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SKM

Government of South Australia

SA Water

Alternative Options Appraisal - Lower Lakes Acidification Management

STAGE I: PRELIMINARY REPORT ON ALTERNATIVE OPTIONS SCORING

- Final
- 6 April 2010

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Executive Summary

As a result of ongoing drought conditions across the Murray-Darling basin and associated low river flows into South Australia, water levels in the Lower Lakes system (including Lake Alexandrina, Lake Albert, the Coorong and associated tributaries) are currently at all time lows and are likely to drop further if drought conditions continue as predicted.

In response to this situation, the South Australian Government has referred a proposal to open the barrages that separate the Coorong from Lake Alexandrina to the Commonwealth Department of the Environment, Water, Heritage and the Arts under the provision of the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). It has been recognised that this action may be necessary as a means of preventing serious and permanent damage to the Lower Lakes system, although the use of seawater is seen as an 'action of last resort' to minimise the environmental consequences of acidification of the Lower Lakes system.

Sinclair Knight Merz Pty Ltd (SKM) was engaged by SA Water to undertake a technical feasibility and practicality assessment of options that may be used to manage acid sulfate soil derived acidification of the Lower Lakes system in South Australia, based on currently available studies and reports.

The general methodology applied in this assessment of potential alternative options was based on Multi Criteria Analysis (MCA), which provided a robust evaluation of multiple options against common criteria using a transparent and defendable assessment framework. Using this framework, qualitative information sourced from site specific studies, as well as broader generic sources, were translated into quantitative scores, so that each option could be assessed relatively.

The assessment criteria were broadly divided under the two headings of 'technical & practical feasibility' and 'costs (direct & indirect)'. Each option was also assessed with respect to potential negative risks to the environment as a result of its implementation.

Sensitivity analysis of the effect of variation in contribution from each of the two broad criteria was undertaken. The assessment currently indicates that the 'provision of freshwater via environmental allocations' option is generally ranked as the number 1 option across the majority of technical versus costs contribution ratios. The provision of freshwater (buy-backs) also shares the number 1 ranking when costs contribution is minimised (i.e. 0%). The Vegetation option ranks at number 2 for certain contribution ratios. However, further analysis of the scores indicates that the Vegetation option scores poorly on a technical basis (i.e. in terms of acidification management), but retains a high ranking due to high scores awarded on the costs contribution, coupled to a high multiplier for the perceived low environmental risks.

The ranking of the seawater inundation (via barrages) option increases when the cost contribution is increased, as it a low cost option. It does not score significantly well on the technical contribution as a treatment measure, as it is downgraded by its potentially high environmental risk, associated with inundating oxidised sediments. However, as the option scores a technical ranking of 4 (of 8), there may be merit in using this option as a preventative measure under certain conditions, i.e. to safeguard certain areas of Lake Albert.

Particular focus was given to the potential environmental risks associated with the implementation and operation of each option. The considered likelihood and severity of potential risks were applied as an adjustment factor, which produced an overall score for relative assessment. The high ranking options (i.e. provision of freshwater) were judged to have less environmental risks associated with implementation / operation than the option of last resort (i.e. use of seawater). Further, the majority of the alternative options were considered to have less environmental risk than the use of seawater to mitigate acidity, even when assuming seawater is used as a preventative measure. This high risk is associated with the potential for mobilisation of acidity and metal species to the overlying water column should seawater be applied to oxidised sediments (assuming no preliminary liming – neutralisation – operation has occurred).

Local scale application of options for the management of 'hotspots' of net acidity were also assessed, based on a threshold action criteria of 50 mol H^+/t net acidity, and assuming a 16 km^2 hotspot area. The hotspot application of options was scored with respect to application to the areas of the lakes with significant net acidity (i.e. below -1.0m AHD) as a conservative measure that is also valid for areas above -1.0 m AHD. The soil type (e.g. sands, clays) was considered during the assessment of option feasibility, and the presence of clays in Lake Albert below -1.0m AHD was considered to have a potential effect on the effectiveness of those options dependent on a relatively high hydraulic conductivity (i.e. bioremediation). The local scale assessment resulted in the provision of freshwater (buyback) being ranked the highest option (1) where 50% to 100% technical contribution is considered. This ranking falls significantly to 5 at 100% cost contribution, reflecting the significant financial resources required to implement this option. This pattern is also evident at a large scale. The respective higher scores for 'buy-back' versus 'environmental allocation' are attributable to the increased confidence in obtaining the required volume via purchasing, over that of re-allocation from other sources.

The provision of freshwater (environmental allocation) is ranked as the number 2 option over each cost contribution. Provision of freshwater (allocation) is the most stable ranked option irrespective of cost contribution. A similar pattern is also evident for this option at a large scale, although scores 1 ranking lower at a local scale. This is due to significantly lower costs associated with provision of water through buyback at a local scale where lower water volumes are required.

The assessment presented here is a preliminary assessment of 'blanket' options and is considered to be Stage I of a 2 Stage process. Stage I should not be used as a basis for decision making, as its function is to provide the foundations for Stage 2 of the assessment (detailed assessment). This document is also considered to be a 'live' document which may require adjustment / updating as the environmental situation develops.

1. Introduction

Sinclair Knight Merz Pty Ltd (SKM) was engaged by SA Water to undertake a technical feasibility and practicality assessment of options that may be used to manage acid sulfate soil derived acidification of the Lower Lakes system in South Australia.

This study provides a comparative analysis of the impacts of prescribed options on Lower Lakes acidification, and qualitatively discusses the potential for recovery of the system from the employment of each alternative.

1.1. Background

As a result of ongoing drought conditions across the Murray-Darling basin and associated low river flows into South Australia, water levels in the Lower Lakes system (including Lake Alexandrina, Lake Albert, the Coorong and associated tributaries) are currently at all time lows and are likely to drop further if drought conditions continue as predicted. The location and layout of the Lower Lakes system is presented in Figure F1.

In response to this situation, the South Australian Government has referred a proposal to open the barrages that separate the Coorong from Lake Alexandrina to the Commonwealth Department of the Environment, Water, Heritage and the Arts under the provision of the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). It has been recognised that this action may be necessary as a means of preventing serious and permanent damage to the Lower Lakes system, although the use of seawater is seen as an 'action of last resort' to minimise the environmental consequences of acidification of the Lower Lakes system.

It has been determined that the proposed action to open the barrages and allow seawater to flow into the Lower Lakes system would require approval by the Minister for the Environment, Heritage and the Arts as it has the potential to significantly impact on the following matters of national environmental significance (NES) as recognised by the EPBC Act:

- Wetlands of international importance;
- Listed threatened species and communities;
- Listed migratory species; and
- Commonwealth land.

The proposed action to open the barrages will be assessed by an Environmental Impact Statement (EIS). The preparation of the EIS and the array of supporting technical studies that will be integral to the EIS is the responsibility of the South Australian Water Corporation (SA Water).

The EIS is required to address a range of environmental, social and economic impacts associated with:

- The proposed action to open the barrages;
- Likely mitigation measures to be employed to restore the 'ecological character' of the Lower Lakes system if the proposed action proceeds; and
- The employment of alternative management options to the proposed action.

Given that the proposed opening of the barrages is considered to be an 'action of last resort', the assessment of impacts associated with alternative management options to that proposed is a key priority.

1.2. Acid Sulfate Soils

Acid sulfate soils is a term used to describe soils or sediments that contain significant amounts of sulfide, which upon oxidation can potentially generate sulfuric acid. During the last major sea level rise, rapid sedimentation led to the formation of new coastal landscapes. Bacteria in these waterlogged landscapes converted sulfate from seawater, and iron present in the sediments to produce iron pyrite (FeS_2). When exposed to oxygen, these iron pyrites oxidise to sulphate, which is generated in the form of sulfuric acid.

Acid sulfate soil can be either 'potential' or 'actual' acid sulfate soil (PASS/ASS):

- Potential acid sulfate soil (PASS) are soils / sediments which contain sulfidic material that have not been oxidised (i.e. they are below the water table). The pH of these soils / sediments in their un-oxidised state is above pH 4. Upon oxidation (e.g. contact with air) the sulfide within these PASS will oxidise and generate sulfuric acid, and the pH of the soil / sediment will decrease to below pH 4.
- Actual acid sulfate soils (ASS) are soils/sediments containing sulfidic material that have been oxidised and have produced sulfuric acid, resulting in an existing pH of below pH 4 and often accompanied by a yellow and/or red mottling in the soil profile. ASS generally contain residual potential acidity (as sulfides) as well as existing (actual) acidity.

In this document, ASS will be used to mean both potential ASS (PASS) and actual ASS.

The sulfuric acid produced by oxidation of iron sulfides affects both soil and water, and significantly damage the environment. Most aquatic life needs a minimum pH of 6 to survive. The pH of acid sulfate soil associated drainage and water bodies can be as low as pH 2 and is often around pH 4. Massive fish kills can occur when sulfuric acid is washed into water bodies. This particularly occurs following drawdown of the water table and subsequent oxidation of the iron pyrite layer in the sediment (note that the rate of acid flux to a water body is dependent on several factors including the rate at which pyrite oxidises following exposure to oxygen). Drought breaking rains, a rebound of the water level / table and seiching of exposed sediments by water from the water body can wash substantial quantities of acidity (and pH dependant metals) into water bodies, resulting in significant detrimental effects to the ecosystem.

1.2.1. Describing Acid Sulfate Soils

Acid sulfate soils are characterised by the amount of net acidity (as mol H^+ / t), which is determined by chemical analysis. From the analytical results, the amount of ameliorant needed to be added to the soil to prevent the possibility of net acid export (i.e. neutralisation) can be calculated, using an acid-base account (ABA). While several ABA models have been used for ASS, they all share a common underlying principle, as per the following equation:

Net Acidity = **Potential Sulfidic Acidity** + **Existing Acidity** – **Acid Neutralising Capacity**

A detailed description of this approach can be found in Ahern et al., 2004.

In South Australia, the net acidity of soils disturbed for example during development works can be compared to the guideline net acidity criteria (SA EPA, 2007), as shown in Table 1. However, the net acidity of sediments across the lakes is generally likely to exceed the guideline criteria, and the guideline criteria are only presented here for comparison purposes.

- **Table 1 - South Australian EPA. EPA Guidelines – Site Contamination – Acid Sulphate Soil Material EPA Guideline 638/07. Issued November 2007**

Soil or Sediment Texture	Criteria	
	Sulphur trail % oxidisable sulphur (oven dry basis)	Acid trail mol H^+/tonne (oven dry basis)
Sands to loamy sands	0.03	18
Sandy loams to light clays	0.06	36
Medium to heavy clays and silty clays	0.1	62

1.3. Acid Sulfate Soil in the Lower Lakes Environment

Previous preliminary investigations undertaken by CSIRO (Fitzpatrick et al., 2008) combined current bathymetry, soil and vegetation mapping in Geographical Information Systems (GIS) to predict the distribution of the fourteen sub-types of ASS identified in the Lower Lakes and River Murray below Lock 1, according to the following water level scenarios:

- Pre-drought water level, i.e. +0.5 m AHD; and

- Current drought level (as of February 2008), i.e. -0.5 m AHD.

