy (DRAFT)*. Coorong, Lower Lakes and Murray Mouth Projects, Department for Environment and Heritage, Adelaide, South Australia.

Gorman, D., Ferguson, G., Mathews, C., and Ward, T. M. (2009). *Assessing the potential impacts on inter-tidal infauna of a proposed, temporary saline water discharge (DRAFT). SARDI Publication Number F2009/000000-1*. South Australian Research and Development Institute (Aquatic Sciences), West Beach, South Australia.

Lester, R., Webster, I. , Fairweather, P., and Langley, R. (2009a). *Understanding and quantifying the ecological benefit of dredging the Murray Mouth (Draft). A report prepared for the South Australian Murray-Darling Basin Natural Resources Management Board*. Flinders Research Centre for Coastal and Catchment Environments, Flinders University and CSIRO Land and Water, Adelaide, South Australia.

Lester, R., Webster, I., Fairweather, P. , and Langley, R. (2009b). *Predicting the ecosystem response of the Coorong to the South Lagoon Salinity Reduction Scheme. A report prepared for the South Australian Murray-Darling Basin Natural Resources Management Board*. Flinders Research Centre for Coastal and Catchment Environments, Flinders University and CSIRO Land and Water, Adelaide, South Australia.

NPWS (1990). *Coorong National Park Management Plan*. National Parks and Wildlife Service, Department of Environment and Planning, Adelaide, South Australia.

Paton, D., Deegan, B., Rogers, D., Aldridge, K., and Brookes, J. (2008). *A strategy to enable the Coorong ecosystem to be 'flow ready' upon return of River Murray flows. Unpublished Report*. School of Earth and Environmental Science, University of Adelaide, Adelaide, South Australia.

Paton, D., Rogers, D., Aldridge, K., Deegan, B., and Brookes, J. (2009). A future for the Coorong and Lower Lakes. *Pacific Conservation Biology* **15** 7.

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

Rogers, D. and Paton, D. (2009). *Spatiotemporal Variation in the Waterbird Communities of the Coorong*. CSIRO Water for a Healthy Country National Research Flagship, Canberra, ACT.

SA Water (2009). *Coorong South Lagoon Salinity Reduction Study, Parnka Point Geotechnical Investigations July 2009 (DRAFT). Report prepared for the SA Murray Darling Basin Natural Resources Management Board*. SA Water, Adelaide, South Australia.

SAMDBNRMB (2009). *South Lagoon Pumping Project. Intervention Monitoring Framework*. South Australian Murray-Darling Basin Natural Resources Management Board, Murray Bridge, South Australia.

Tonkin Consulting (2009). *Coorong Temporary Pumping Review. Report prepared for the South Australian Murray Darling Basin NRM Board*. Tonkin Consulting, Kent Town, South Australia.

US EPA (2005). *Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel* Last updated 14/02/2009, Accessed 16/09/2009, Available at http://www.epa.gov/OMS/climate/420f05001.htm

Webster, I. (2009). *Investigation of three variations on management intervention in the Coorong. Unpublished report prepared for the South Australian Murray-Darling Basin Natural Resources Managment Board*. SAMDBNRMB, Adelaide, South Australia.

Webster, I. T. (2005). *An Overview of the Hydrodynamics of the Coorong and Murray Mouth. Technical Report No. #/2005*. CSIRO: Water for a Healthy Country National Research Flagship,

Williams, W. D. (1986). Conductivity and Salinity of Australian Salt Lakes. *Australian Journal of Marine and Freshwater Research* **37** 177.

Wiltshire, K., Gluis, M., and Tanner, J. (2009). *Tolerances of juveniles and early life stages of the pipi, Donax deltoides, to elevated salinity produced by mixing of Coorong and seawater. SARDI Publication No. F2009/000678-1*. South Australian Research and Development Institute (Aquatic Sciences), West Beach, South Australia.

13 GLOSSARY OF TERMS

13.1 Acronyms

AHD	Australian Height Datum
CLLMM	Coorong, Lower Lakes and Murray Mouth
CSIRO	Commonwealth Scientific & Industrial Research Organisation
CSLFRP	Coorong South Lagoon Flow Restoration Project
CSMS	Coorong Salinity Management Strategy
DEH	Department for Environment and Heritage (SA)
DWLBC	Department of Water, Land and Biodiversity Conservation (SA Government)
EC	Electrical Conductivity (salinity measure)
EPA	Environment Protection Authority (SA Government)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
GL	Gigalitres (1,000 megalitres)
ML	Megalitres (1 million litres)
NRMB	Natural Resource Management Board
Ppt TDS	Parts per thousand, total dissolved solids (measure for salinity)
SARDI	South Australian Research and Development Institute
SLSRS	South Lagoon Salinity Reduction Scheme