Field verification inspections were used to assist in the calibration of the predictive GIS mapping, which consisted of the development of the following predictive ASS maps:

i. Lake Albert (Figure 1); and

ii. Lake Alexandrina (Figure 2).

These maps predict the spatial range of ASS sub-types when the water levels were at pre-drought levels (i.e. +0.5 m AHD) and the approximate present day levels (i.e. -0.5m AHD).

Figure 1 – Predictive scenario maps depicting changes in ASS materials at different water levels in Lake Albert (after Fitzpatrick et al., 2008)

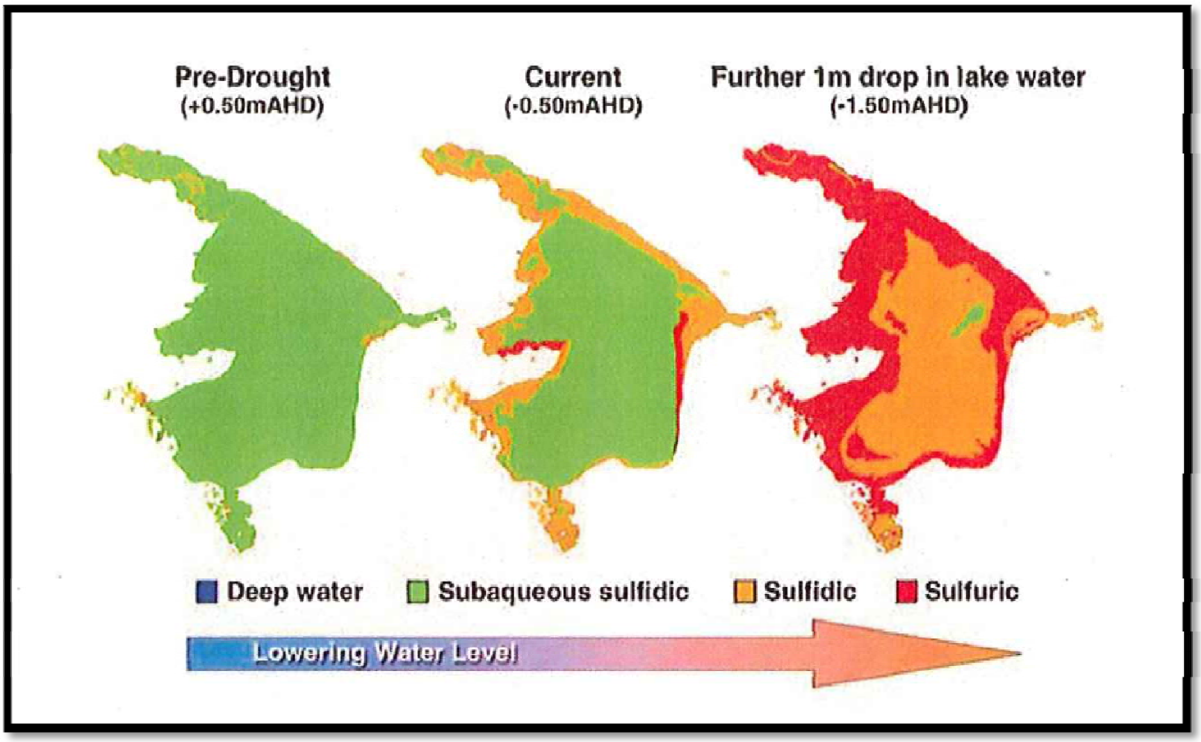
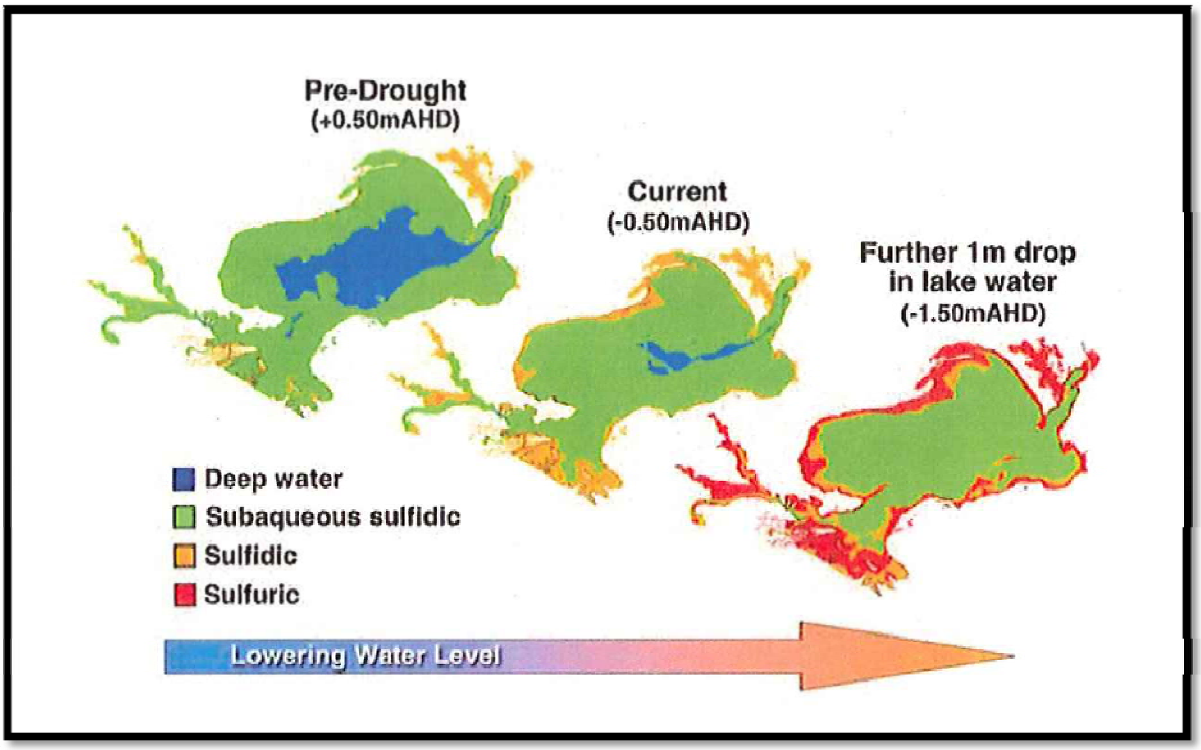


Figure 2 - Predictive scenario maps depicting changes in ASS materials at different water levels in Lake Alexandrina (after Fitzpatrick et al., 2008)



As the water levels drop, previously deep water soils become sub-aqueous, with these sub-aqueous soils eventually becoming exposed as water levels decrease further (although these soils are still waterlogged and therefore anaerobic). Following a further decrease in water levels, these sub-aqueous soils are dewatered, and become dry and oxidised, leading to oxidation of pyrite and concomitant generation of sulfuric acid (i.e. resulting in a pH <4), assuming sufficient sulfidic material is present in the drying layers.

As shown in the predictive GIS maps developed by CSIRO, the oxidation (and consequential acid generation) of sulfidic materials in the shallow lower lakes is potentially significant.

Building on the predictive mapping undertaken in 2008, increased spatial variability assessment of sub-aqueous and terrestrial acid sulfate soils within the Lower Lakes was undertaken in 2009 (Grealish et al., 2009). The resulting updated maps identified areas of concern where low $pH_{soil:water}$ (sulfuric material) or/and high net acidity (Figure F2), and medium to high electrical conductivity occurred at Loveday Bay, near the barrages to the south of Alexandrina, near Clayton, Finniss River and Currency Creek, in the north of Lake Alexandrina (Boggy Lake and Dog Lake), and numerous isolated areas around the margins of Lake Albert.

Other areas were identified with low $pH_{soil:peroxide}$, net acidity and $pH_{incubation}$ that would indicate potential areas of concern (i.e. sulfidic material) if water levels continue to lower and the acid sulfate soils are oxidised. These areas include isolated locations throughout Lake Alexandrina and the majority of Lake Albert.

The spatial assessment indicates that there are several (generally marginal / peripheral) areas in both Lakes that are considered to exhibit < 0 mol H^+/t net acidity. These areas are largely associated with sand strata that have low sulfidic acidity and adequate acid neutralising capacity. The majority of sediments within both Lakes and the Finniss River and Currency Creek however demonstrate medium (25-50 mol H^+/t) to high (50 - >1,000 mol H^+/t) net acidity. As discussed previously, an upper limit of net acidity with respect to protection of the environment is generally considered to be 18.7 mol H^+/t (SA EPA, 2007).

The areas of significantly high net acidity are located in the central areas of Lake Alexandrina, and in the north western and south eastern quadrants of Lake Albert. The lithology of Lake Albert comprises more clays than Lake Alexandrina, and hence the propensity for higher net acidity in Lake Albert is increased.

Table 2 details the net acidity (mol H^+/t) classes by area (ha) in Lake Albert as the water level lowers. A significant area of acid sulfate soils with significantly elevated net acidity (>500 mol H^+/t) is predicted to be present as the water level drops to below -2.0 m AHD, with a significant area of acid sulfate soil predicted to be exposed as the water level drops from -0.75 m AHD. The highest net acidity is predicted to occur between -1.0 m AHD and -2.0 m AHD (Table 3).

- **Table 2 - Net Acidity Statistics: Lake Albert[1]**

Water Levels (m AHD)	Net Acidity Classes (mol H^+/t; area in hectares)							Total for each water level (ha)	Cumulative Total (ha)
	>1000	500-1000	100-500	50-100	25-50	0-25	<0		
>-0.5	3	513	1721	393	216	179	539	3564	3564
-0.75 to -0.5	0	496	1204	260	115	89	472	2636	6200
-1.0 to -0.75	71	1069	990	109	62	32	111	2444	8644
-2.0 to -1.0	112	2961	4805	296	77	51	191	8493	17137
<-2.0	0	2	9	4	2	3	3	23	17160

1 Source: CSIRO (net acidity data) and DEH, November 2009

Table 3 - Lake Albert Net Acidity - Excluding <0 range[2]

Water Levels	Mean Net Acidity
>-0.5	274
-0.75 to -0.5	298
-1.0 to -0.75	506
-2.0 to -1.0	452
<-2.0	190

With respect to Lake Alexandrina, zonal statistics were used to determine potential net acidity ranges associated with bathymetry. A significant range of net acidity was predicted throughout all ranges of bathymetry, although the highest mean was predicted to occur as the water level falls below -2.3m AHD (Table 4).

Table 4 - Zonal Statistics on the Net Acidity (all values are mol H+/t unless otherwise stated)[3]

ZONE	DEPTH RANGE	AREA (ha)	MIN	MAX	RANGE	MEAN	STD
1	<-2.3m	22190	-464.448	1321.5	1785.95	231.194	150.442
2	-2.3m to -2.0m	10097	-795.806	640.427	1436.23	92.5058	143.715
3	-2.0m to -1.5m	9511	-702.345	1274.27	1976.61	49.3756	147.680
4	-1.5m to -1m	7186	-773.249	890.602	1663.85	29.6113	133.378
5	>-1m	12797	-804.595	785.818	1590.41	85.0631	147.144

The net acidity data presented in Table 4 highlights the principle risk to the environment of acid sulfate soils, which is the drawdown of water level to below -1.5 m AHD, with a then a subsequent rise back above this datum, which would leach a significant amount of acidity into the environment.

1.4. Environmental Impacts of Acid Sulfate Soils in the Lower Lakes Environs

Although the significantly elevated areas of net acidity are considered to be located in the central area of Lake Alexandrina and the north western and south eastern areas of Lake Albert, a high

[2] Source: CSIRO (net acidity data) and DEH, November 2009
[3] Source: CSIRO (net acidity data) and DEH, November 2009

proportion of the Lakes environs demonstrate net acidity above the upper limit of 18.7 mol H^+/t. Some peripheral areas within the Lower Lakes environs have experienced water level drawdown and subsequent exposure of acid sulfate soils, with significant generation of acidity. Around 200 ha of acidic water has been reported in Loveday Bay, in the southern region of Lake Alexandrina. Monitoring of pH in Loveday Bay lake water reported values less than 3. Completely or partially dissolved mussel shells were identified in this area (DEH, 2009a).

1.5. Objectives of the Alternative Options Study

A large number of studies have been completed or are currently being undertaken that are relevant to the consideration of alternative management options for the Lower Lakes system. As these studies have been (or are currently being) undertaken by a range of Government agencies and consultants, a key objective of the Alternative Options Study (AOS) is to bring together and review these studies as a necessary first step in assessing the technical feasibility and practicality of alternate potential management options.

A further consideration of this study is to identify possible combinations of alternative management options.

1.6. Scope of Work (Up to Mid-Term Workshop)

The Scope of Works was developed from the Request For Tender (RFT, reference CS4582B), and in consultation with the Alternative Options Study Management Team (SMT), during the project inception workshop component of the project. The Scope of Works that has been covered in the AOS up to the mid-term workshop (yet to be undertaken) has comprised:

- *To review and analyse the literature and array of studies listed below;*
- *To describe and compare the impacts of each alternative management option (listed above) on acidification of the Lower Lakes system;*
- *To describe and compare the environmental costs and benefits of employing each alternative management option;*
- *To determine the technical feasibility/effectiveness and practicality of employing each alternative management option to prevent/remediate/neutralise acidification of the Lower Lakes System;*
- *To identify and propose effective alternative management options to prevent/remediate/neutralise environmental harm to the Lower Lakes system;*
- *To propose a suitable timeframe to develop and implement effective alternative management options identified as technically feasible and practicable; and*
- *To list uncertainties in the assessment of the effectiveness and practicality of different options and make recommendations (where required) to reduce those uncertainties.*

1.7. Preliminary Assessment

The assessment of alternative options presented within this document is of a preliminary nature and should not be used as the basis and/or to support decision making on the use of one or more options to mitigate acidification of the lower lakes. This preliminary assessment is Stage I of a 2 Stage process, and is designed to support further more detailed assessment in Stage II. Thus the results of the assessment and the conclusions drawn should not be used out of context.

1.8. Nominated Options

The options nominated for assessment are as follows:

1. Do Nothing;
2. Bioremediation;
3. Inundation of Lakes with Seawater (via barrages);
4. Vegetation;
5. Neutralisation;
6. Provision of Freshwater via buy-backs; and
7. Provision of Freshwater (environmental allocations).

In addition, the pumping of seawater direct into Lake Albert from the Coorong was also considered in relation to the above seven options. A summary of each option is provided below, with a more detailed description (SMART review) of each option provided in Appendix A[4].

1.8.1. Do Nothing

No active preventative management measures will be undertaken to address environmental acidification of the lower lakes, assuming that the Wellington Weir and the Clayton regulator will both be in place and operational.

1.8.2. Bioremediation

Bioremediation refers to management approaches that aim to promote microbial activity (sulphate-reducing bacterial activity) in order to convert dissolved sulphate to sulphide minerals, while consuming acid. This essentially reverses the pyrite/iron monosulfide oxidation reactions that generated acidity in the first place.

1.8.3. Inundation of Lakes with Seawater

Although the intent is to maintain fresh water in the Lower Lakes, if water levels and water quality drop below a critical point and acidification is imminent then allowing sea water into the Lower Lakes will need to be considered. This would not involve flooding the Lower Lakes with sea water,

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[4] Note that freshwater (environmental allocations) is considered to be a mirror option to 'buy-backs' and so is not replicated in Appendix A.

but allowing just enough water through the barrages to maintain the level of Lake Alexandrina above the trigger level of -1.5 metres below sea level.

1.8.4. Vegetation

In the context of this project Vegetation is the term used for covering with vegetation the soils affected by lack of water within the Lower Lakes system.

The Vegetation may include local native plant species, exotic annuals or exotic perennials identified as effective in covering soils to assist in the bioremediation of the area.

Although biodiversity is extremely important in this region, the Vegetation that is proposed does not have the sole purpose of improving biodiversity. Rather, the primary purpose of the initial Vegetation is to provide ecosystem stability or resilience by immediate soil cover, stabilising moving sand to reduce the impacts on the natural ecosystem, individuals and communities. These actions are likely to have an effect on reducing soil acidification by assisting to maintain soil moisture in the short-term, and by providing longer-term benefits as part of a bioremediation process.

1.8.5. Neutralisation

Generally, in environmental or development works, where the disturbance of ASS is unavoidable, the most common technique for managing ASS is neutralisation of the acidity using a buffering agent such as limestone.

1.8.6. Provision of Freshwater via buybacks

The sediments identified as being potentially acid sulphate generating would be saturated (not necessarily inundated) with freshwater to maintain a low redox environment and prevent pyrite oxidation. Freshwater would be resourced from water purchase.

1.8.7. Provision of Freshwater via Environmental Allocations

As Section 1.8.6 above but using freshwater from environmental allocations and re-allocation of current licenses not required / used.

1.8.8. Transfer of Seawater from the Coorong to Lake Albert

Although the intent is to maintain fresh water in the Lake Albert, if water levels and water quality drop below a critical point and acidification is imminent then allowing sea water into the Lake will need to be considered. This would not involve flooding the Lake with sea water, but allowing just enough water into the Lake to maintain the level of the Lake above the trigger level of -0.75 metres below sea level. The transfer of water into Lake Albert would be achieved via

- pumping of water from the Coorong; or
- establishment of a channel from the Coorong to the Lake.

2. Methodology

2.1. Overview

The general methodology applied in this study to review potential alternative options was based on Multi Criteria Analysis (MCA). The key principles of the MCA approach being as follows:

- Provides robust evaluation of multiple options against common criteria;
- Transparent and defendable assessment framework;
- Gain strong stakeholder 'buy-in' to process and therefore to outcomes;
- Minimisation of individual bias (consensus outcomes); and
- Objective assessment where possible (minimise subjectivity).

The first step of the methodology was a Project Inception Meeting (Step 1), which was undertaken in order to open up an early dialogue with the Study Management Team (SMT) and research teams, and develop / finalise the MCA framework, the review methodology and communication plans.

Step 2 involved the development and finalisation of the MCA framework, using the criteria and parameters agreed with the Study Team during the project inception workshop. Both the criteria and options were developed using a SMART approach:

- Specific;
- Measurable;
- Achievable;
- Relevant; and
- Time bound

This collaboratively designed and SMART reviewed assessment tool allowed the review to be approached with clear goals in mind.

Following the achievement of a consensus on the assessment metrics, the review was better positioned to determine each option's suitability, with respect to technical feasibility, practicality and lifecycle / environmental costs (note that these terms are defined in Appendix B - Weighting Justification).

Each option was reviewed in light of currently available studies / information, to identify potential shortcomings with respect to the chosen assessment criteria. The opinions derived from the review of each option were used to determine relative scores within the MCA framework. The significance of the technical and practicality merits of each potential option were identified during the data and information review using an issue decision process (IDP) with the ultimate outcome of this Step being the identification of which alternative options (or sub-components) are potentially effective.

A more detailed description of the individual steps is provided below.

2.2. Step One – Project Inception

This step involved SKM and the SMT working collaboratively to identify and articulate the objectives, requirements, constraints and sensitivities for future activities. This inception workshop supported the development of the review framework and parameters and the Issue Decision Process (IDP) for managing the review of the current information and data (i.e. amendment and finalisation of the Step 2 framework).

The assessment criteria for the MCA Framework were based on criteria developed for the EIS, which were deemed directly relevant to the alternative options, and agreed upon within the Project Inception workshop. The assessment focussed on the following broad criteria:

1. Technical and Practical Feasibility of the option (with regards to mitigating environmental acidification of the Lower Lakes); and
2. Costs – both direct (i.e. to Government) and indirect (i.e. the Lakes region and the wider environment).

A summary of the chosen criteria is presented below (Table 5).

Table 5 - MCA Criteria

Criteria Level	Criteria		
Heading	**Technically feasible and achievable in practice on the scale required**		
Sub-criteria		Technically feasible (theoretically, will it work?)	
Base Criteria			• A - Option is theoretically viable • B– Theoretically viable on the scale (spatial) required
Sub-criteria		Achievable in practice (has it been proven to work?)	
Base Criteria			• A - Generic Proof of Concept established • B - Proof of Concept established in similar (representative) environs • C – Proof of concept established in Lower Lakes environments and environs
Sub-criteria		Implemented successfully before acidification of the Lakes occurs – Dependant on Lakes recharge	
Base Criteria			• A1 – on a large scale • A2 – on a localised scale

Heading	Costs to Government (State or Federal)		
Sub-criteria		8.1 Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)	
Base Criteria			• Capital / Establishment costs are minimal • Operational / Maintenance costs are minimal • Decommissioning costs are minimal
Sub-criteria		8.2 Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)	
Base Criteria			• Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region) • Maximises the indirect benefits experienced in the wider Lower Lakes region (e.g./ tourism, agriculture, wine, lifestyle)

2.3. Step Two – MCA Development

The chosen criteria (as above) were then processed through a SMART review (see Section 2.1) in order to fully define the exact interpretation of each criterion to sub-criteria level, as presented in Table 7 .