13.2 Definitions

Aquatic	Consisting of, relating to, or being in water; living or growing in, on or near the water. An organism that lives in, on, or by the water.
AHD	Australian height datum – national survey datum corresponding approximately to average sea level.
Alkalinity	An expression of the ability of a solution to neutralise acids, measured as the milliequivalents of hydrogen ions neutralised by a litre of water (expressed as $CaCO_3$ in mg/L).
Barrages	A series of five structures that separate the fresh waters of the River Murray and Lower Lakes (Lakes Alexandrina and Albert) from the more saline waters of the Murray Mouth estuary and Coorong lagoons. These barrages - Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere - were constructed in the 1930s between the mainland and Hindmarsh, Mundoo, Ewe and Tauwitchere Islands, which are situated between the Lower Lakes and the Coorong.
Biodiversity	The range of different plants and animals found in a region.
Biota	All living organisms of a region.
Coorong	The Coorong is a long, shallow saline lagoon that stretches more than 100km and is separated from the Southern Ocean by a narrow sand dune peninsula.
Dredging	The process of sand pumping to maintain an open Murray Mouth to the Southern Ocean.
EC	Electrical conductivity – a measure of water's ability to conduct electricity. EC units (measured in µs/cm – micro Siemens per

	centimetre) are used to express salinity levels in soil and water. When salt is dissolved in water the conductivity increases, hence higher salinities are directly related to higher EC values.
Ecological character	The sum of the biological, physical and chemical components of an ecosystem, and the interactions, that maintain it and its products, functions, and attributes.
Ecological communities	Any naturally occurring group of species inhabiting a common environment, interacting with each other especially through food relationships and relatively independent of other groups. In the *Environment Protection and Biodiversity Conservation Act 1999* they are defined as assemblages of native species that inhabit particular areas in nature.
Ecosystem	A dynamic assemblage of plant, animal, fungal and micro–organism communities and the associated non–living environment interacting as an ecological unit.
Fauna	Animal species.
Flora	The assemblage of plant species within a defined collection or area.
GL	Gigalitre - 1 billion litres or approximately 444 Olympic swimming pools.
Habitat	The place in which an organism lives; comprising its physical structure, such as reef, sediments or water column properties, as well as biological structures, such as the dominant plant types. Specific place where a plant or animal lives.
Head	Water level gradient. Water flows in a direction of high hydraulic head to points of low hydraulic head.
Hydrodynamic	Pertaining to, or derived from, the dynamical action of water.
Hydrology	The science dealing with surface waters and groundwaters of the Earth; their occurrence, circulation and distribution; their chemical and physical properties; and their reaction with the environment.
Hypermarine	Water that is extremely saline and saltier than the sea.
Lower Lakes	Lake Alexandrina and Lake Albert form the Lower Lakes of the River Murray.
Migratory species	Migratory species are those animals that migrate to Australia and its external territories, or pass though or over Australian waters during their annual migrations. Examples of migratory species are species of birds (e.g. albatrosses and petrels), mammals (e.g. whales) or reptiles. Migratory species listed in the *Environment Protection and Biodiversity Conservation Act 1999* also include any native species identified in an international agreement approved by the Minister.
Murray Mouth	The terminus of Australia's largest river system and the only site where water contaminants such as silt, salt and nutrients can be exported from the Murray-Darling Basin.
North Lagoon	North Lagoon of the Coorong, defined as the lagoonal area between Parnka Point to Pelican Point.

Ramsar	Also known as the Ramsar Convention (first convened in Ramsar, Iran 1971). It is an intergovernmental treaty with global wetland sites designated for inclusion in the list of wetlands of international importance. In 2000, Australia had 56 Ramsar sites. The Coorong, Lakes Alexandrina and Albert was nominated and accepted in 1985 as a Wetland of International Importance, commonly known as a 'Ramsar Site'.
Regulator	Structure to regulate the flow of water, raise water levels and keep acid sulfate soils saturated. In doing so, acidic soils will remain wet, and limit the formation of acid that would otherwise be generated.
Salinity	Salinity is a measure of the salt concentration of water. Higher salinity means more dissolved salts. Electrical Conductivity (EC) is the measurement of salinity. Dissolved salt in soil or water creates a stronger electrical current, so the more salt in the soil or water, the higher the EC units will be.
South Lagoon	South Lagoon of the Coorong, defined as the lagoonal area between Parnka Point and 42 Mile Crossing.
Submerged	Existing beneath the surface of the water.
Technical feasibility	Technical feasibility assessments provide detailed analyses of the objective, rationale, critical assumptions and costings of implementing an action or intervention.
Threatened species	Any species that is threatened with extinction, throughout all or a significant part of its range. A species of wildlife or plants listed as 'threatened' in a specific Act. The *Environment Protection and Biodiversity Conservation Act 1999* lists threatened native species in the following categories: extinct; extinct in the wild; critically endangered; endangered; vulnerable; and conservation dependent.
Threatened ecological communities	An ecological community is a unique and naturally occurring group of plants and animals. Threatened ecological communities are those at risk of extinction. The *Environment Protection and Biodiversity Conservation Act 1999* lists threatened ecological communities as: critically endangered; endangered; or vulnerable.
Turbidity	The muddiness, cloudiness or milkiness of water. Related to the amount of suspended sediment in the water. Generally measured in Nephelometric Turbidity Units (NTU).
Water quality	The condition of water in the context of one or more beneficial uses. Usually described in terms of water quality indicators (such as pH, temperature and concentrations of salts, nutrients or contaminants).
Wetland of International Importance	See 'Ramsar'.
Wind seiche	The term given to the movement of water by wind energy.

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