Table 6 - SMART Interpretation of criteria

Criteria			Technically feasible and achievable in practice on the scale required		Costs to Government (State or Federal)	
	Sub Criteria		Technically feasible on the scale required.	Achievable in practice on the scale required.	Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option)	Indirect or environmental costs & benefits.
		Specific	Requires 'proof of concept' or high levels of confidence to determine technical feasibility	Requires modelling confidence to determine achievability at this scale	Requires assessment of the relative dollar value associated with the lifecycle costs of the option	Assessment of the relative socio-economic costs
		Measurable	Yes – if relevant parameters are defined	Yes – if relevant parameters are defined	Yes – all options will have high level determinable lifecycle costs	Yes – all options will have high level socio-economic costs
		Achievable	Unknown – could be limited by resources (dollars and other)	Unknown – could be limited by resources (dollars and other)	Achievability is related to unknown dollar value of resource	As defined by chosen acceptable boundaries for socio economic impact
		Relevant	Relevant parameters need to be chosen	Relevant research and testing needs to occur and then parameters need to be chosen to gauge success	Relevant to other options due to unknown available dollar value	Relevant to socio-economic study (separate) but as indicator here
		Time bound	Over what period of time is the criteria expected to be relevant?	Over what period of time is the criteria expected to be relevant?	Over what period of time are financial inputs required?	Period of time socio-economic effects / benefits are of concern?

A SMART review was also undertaken for each of the prescribed potential alternative options, in order to assess each option in the same 'currency' as the criteria, as presented in Table 7.

Table 7 - Interpretation of SMART parameters for potential options

SMART Component	Descriptive
Specific	Define the specific scope of the option
Measurable	How do we measure what happens?
Achievable	Is there proof of concept, trials etc
Relevant	Is the option suitable in the Lower Lakes environs?
Time bound	When do we expect to see results? / How long are we measuring for?
Other Comments	Risks, costs etc (i.e. input as adjustments to MCA Framework)

The resulting SMART review for the options is presented in Appendix A.

The determined criteria were then built into an MCA framework, which allowed increasing points to be awarded against each criteria (i.e. '0' for no benefit, up to a maximum of '10' for maximum benefit) in relation to how each option aligned with the criteria, as follows:

Alignment with Criteria:

- No / Not Applicable = 0
- Unlikely = 2
- Probable = 5
- Yes = 10

The criteria headings (Table 5) were weighted on a percentage basis, in order to assess the sensitivity of the contribution of 'technical & practical feasibility' vs. 'costs (direct & indirect)'. These heading weightings were set at 50 % / 50 %, with subsequent sensitivity analysis demonstrating a sliding scale of contribution from 100% Technical & Practicality / 0% Costs to 0% Technical & Practicality / 100% Costs.

The contribution of each criteria sub-heading was then allocated from 100% total, with the base criteria also having an allocation from 100% Total. Table 5 presents the contribution hierarchy. The weighting given to each of these criteria is presented in Appendix B along with a justification for the allocated weighting.

Decision confidence adjustment

Each of the individual scores was assessed in terms of the confidence of the decision, as follows:

- High confidence that the score is accurate = 1.0
- Medium confidence score = 0.75
- Low confidence score = 0.5

These confidence scores were allocated based on which parameter specific status was most applicable to the review / output of the review (Appendix CAppendix C - Decision Confidence Assessment). The sub total of the scores allocated across all criteria was then processed through several adjustment factors, as outlined below:

- **Preventative vs. Treatment**

  The sub total was multiplied by either a factor of 1.0 if it was deemed to be a preventative measure, or a factor of 0.75 if deemed to be a treatment (i.e. post acidification). The multiplier for 'preventative' was higher than 'treatment' to allow benefit to be provided for a measure likely to mitigate acidification before it may occur, and thereby minimising risk to the environment.

- **Risk of negative impact**

  This adjustment factor is a reflection of the direct environmental negative impacts associated with the option being scored, in terms of implementation, and is split over two multipliers:

  - Likelihood of negative impact
  - Severity of negative impact

  Based on the following standard risk assessment matrix (Table 8):

Table 8 - Risk Matrix for Assessment of Negative Impacts

Severity Level					
Likelihood	**1** (negligible)	**2** (slight)	**3** (moderate)	**4** (dangerous)	**5** (critical)
E (almost certain)	H	H	E	E	E
D (likely)	M	H	H	E	E
C (possible)	L	M	H	E	E
B (unlikely)	L	L	M	H	E
A (very rare)	L	L	M	H	H

Where:

Risk Level	
E =	Extreme Risk
H =	High Risk
M =	Moderate Risk
L =	Low Risk

Thus risks are categorised according to the likelihood of the risk occurring and the consequence of its occurrence. A description of the matrix phrases is provided below in Table 9 and Table 10:

Table 9 - Likelihood of risk

Likelihood – Qualitative measures		
Level	**Descriptor**	**Detailed Description**
E	Almost Certain	The event ***will occur*** during the implementation / operation.
D	Likely	The event ***is likely to occur*** during the implementation / operation.
C	Possible	The event ***may occur*** during the implementation / operation.
B	Unlikely	The event is ***not likely to occur*** in the implementation / operation.
A	Very Rare	The event will ***only occur in exceptional circumstances***.

Table 10 - Consequence of risk

Consequence – Qualitative measures		
Level	**Descriptor**	**Detailed Description**
5	Critical	Disaster – loss of human life, extensive loss of flora and fauna, loss of property, reputation, financial resources. (Financial consequences: 75% or greater of operation budget).
4	Dangerous	Critical event, which with proper management can be endured. (Financial consequences: 50% - 75% of operation budget).
3	Moderate	Significant event that can be managed under normal operating procedures. (Financial consequences: 20% - 50% of operation budget).
2	Slight	Consequences can be readily absorbed but management effort is still required to minimise impacts. (Financial consequences: 10% - 20% of operation budget).
1	Negligible	Very low significance. (Financial consequences: less than 10% of operation budget).

2.4. Step Three - Options Review

This step comprised a review of available supplied data and information, coupled with a review of existing system conditions, in order to better understand the Lower Lakes system, its environmental characteristics and potential data gaps associated with the studies supporting the current ensemble options. The focus of the review was guided by the criteria and parameters finalised in the MCA Framework (See Output from Step 2).

A comprehensive list of the studies and reports undertaken on the Lower Lakes with respect to acid sulfate soils, as provided to SKM by the SMT is provided as Appendix D.

Maintaining a justifiable and transparent record of the technical issues arising from the review was recognised as a necessary part of the review process. Therefore the potential issues were assessed using the Issue Decision Process (IDP) to identify the significance of each issue. The IDP used in this review is presented in Figure F3, and is based on an Issue Decision Process previously devised and implemented by British Nuclear Fuels / UK Environment Agency for the environmental assessment of radioactive site development and management. Thus the IDP is based on a sound technical review and decision process and can be used right down to the data review / data implementation level.

Note that the term 'effectiveness' used in Figure F3 and herein is defined by SKM as representing technical effectiveness and practicality.

The proposed IDP results in five possible levels of significance dependant on certain review criteria, as follows:

1. Non-significant issue;
2. Review Criterion met;
3. Review Criterion met (observations);
4. Review criterion met (reservations); and
5. Review criterion failed.

Outcomes 1 and 2 indicate that the specific issue is unlikely to be significant to the robustness / effectiveness of the option. Outcome 3 indicates that the issue is potentially significant although is not thought to unduly affect the overall robustness / effectiveness of the option. Outcome 4 indicates that the specific issue may seriously affect the robustness / effectiveness of the option unless further supporting information / data or option amendment is available, while Outcome 5 indicates that the specific issue is likely to seriously affect the robustness / effectiveness of the option and that no further information / data or amendment would be likely to resolve the situation.

An Issues Register was developed for each option that was used to record all the comments, issues and level of significance arising from the review process. The Issues Register allows ease of access to the comments that form the core of the review (and output), and the decisions made on each review issue.

The Issues Register assists in the thought and decision process regarding the technical feasibility and practicality of each option in terms of being transparent and auditable, and importantly, readily accessible by the Study Management Team.

The findings of this Step were drawn together and used to develop scorings for each option (with full justification provided, Section 3).

2.5. Step Four – MCA scoring & reporting

Step 4 of the process comprises the collation of scoring justification and translation of the determinations into a semi-quantitative result using the MCA scoring process.

The results of the MCA for each option can then be assessed in relation to each other to indicate where each option may be potentially beneficial / detrimental to the environment, and indicate potential high level cost issues.

3. Scoring Assessment

The results and associated justification of the scoring assessment for each option is presented in this section. The Issues Registers providing the underpinning support to this section and completed during the review of each option are presented in Appendix E. The confidence determination is based on the parameter specific requirements presented in Appendix C.

The MCA scoring matrices for each option are presented as Tables 001 to 008 in Appendix F.

3.1. Option: Do Nothing

This option comprises no active preventative measures being undertaken to address acidification of the Lower Lakes. The issue register for this option is presented as Table I in Appendix E - *Issues Registers*. The MCA Scoring Assessment is presented as Table 001.

3.1.1. SMART Review

The SMART review for the 'do nothing' option is presented in Appendix A.

3.1.2. Technically feasible and achievable in practice on the scale required

3.1.2.1. Technically feasible (theoretically, will it work?)

A - Successful implementation of option is theoretically possible

Score: 'Probable' alignment with criteria, with a 'high' level of confidence in this score.
Justification: Theoretically, the 'do nothing' option could be successful in mitigating the acidification of the Lower Lakes, assuming the following:

- that there was a sudden return to more normalised flow conditions;
- the generation of acidity was not as significant as forecast; or
- the buffering capacity of the system was such that any acidity generated could be naturally attenuated.

B– Theoretically viable on the scale (spatial) required

Score: 'Unlikely' alignment with the criteria, with a high level of confidence in this score.
Justification: Whilst the 'do nothing' option may work on the local scale, increasing the spatial size will probably limit the effectiveness of this option. For instance, conditions in part of the system may be such that any acidity generated can be naturally attenuated, but due to the spatial variability in many environmental parameters, ideal conditions (i.e. effective inherent neutralisation capacity) are unlikely to occur across the entire system (based on the currently available information regarding heterogeneity of soils).

3.1.2.2. Achievable in practice (has it been proven to work?)

A - Generic Proof of Concept established

Score: 'Probable' alignment with the criteria, with a medium level of confidence in this score.
Justification: In some cases, a 'do nothing' approach has worked to treat environmental acidification. For instance, there are sites where acid discharge occurs (not necessarily from ASS), but natural processes are sufficient to treat the acidity generated (e.g. Sarmientoa et al., 2009; Ergas et al., 2006). It is possible that there are other cases where a 'do nothing' option has worked, but they are not reported as no problem is evident.

B - Proof of Concept established in similar (representative) environments

Score: 'Unlikely' alignment with the criteria, with a moderate level of confidence in this score.
Justification: There is documented proof of some acid sulfate soils (in estuarine wetlands in Australia) having an inherently high Acid Neutralising Capacity, which exceeds their acid generation potential (McElnea et al. 2004). In such cases, a 'do nothing' approach would be effective as there would be no net acid generation upon the oxidation and subsequent flushing of these sediments. However, most documented evidence throughout estuarine environments in Australia, suggests a 'do nothing' approach to acid sulfate soils may result in subsequent acid generation and discharge.

C – Proof of concept established in Lower Lakes environments and environs

Score: 'No' alignment with the criteria, with a high level of confidence in this score.
Justification: There is no apparent proof of concept that indicates that doing nothing to manage acidification in the Lower Lakes and allowing lake levels to decline will not result in the generation of acidity. Indeed there is evidence to the contrary, with a significant generation of acidity already noted in the Finniss/Currency Creek region as water levels have declined (refer study 15).

3.1.3. Implemented successfully before acidification of the Lakes occurs

A1 – on a large scale

Score: 'Unlikely' alignment with the criteria, with a low level of confidence in this score.
Justification: Current indications suggest the 'do nothing' option will not be successful in treating the acidification from ASS (CSIRO, 2009). In addition, the 'do nothing' option is currently the status quo, and increased evidence of acidification has been identified. Therefore it is unlikely that this option could be effective in terms of acidification mitigation prior to acidification of the system.

A2 – on a localised scale

Score: 'Unlikely' alignment with the criteria, with a moderate level of confidence in this score.
Justification: Current indications suggest the 'do nothing' option will be unlikely to successfully treat the acidification from ASS (CSIRO, 2009). However, it is theoretically possible that the approach could work

in some localised zones where conditions are conducive to minimal acidification (i.e. below predicted sulfuric content and / or presence of sufficient inherent buffering capacity).

3.1.4. Costs to Government (State and Federal)

3.1.4.1. Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)

A - Capital / Establishment costs are minimal

Score: 'Yes' alignment with the criteria, with a high level of confidence in this score.
Justification: Assuming that the 'do nothing' option is applied indefinitely, regardless of the effectiveness of the approach, then it is likely that its capital / establishment costs can be confidently predicted as minimal.

B – Operational / Maintenance costs are minimal

Score: 'Yes' - Maximum alignment with the criteria, with a high level of confidence in this score.
Justification: A 'do nothing' approach will involve minimal operational and maintenance costs besides those costs required for environmental monitoring expenditure, which are applicable to other options regardless.

C – Decommissioning costs are minimal

Score: Maximum alignment with the criteria, with a high level of confidence in this score.
Justification: As no infrastructure or specific management plan is required, it is considered that the 'do nothing' option would incur minimal decommissioning costs.

3.1.4.2. Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)

A - Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region)

Score: 'Unlikely' alignment with the criteria, with a moderate level of confidence in this score.
Justification: Although the implementation of the option will involve no indirect costs to other environments in terms of environmental factors (i.e. the option has a relatively small carbon footprint and requires no raw materials – including water), there is a potential linked effect to other environments in terms of ecological contribution to other environments, should habitats be lost as a result of decreasing water levels and absence of specific management intervention. Accordingly, this criterion has been assessed as 'unlikely'.

B - Maximises the indirect benefits experienced in the wider Lower Lakes region (e.g. / tourism, agriculture, wine, lifestyle)

Score: 'No' – least alignment with the criteria, with a high level of confidence in this score.
Justification: It is difficult to identify where the implementation of this option might benefit the wider Lower Lakes region as whole. It is anticipated that some active management would be required in order to sustain indirect benefits.

3.1.5. Adjustments

Preventative or Treatment: This option is regarded as a 'treatment' approach due to its non-preventative nature.
Risk of Negative Impacts: Even if it is assumed that the option is effective in treating the acidification of the Lower Lakes, there is a risk that the following adverse impacts could eventuate as a result of undertaking this option (See Issues 1-1 to 1-14 in Table I, Appendix E for further information):

- significantly lower lake levels (including a completely dry Lower Lakes environment);
- increased salinity due to a lack of flushing and evaporative concentration;
- dust generation and erosion of exposed lake beds;
- eutrophication as water levels recede; and
- anoxic conditions developing.

Therefore the option is regarded as having the following risk matrix inputs:

- **Likelihood:** Likely
- **Severity:** Dangerous

Resulting in an '**Extreme**' risk in terms of adverse impacts.

Additionally, the 'do nothing' option does not remove the risk of pyrite oxidation and seiching of lake water over oxidised sediments (potentially the primary pathway for lake acidification) and / or rainfall events which may flush / export acidity and metals to the water bodies or discharge to the marine environment (Indraratna et al., 2002; Macdonald et al., 2007). The effect of sulfuric acid discharge to freshwater chemistry would be significantly detrimental to the environment (Russell and Helmke, 2002., Haraguchi, 2007). The 'extreme' risk rating reflects this consideration.

3.2. Option: Bioremediation

Bioremediation refers to management approaches that aim to promote microbial activity (sulfate-reducing bacterial activity) in order to convert dissolved sulfate to insoluble sulfide minerals, while consuming acid. This essentially reverses the pyrite/iron mono-sulfide oxidation reactions that generated acidity in the first place.

Whilst this option is primarily bioremediation (microbial breakdown, algal flocculants etc), this option also comprises measures to optimise conditions to enable bioremediation (i.e. sulfate reduction) to occur. Therefore, assessment of this option takes into account provision of freshwater, lime additions, re-vegetation and any associated infrastructure to enable this.

The Issues register for this option is presented as Table II, Appendix E. The MCA scoring assessment is presented as Table 002.

3.2.1. Bioremediation SMART Review

The SMART review for the 'bioremediation' option is presented in Appendix A.

3.2.2. Technically feasible and achievable in practice on the scale required

3.2.2.1. TECHNICALLY FEASIBLE (theoretically, will it work?)

A - Successful implementation of option is theoretically possible.

Score: 'Yes' – maximum alignment with criteria, with a 'high' level of confidence in this score.
Justification: It is considered that theoretically, the 'bioremediation' option could be successful in mitigating the acidification of the Lower Lakes, with a number of successful studies undertaken in this field. Study 18 by Earth Sciences, provides supporting information (Appendix D).

Equations 1 – 4 below outline the reactions of importance with respect to pyrite oxidation and reduction of sulfate (H_2SO_4 associated) to sulfide. The oxidation of pyrite can be represented as follows (1), note that the associated products with respect to pyrite oxidation are acidity, sulfate and ferric Fe.

- $FeS_2 + 3.75O_2 + 3.5H_2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$ **(1)**

Microbes maybe actively encouraged to alter the sulfate to sulfide, which has an associative effect of removing acidity (as H^+) from solution outlined as follows (shown here with H_2 as the donor):

- $4H_2 + SO_4^{2-} + H^+ \rightarrow HS^- + 4H_2O$ **(2)**

And can also generate alkalinity when considering the organic substrate required (CH_2O is used here to simplify organic matter):

- $2CH_2O + SO_4^{2-} \rightarrow H_2S + 2HCO_3^-$ **(3)**

The sulfide produced is then partitioned into the sediment as pyrite (FeS_2) or lesser iron mono-sulfides (FeS, e.g. mackinawite or greigite) which form much more rapidly than pyrite.

Sulfate is highly soluble and is delivered to the microbial community via groundwater flow or from dissolution of sulfate bearing minerals (e.g. $CaSO_4$). Sulfate may also be produced from the oxidation of sulfidic material or minerals (e.g. FeS, as described above). Note that this generally occurs where dewatering or exposure of previously anoxic sediment has occurred, and that for sulfate reduction to occur, these sediments (or more accurately, the pore water) must return to a suitably negative redox (i.e. reducing conditions).

Note that the transfer of electrons to sulfate, culminating in reduction to sulfide, theoretically occurs when all other Terminal Electron Acceptors (TEAs; such as nitrate, manganese, Fe(III)) have been exhausted, and results in an increased sulfide concentration in pore water (Konhauser et al., 2002).

Sulfate reducing bacteria (SRB) are a specialised group of anaerobes that are responsible for the dissimilatory reduction of sulfate to sulfide. They are important in the anaerobic degradation of organic matter in most aquatic habitats, where they are situated at the bottom of the anaerobic food chain. Following the process of reduction, SRB are also a major contributor to sulfide formation, which is highly reactive and geochemically important. Sulfide reaction with extra-cellular Fe (and concomitant formation of insoluble FeS) is a common detoxification mechanism for the microbes (O'Flaherty et al., 1998) while partitioning the sulfide into an insoluble form. With respect to electron donors, it is generally accepted that SRB oxidise products of fermentative bacteria such as lactate, fatty acids, alcohols, some aromatic acids, a few amino acids and hydrogen. The suite of substrates varies among microbial genera (Postgate, 1984; Skyring, 1987; Odom and Singleton, 1993; Wawer and Muyzer, 1995; and Minz et al., 1999).

The SRB are widely distributed in nature, and are regular components of both natural and engineered systems including, for example, petroleum reservoirs and oil production facilities. SRB are currently subject to extensive genomic studies, which are yielding new understanding of their basic biochemical mechanisms, and aiding in the development of novel techniques for the analyses of their environmental roles. Barton (1995) provides an in-depth review of the SRB in terms of taxonomy, physiology and ecology.

It is worth noting that certain genera of SRB can also reduce Fe(III) to Fe(II) prior to sulfate reduction (Coleman et al., 1993), which with respect to the bioremediation option, would increase the partition of sulfide as $FeS_{(s)}$, and may reduce the requirement for Fe addition.

B – Technically feasible on the scale required.

Score: 'Unlikely' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: The area (whole system) that requires bioremediation will probably introduce a number of issues relating to optimising conditions suitable for bioremediation to occur (Study 18). Whilst such issues may technically be addressed, they introduce a further degree of complexity to this option, which is captured in our assessment by a significantly reduced alignment with the criteria and a corresponding lower confidence weighting.

A groundwater (or introduction of other water source) resource would be required in order to keep sediments saturated and incur sub-oxic conditions. The volumes of groundwater potentially required to achieve this are considerably lower than attempting to maintain levels within the entire lake system (using groundwater). However, additional engineering is required either using some form of irrigation system or another method to trap the water to prevent the soils from drying out. It is anticipated given the aquifer properties and groundwater quality, that in order to sustain an operation of this type for any significant period of time is likely to have significant impacts on the groundwater system that could be irreversible given that natural recharge is very low (SKM, 2009).

3.2.3. Achievable in practice (Has it been proven to work?)

A - Generic Proof of Concept established

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Actively managed bioremediation technologies have become well established methods in the treatment of contaminated land issues (Environment Agency, 1999), with numerous successful projects undertaken (e.g. see www.cl:aire.org.uk). The managed application of microbes to reduce sulfate as a preventative measure / treatment for acid sulfate soil has not yet been fully realised; however the occurrence of such processes in the natural environment are reasonably well documented. Several studies have identified the presence of SRB and active reduction of sulfate in saline and hyper-saline environments (Jakobsen et al., 2006; Foti et al., 2007 and Porter et al., 2007).

Sulfate reduction has been documented in meromictic lakes (Tonolla et al., 2004) and oligotrophic lakes (Bak and Pfennig, 1991). It is considered that where anaerobic conditions exist (e.g. sediments and appropriate lake depths), then sulfate reduction can occur.

B - Proof of Concept established in similar (representative) environments

Score: ''Probable' alignment with the criteria, with a moderate level of confidence in this score.
Justification: It is worth noting that SRB are ubiquitous in nature, and given the onset of the appropriate conditions, are expected to become prevalent in such environments similar to the Lower Lakes system. Previous research undertaken in a similar environment has indicated the possibility of sulfate reduction via microbial mediation (Wright, 1999). The extrapolation of this work to the Lower Lakes system or an environment representative of this system is achievable at a high level, although confidence in the proof of concept in the actual Lakes system cannot be currently absolutely maximised due to the lack of site specific information (see below). Previous research was undertaken in highly saline water bodies characterised by high pH and elevated concentrations of carbonate, which may not be the case for the Lakes proper (i.e. lower pH and low carbonate concentrations).

C – Proof of concept established in Lower Lakes environments and environs

Score: 'Probable' alignment with the criteria, with a moderate level of confidence in this score.
Justification: In the absence of a comprehensive desktop analysis, proof of concept in this technology applied in Lower Lakes circumstances is considered to be probable (taking into account the discussion presented above in base criteria B and C. However a potential data gap relating to the bioremediation

potential within the Lower Lakes exists, due to the absence of information relating to the presence of suitable microbes (the SRB) available within the respective soil systems. In addition, there may also be other associative limitations in terms of in-situ carbon (organic substrate). Note that some species can utilise H_2 as an electron donor (Smith and Klug, 1981), although the capacity for this would need to be assessed.

As discussed above, another factor that may require consideration is the source water required for inundation (i.e. to achieve sub-oxic conditions). Assuming a groundwater source is preferred (note Earth Systems preliminary acid flux results indicate continuity between sediments and underlying Bridgewater Aquifer) then the yield available versus required will need careful consideration. The current understanding of the available groundwater yield in the majority of the Lower Lakes is that it is insufficient for supporting large scale bioremediation (SKM, 2009). However, the inundation of sediments with freshwater (i.e. via buy-backs and or environmental allocations would assist in creating sub-oxic environments in the same manner as using a groundwater source).

Note that it is possible that pre-neutralisation of the sediments would also be required in order to ensure optimum pH conditions for bioremediation (i.e. circum-neutral, although some species of microbes can function in extreme pH environments, e.g. acidophiles) assuming this option is implemented post oxidation of sediments.

3.2.4. Implemented successfully before acidification of the Lakes occurs.

A1: On large scale

Score: 'Unlikely' alignment with the criteria, with a low level of confidence in this score.
Justification: Whilst the option is theoretically possible, the absence of proof of concept reduces the confidence attributed to its successful implementation for the entire Lower Lakes system. It is also possible that active management of groundwater levels would be required to ensure sufficient redox environments. This may not be achievable over a large scale. In addition, if neutralisation of sediments is required, the potential requirement for large scale neutralisation of the Lakes may decrease the feasibility of bioremediation as a practical and cost effective option.

A2: On a localised scale.

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: On a smaller scale, optimising the conditions to provide a suitable environment (namely elevated water table to encourage negative redox suitable for sulfate reduction to occur) would be more achievable, and thus this option lends itself to treatment of hotspots, rather than a blanket approach to the entire system. This is also true of the potential requirement for pre-neutralisation of sediments, which is significantly more achievable over a localised scale than a large scale approach.

This maximum alignment with the localised scale criteria is based on an assumed use of freshwater from sources other than groundwater, with respect to in-sufficient groundwater yields that would be required to inundate hotspots over the required period of time.

3.2.5. Costs to Government (State and Federal)

3.2.5.1. Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)

A - Capital / Establishment costs are minimal

Score: 'Unlikely' alignment with the criteria, with a high level of confidence in this score.
Justification: This option is likely to be a reactive approach, in respect to optimising conditions over a large scale, suitable for bioremediation – the strength of this option is likely to be associated with small scale / localised implementation in and around 'hotspots'. As such, this prevents an accurate costing profile to be identified (large vs. small scale), with only minimal assumptions possible regarding infrastructure. However, it is considered that a significant level of infrastructure would be required (e.g. bores, well permits / licenses, pumps, distribution networks and possibly telemetry / monitoring systems). This would therefore result in some capital costs being required.

B – Operational / Maintenance costs are minimal

Score: 'Probable' alignment with the criteria, with a low level of confidence in this score.
Justification: Knowledge gaps (as discussed above) reduce the confidence attributed to this score, relating to capital expenditure. This includes unknown costs relating to optimising conditions (e.g. pumps and pipelines for inundation). Relocation of pumps may also be required to address changes in system as this is a reactive approach. The absence of detailed cost estimates introduces a significant data gap into the assessment of this option. However, in terms of orders of magnitude, this option's acceptance is considered probable. A moderate confidence has been attributed due to the large scales involved in successfully implementing this option.

C – Decommissioning costs are minimal

Score: 'Probable' alignment with the criteria, with a high level of confidence in this score.
Justification: Based on the assessment undertaken in A and B of this criterion, it is evident that some infrastructure would be required in order to achieve appropriate conditions for bioremediation. The decommissioning costs identified (based on the limited information associated with commissioning) are associated with removal of pumps and distribution network, noting that the pumps may well have a resale value. Therefore the costs have been awarded a probable alignment.

3.2.5.2. Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)

A - Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region)

Score: 'Probable' – moderate alignment with the criteria, with a moderate level of confidence in this score.
Justification: No significant impacts upon environments external to the Lower Lakes environment have

been identified, with the exception of increasing water table drawdown due to over extraction for inundation purposes. However, it is considered that if sufficient information is obtained concerning the localised and regional hydrogeology, that the drawdown can be managed in a sustainable manner.

B - Maximises the indirect benefits experienced in the wider Lower Lakes Region (e.g. tourism, agriculture, wine, lifestyle)

Score: 'Probable' – moderate alignment with the criteria, with a moderate level of confidence in this score.

Justification: It is considered that the successful implementation of this option would have some indirect benefits (i.e. primarily the maintenance of a steady state system), with the contribution of the groundwater resource potentially adding to the lake volume in certain locations, which could be actively managed to increase ecological and associated benefits. No significant impacts upon environments external to the Lower Lakes environment have been identified.

3.2.6. Adjustments

Preventative or Treatment: This option is regarded as a 'treatment' approach, based on the fact that it actively targets sulfate for reduction to sulfide (i.e. the oxidation of sulfide has already occurred and therefore the action is not preventative). However, the inundation of sediments with groundwater with a view to encouraging bioremediation may act as a preventative measure in some locations, depending on site specific pyrite oxidation rates.

Risk of Negative Impacts: The reduction and partition of sulfate as a mono-sulfide is dependent on maintaining suitable redox conditions, which would likely be managed by water level. If redox conditions cannot be maintained, then re-generation of acid may become likely, with flushing via rainfall / seiching becoming increasingly likely (Macdonald et al., 2007). The application of Fe in order to encourage partition of sulfide as FeS may initially cause increased oxidation of pyrite if applied incorrectly to sediments with a pH <3.5. Initial neutralisation may be required.

Therefore the option is regarded as having the following risk matrix inputs:

- **Likelihood:** Possible
- **Severity:** Slight

Resulting in a '**Moderate**' risk in terms of adverse impacts.

3.3. Option: Use of salt water via the barrages to inundate the Lower Lakes

It is envisaged that this option would not involve flooding the Lower Lakes with sea water, but allowing just enough water through the barrages to maintain the level of Lake Alexandrina above the trigger level of -1.5 metres below sea level (i.e. inundation).

SKM has considered the option in the absence of specific information regarding operating rules for the barrages and means of delivering water via the barrages.

The issues register for this option is presented in Table III, Appendix E. The MCA Scoring Assessment is presented as Table 003.

3.3.1. Seawater Inundation SMART review

The SMART review for the seawater inundation option is presented in Appendix A.

3.3.2. Technically feasible and achievable in practice on the scale required

3.3.2.1. Technically feasible (theoretically, will it work?)

A - Successful implementation of option is theoretically possible

Score: 'Probable' alignment with criteria, with a moderate level of confidence in this score.
Justification: Theoretically, the inundation of ASS with salt water can be an effective strategy in preventing acidification.

The shift to reducing conditions initiated by inundation of ASS may favour sequestration of iron-sulfide minerals and the in-situ transformation of soil acidity (Burton et al., 2008). Pyrite formation can be rapid in natural inter-tidal environments (Howarth, 1979), although it is likely that due to generally sluggish pyrite kinetics, that FeS minerals would preferentially exist (e.g. mackinawite, griegite). Both pyrite and mono-sulfides are known to reform in coastal acid sulfate soil landscapes due to seasonal shifts in hydrology or the formation of localised, highly reducing sub-environments (Bush and Sullivan, 1997; Rosicky et al., 2004; Burton et al., 2006, 2007). Portnoy and Giblin (1997a) demonstrated that saturating a drained and acidified former saltmarsh with seawater stimulated both Fe(III) and SO_4^{2-} reduction. However, there are few examples of field-based investigations in acid sulfate soil landscapes which demonstrate the effectiveness of re-establishing tidal inundation (or application of seawater) at either ameliorating acidity or sequestering Fe(II)-sulfide minerals such as pyrite (see Powell and Martens, 2005).

Previous research (Ahern et al., 2009) undertaken at the East Trinity Site, Queensland, has indicated significant time lags (>17 months) associated with sediment pH increase and total actual acidity (TAA) decreases with respect to seawater inundation. These experiments also used hydrated lime dosing of the seawater, although the quantities of lime used is not provided. Additionally, the study by Ahern et al., indicated that mixing of freshwater with the saline inundation source may effectively dilute the neutralisation capacity of the marine source, and therefore additional volumes may be required (increasing the lake water salinity). However, it should be noted that the East Trinity test sediments were initially acidic (c. pH 2.5) and so the inundation was originally handicapped in terms of buffering the sediment.

The inundation at East Trinity can be viewed as a success based on the 'before' and 'after' scenario, whereby the initially acidic environment was returned to a circum-neutral environment, with associative environmental betterment in terms of vegetation. Therefore a 'probable' score has been recorded with a medium level of confidence. The application of seawater as a preventative measure is, in theory, relatively different, although the neutralisation of TAA may be expected depending on the mixing status of the source.

B– Theoretically viable on the scale (spatial) required

Score: 'Probable' alignment with criteria, with a 'moderate' level of confidence in this score.
Justification: Theoretically, inundation will be as effective on a large scale as on a local scale, assuming significant environmental homogeneity with respect to the sediments across the system. As discussed above, there may well be differences in neutralisation time scales, based on the initial TAA and pH, and depth of sediment. The landform may also be an issue. Where land elevation exceeds the height of inundation, a cyclical wetting and drying scenario may develop, which can increase TAA and Fe content in pore water over time (Ahern et al., 2009).

Furthermore, as a standalone option, this treatment may not be sufficient to treat (neutralise) the oxidising margins of the lake, and would thus leave these areas vulnerable to seiching, with subsequent transport of acid to waters. Previous research (Ahern et al., 2009) indicates that re-flooding of sediments is less effective furthest from the marine source (i.e. northern edge of lake) and on slightly higher elevations. This issue is more relevant when considering the current pumping rates were given in April 2008. The water level is now lower within the lake and therefore more water may be required to inundate the margins and maintaining a higher head. Alternatively, if the marginal sediments were completely dry then the risk of acid export would be lower, however a significant acid spike may still occur following extreme rainfall events (Indraratna et al., 2002).

3.3.3. Achievable in practice (has it been proven to work?)

A - Generic Proof of Concept established

Score: 'Maximum' alignment with the criteria, with a high level of confidence in this score.
Justification: The application of this option has proved to be effective in a number of settings, although it is worth considering that the generic proof of concepts are generally on a different scale under different environments – see below. Application of seawater to acidic sediments has generally proven successful at the East Trinity site (Martens et al., 2004; Ahern et al., 2009), and thus it is considered that a generic proof of concept is available.

B - Proof of Concept established in similar (representative) environments

Score: 'Probable' alignment with the criteria, with a high level of confidence in this score.
Justification: Whilst the option has proven to be effective in estuarine acid sulfate soil environments throughout Australia (e.g. White et al., 1997; Indraratna et al., 2002, Johnston et al., 2005), there are no documented cases where saline water (with a salinity higher than seawater) has been used to inundate a previously fresh water environment (i.e. East Trinity was a previous brackish estuarine environment that was already totally environmentally degraded). The use of water (saline or otherwise) for inundation would limit oxidation of previously exposed sediments, and may initiate diagenetic processes that are similar to those found in intertidal sedimentary environments such as mangroves (i.e. higher water tables, abundant sulfate and organic matter). Such conditions would stimulate upward migration of the redox boundary, favouring the reductive dissolution of Fe(III) minerals and the reduction of sulfate (as a function of Eh, Johnston et al., 2009a).

C – Proof of concept established in Lower Lakes environments and environs

Score: 'Unlikely' alignment with the criteria, with a moderate level of confidence in this score.
Justification: In 2008 to 2009, water was pumped from Lake Alexandrina into Lake Albert, which was considered to successfully prevent any acidification of Lake Albert (Study 18). Previous research has focussed on application of seawater to already acidified sediments (Johnston et al., 2009b), therefore the buffering / neutralisation of sediments that are not fully oxidised would appear to be achievable, and the inundation in terms of preventing oxidation is certainly achievable as a preventative measure. However, previous inundation research has generally used un-diluted lime assisted seawater. The seawater applied to the Lakes water bodies may be diluted by the remaining freshwater and the current option does not include lime assistance with respect to dosing the inflow.

The influx of seawater and lack of flushing may lead to a hyper-saline environment in the Lake, due to evaporation and to some extent limited flushing of the system, depending upon barrage operating rules. This would be particularly evident with Lake Albert. A moderate level of confidence has been attributed to this score, due to the large scale of the environment involved, whereby unforeseeable risks may occur.

3.3.4. Implemented successfully before acidification of the Lakes occurs

A1 – on a large scale

Score: ''Yes' alignment with the criteria, with a moderate level of confidence in this score.
Justification: Operation of the barrages to allow seawater to inundate Lake Alexandrina (and assuming subsequently Lake Albert) is assumed to be achievable within the timeframes required (i.e. in the absence of specific barrage operating protocols for this procedure). Whilst data gaps exist in relation to specific timeframes associated with inundating the entire Lower Lakes environment, this is not anticipated to be of significant duration.

A moderate confidence has been attributed to address previous studies which indicate that sediment buffering / neutralisation has occurred over a period of at least 17 months (depth and location dependant) (Ahern et al., 2009) and therefore it is not clear that unassisted seawater (with potential for dilution) may effectively buffer / or neutralise acidic sediments. This is of specific focus to sediment that has undergone oxidation. Where the option is designed primarily to inundate as an anti oxidation measure, then a reasonable level of success could be expected.

A2 – on a localised scale

Score: 'Probable' alignment with the criteria, with a low level of confidence in this score.
Justification: The feasibility of inundating localised areas of the Lower Lakes, as part of a hot spot management approach has been allocated a probable score with low confidence. This addresses a number of data gaps concerning operational implementation of such an approach, and the inherent difficulties in transferring water (and maintaining water) to localised sections, on the large scale of the Lower Lakes.

It is considered that further developmental works may be required, e.g. land-forming that can retain localised bodies of seawater around the extremities of the lake bodies, should extremity hotspots require treatment via this method. However, the SMART appraisal of this option has determined that the inundation would be required to a level of -1.5 m AHD (Lake Alexandrina, i.e. the 'care and maintenance' approach), and therefore the review of this option does not consider the use of seawater as a 'hotspot' treatment for lake body margins. Subsequently, this approach to the seawater option does not reflect potential costs (section 3.3.5) associated with lake land-forming for the retaining of seawater, such as what may be required for localised (lake extremities) treatment.

3.3.5. Costs to Government (State and Federal)

3.3.5.1. Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)

A - Capital / Establishment costs are minimal

Score: 'Yes' alignment with the criteria, with a high level of confidence in this score.
Justification: Management of the barrages in their current state (as it has been assumed the Clayton regulator and proposed Weir at Pomanda Island are operational) is currently underway and requires minimal capital expenditure.

B – Operational / Maintenance costs are minimal

Score: 'Maximum' alignment with the criteria, with a high level of confidence in this score.
Justification: The ongoing maintenance costs can be forecast with a high level of confidence as being minimal.

C – Decommissioning costs are minimal

Score: 'Unlikely' alignment with the criteria, with a moderate level of confidence in this score.
Justification: The decommissioning costs can be forecast with a high level of confidence as being

minimal, with respect to infrastructure. However, in terms of completely decommissioning the option and removing the salinisation of the system (i.e. returning the system to pre-drought conditions), the alignment is 'unlikely' against cost criteria.

3.3.5.2. Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)

A - Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region)

Score: 'Yes' alignment the criteria, with a high level of confidence in this score.
Justification: This option requires no significant infrastructure requirements (material input) and therefore has a relatively low carbon footprint. Impacts outside of the Lower Lakes environment, as defined by the SMART criteria are not anticipated.

B - Maximises the indirect benefits experienced in the wider Lower Lakes region (e.g. tourism, agriculture, wine, lifestyle)

Score: 'Probable' alignment the criteria, with a low level of confidence in this score.
Justification: The inundation of the area with seawater is considered to be beneficial in terms of maximising lifestyle (relatively, via return of amenity value) although this is tempered by the salinisation of the system and the potential impacts on agri / viticultural extraction and potential increased requirement for ion exchange of lake waters prior to use.

3.3.6. Adjustments

Preventative or Treatment: This option is regarded as a 'preventative' approach. Note that if the option is used as a treatment, then potentially significant negative impacts to the environment may occur (see below).
Risk of Negative Impacts: Even if it is assumed that the option is effective in treating the acidification of the Lower Lakes, there is a risk that the following adverse impacts could eventuate as a result of implementing the option under the wrong conditions (i.e. post oxidation):

- salinisation of a fresh water resource (with the potential to become hyper-saline due to lack of flushing regime);
- The provision of a refuge environment within the AMLR tributaries (Currency Creek and Finniss Creek) presents significant ecological safeguards should the Lower Lakes become a saltwater environment. However, due to the large scale of freshwater environment potentially impacted, the risks have still been classified as extreme;
- potential generation of hydrogen sulfide gas due to high quantities of sulfate in water from the Coorong that could result in an imbalance between sulphur and available iron (attributable to high salinity and considered less likely using standard ocean water);
- risk of adverse impacts on the Coorong and Murray Mouth associated with altered flow dynamics;

- potential loss of freshwater connection to the Coorong and with particular impacts upon diadromous fish species;
- Disconnection of Murray mouth to River Murray, with particular impacts upon fish diadromous fish species (this assumes fish passage is not possible for the proposed weir at Pomanda Island); and
- Mobilisation studies have indicated that seawater mobilises a significant amount of acidity and heavy metals / nutrients during inundation, if sulfidic sediments have oxidised (Sullivan et al., 2009, Hicks et al., 2009). Recent indications from Loveday Bay in the south-east corner of Lake Alexandrina show that overlying water can decrease to approximately pH 2 following re-wetting of ASS.

Based on the above considerations and implicit timing issues, this option is regarded as having the following risk matrix inputs:

- **Likelihood:** Possible
- **Severity:** Critical

Resulting in an '**Extreme**' risk in terms of adverse impacts.

3.4. Option: Vegetation

In the context of this project *Vegetation* is the term used for covering with vegetation the soils affected by lack of water within the Lower Lakes system.

Vegetation may include local native plant species, exotic annuals or exotic perennials identified as effective in covering soils to assist in the bioremediation of the area.

Although biodiversity is extremely important in this region, the Vegetation that is proposed does not have the sole purpose of improving biodiversity. Rather, the primary purpose of the initial Vegetation is to provide ecosystem stability or resilience by immediate soil cover, stabilising moving sand to reduce the impacts on the natural ecosystem, individuals and communities. These actions are likely to have an effect on reducing soil acidification by assisting to maintain soil moisture in the short-term, and by providing longer-term benefits as part of a bioremediation process (see Section 3.3).

However, the Vegetation option assessed here is as described in Study 4 (Appendix D) Appendix D - Lower Lakes Studies / Reportsand relates to the active use of vegetation to actively manage soil / sediment pH.

The Issues Register for this option is presented as Table IV, Appendix E. The MCA Scoring Assessment is presented as Table 004.

3.4.1. Vegetation SMART Review

The SMART review for the Vegetation option is presented in Appendix A.

3.4.2. Technically feasible and achievable in practice on the scale required

3.4.2.1. Technically feasible (theoretically, will it work?)

A - Successful implementation of option is theoretically possible.

Score: 'Unlikely' alignment with criteria, with a 'moderate' level of confidence in this score.
Justification: Theoretically, the 'Vegetation' option could be successful in mitigating the acidification of the Lower Lakes, as discussed in Study 14 (Appendix D). As these studies have not been subjected to scientific rigour, a 'moderate' confidence has been allocated to this score.

A variation on the theme of the use of vegetation in such an environment as a management option is the use of aerobic wetlands, which are one of the most commonly used passive treatment techniques for acid soils (where disturbed through anthropogenic activities) and acid mine drainage. They are simple to construct and can be used to develop public amenities and wildlife sanctuaries in areas where soil and water have become acidified. They consist of a large area of reeds (often *Typha* or *Phragmites* species are used) planted in an organic-rich substrate. Their role is to provide sufficient oxygen and residence time to allow iron and some other metals to be precipitated as oxyhydroxides. These systems are most effective for water that has high iron content but a low acidity. Often, drainage is first passed through settling ponds to precipitate some iron before discharge to aerobic wetlands to ensure that the wetland is not rapidly

smothered with precipitates. Reeds and sludge have to be periodically harvested from aerobic wetlands to maintain their effectiveness.

Compost wetlands have also been used to treat acidic drainage, and differ from aerobic wetlands in having very thick (> 30 cm) substrates of various forms of organic matter. The substrate encourages bacterial activity which reduces sulfate to sulfide, generating alkalinity in the process. This process is more akin to bioremediation than the actual vegetation undertaking neutralisation of acidity. Additional alkalinity can be generated by mixing crushed limestone with the organic substrate. Iron and some other metals are removed from solution by the formation of insoluble sulphide minerals within the organic matter. Aluminium accumulates as a precipitate of aluminium hydroxide on the top of the compost material.

The organic sludge in the wetlands has to be periodically removed to maintain the effectiveness of the system. As the material accumulates sulfide minerals, it needs to be handled and treated as ASS.

It should be noted however that wetlands as described above are generally used to treat drainage as a flow through process and not as a management option for large scale management of acidic sediments.

B– Technically feasible on the scale required.

Score: 'Unlikely' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Significant knowledge gaps have been identified in relation to the success of Vegetation techniques within a similar environment to the Lower Lakes (Study 14). There may be an apparent window of opportunity for plant colonisation as solubilisation of aluminium is considered likely to occur at <pH 4.5. This window is dependent on oxidation rates, which may be estimated from system modelling although this would be difficult to determine in situ unless field monitoring for pH was undertaken to determine the pH prior to seeding – i.e. <pH 4.5 may exclude seeding.

In addition, the role of evapo-transpiration (ET) requires better understanding with respect to large scale application of biomass, especially over summer months. Current trials by the Department for Environment and Heritage (DEH) may provide more insight into this if they run over summer. The mass of biomass may increase ET and lower the water table while still regulating some portion of soil moisture which may increase ASS oxidation. This may occur as drawdown of the water table which is recharged via rainfall (cyclical action) which may exacerbate oxidation.

3.4.3. Achievable in practice (has it been proven to work?)

A - Generic Proof of Concept established

Score: 'No' alignment with the criteria based on the assumption that the plants themselves are not the agent, but rather the accompanying substrate (i.e. bioremediation).
Justification: Study 14 (Appendix D) discusses the generic proof of concept for this technology (plant

uptake of acidity), however, there is no apparent theoretical evidence for direct application of plant species in acid soil management.

A proof of concept for the use of compost wetlands (i.e. organic substrate) has been shown to have potential for the reduction of sulfate to sulfide (Piramid, 2003).

B - Proof of Concept established in similar (representative) environments

Score: 'No' alignment with the criteria.
Justification: A number of data gaps have been identified to clarify this assumption, which is consistent with the literature review undertaken as a component of Study 14. However, Johnston et al., (2005b) report that the type of vegetation used can have large differences in the quality and lability of carbon, which strongly influenced decay/redox processes and the chemical composition of surface waters. Grass species had more labile carbon. Sites with grass stands had surface waters which displayed rapid sustained O_2 depletion and sustained low redox potential (Eh, ~0 mV), high dissolved organic carbon (DOC), and moderate pH (5-6). Their soil acidity was partially neutralised, sulfides were re-formed, and reductive dissolution of Fe(III) led to the generation of stored acidity in the water column as $Fe^{2+(}$aq). In contrast, sites which had *M. quinquenervia* litter was high in decay-resistant compounds. Its surface waters had lower DOC and low pH (<4) and only underwent a short period of low O_2/Eh. Soluble Al caused *M. quinquenervia* surface waters to have higher titratable acidity (assumed to be as a reflection of total acidity) and soil pH remained consistently low (~3.8-4.0). Concentrations of Cl^- and Al in surface waters appeared to be strongly correlated to initial soil contents, whereas the behaviour of Fe and SO_4^{2-} varied according to pH and redox status. This demonstrates that changes in vegetation communities in ASS environments that substantially alter either: (a) the pool of labile vegetative organic carbon; or (b) the concentration of acidic solutes in surface soil can have profound implications for the chemical characteristics of surface waters.

C – Proof of concept established in Lower Lakes environments and environs

Score: 'No' alignment with the criteria.
Justification: A number of data gaps have been identified to clarify this assumption, which is consistent with the literature review undertaken as a component of Study 14. However, it is acknowledged that more focussed studies are underway and thus this score should be revisited after review of these studies.

3.4.4. Implemented successfully before acidification of the Lakes occurs

A1: On a large scale

Score: 'Unlikely' alignment with the criteria, with a high level of confidence in this score.
Justification: Whilst the option is theoretically possible, the absence of proof of concept reduces the confidence attributed to its successful implementation for the entire Lower Lakes system. A number of risks have also been identified in Study 14 relating to practicalities of establishing vegetation in ASS and PASS on a large scale. It is noted that the results of Lower Lakes Vegetation trials are not available at this time.

A2: On a localised scale

Score: 'Probable' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: On a smaller scale, Vegetation is likely to reduce acidification of the Lower Lakes, as discussed in Study 14. However, the absence of a proof of concept reduces the confidence attributed to its success.

3.4.5. Costs to Government (State and Federal)

3.4.5.1. Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)

A - Capital / Establishment costs are minimal

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Study 6 presents cost estimates associated with Vegetation and associated preparatory and management works required for Lake Alexandrina and Lake Albert.

B – Operational / Maintenance costs are minimal

Score: 'Probable' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Study 6 presents costs associated with Vegetation and associated preparatory and management works required for the Lower Lakes. As risks are associated with successful establishment of Vegetation on the scale required within PASS and ASS environments (as detailed in Study 14), re-seeding may be required. Therefore, a moderate confidence has been attributed to this score. Managing water levels over a 5-10 year period may also introduce risks associated with establishing and maintaining vegetation within the entire Lower Lakes environment.

C – Decommissioning costs are minimal

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: It is considered likely that decommissioning costs would be minimal for this option.

3.4.5.2. Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)

A - Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region)

Score: 'Yes' alignment with the criteria, with a high level of confidence in this score.
Justification: No significant impacts upon environments external to the Lower Lakes environment have been identified.

B - Maximises the indirect benefits experienced in the wider Lower Lakes region (e.g. tourism, agriculture, wine, lifestyle)

Score: 'Probable' alignment with the criteria, with a moderate level of confidence in this score.
Justification: It is considered possible that the application of this option would have some benefit to the wider Lakes region in terms of increasing amenity value, although these benefits may not be passed on to all stakeholders in the region (i.e. water extraction will still be poor).

3.4.6. Adjustments

Preventative or Treatment: Option is regarded as a 'preventative' approach.
Negative Impacts: Moderate impacts have been identified for this option. These relate to:

- loss of freshwater environment and associated flora and fauna impacts and significant species loss;
- salinisation of lake basin as water levels recede;
- potential for eutrophication to occur as water levels recede;
- ecological disturbance impacts during installation of infrastructure and ongoing management and monitoring; and
- Potential disturbance of PASS and ASS environments which may create acidification issues.

Therefore the option is regarded as having the following risk matrix inputs:

- **Likelihood:** Unlikely
- **Severity:** Slight

Resulting in a '**LOW**' risk in terms of adverse impacts.

3.5. Option: Neutralisation

The 'neutralisation' option comprises the addition of a neutralising agent that is capable of buffering acid that is generated in the subsurface as a result of pyrite oxidation.

This option considers the application of neutralising agent to the sediment.

Note that the contemporary literature on acid landscape treatments discusses both Anoxic Limestone Drains (ALDs) and Oxic Limestone Drains (OLDs), which are often used in the treatment of acid sulfate soil related drainage. However, these are not considered here as they are designed for treatment of a 'stream' of drainage rather than exposed sediments.

The Issues register for this option is presented as Table V, Appendix E. The MCA Scoring Assessment is presented as Table 005.

3.5.1. Neutralisation SMART review

The SMART review for the 'neutralisation' option is presented in Appendix A.

3.5.2. Technically feasible and achievable in practice on the scale required

3.5.2.1. Technically feasible (theoretically, will it work?)

A – Successful implementation of option is theoretically possible.

Score: 'Yes' alignment with criteria, with a 'high' level of confidence in this score.
Justification: Theoretically, the 'neutralisation' option could be successful in mitigating the acidification of the Lower Lakes, as discussed in Study 9, with a number of neutralisation schemes undertaken, including successful limestone addition in acidic lakes within Northern Europe (Anderson, 2006). On a global basis, treatment of acid soils using limestone technology appears to have yielded promising results (Green et al., 2008a; Green et al., 2008b).

B– Technically feasible on the scale required.

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Some knowledge gaps exist when treating a large area, such as ability to treat deep acidification within the soil profile (also, there are no known documents that report mass neutralisation across the area in question). This has been captured by a moderate confidence score.

Previous research has indicated that a firm understanding of both water and sediment chemistry is vital to treatment (Young et al., 1986).

3.5.2.2. Achievable in practice (has it been proven to work?)

A – Generic Proof of Concept established

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Study 9 identifies a number of successful cases where neutralisation has been implemented. Green et al., 2008a and Green et al., 2008b provide some interesting reports on investigations into practical application, one of these being the use of a closed tank reactor (CTR, Green et al., 2008b) which although increased solution pH and reduced metal loading, was considered to present operational problems due to accumulation of aluminium inside the CTR This would not really affect the Lower Lakes treatment scenario as it is unlikely that reactor based treatment would be utilised, but such tank reactor technology may be limited in application to many coastal acid sulfate soil systems. However, the example of neutralisation (generic) exists.

B – Proof of Concept established in similar (representative) environments

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Study 9 identifies a number of successful cases where neutralisation has been implemented. However, fine limestone slurry was found to remove acidity to varying degrees of effectiveness (from 12 to 100%) in trials at Clothiers Creek, NSW (Green et al., 2006). The efficiency decreased as the pH of the water approached neutrality due to calcite saturation and the slow reaction rate of limestone at high pH. Hydrated lime powder was also mixed with drain water in a rotating drum though most mixing occurred once the slurry entered the drain where efficiencies ranging from 67 to 89% were observed. A powdered mixture of $MgCO_3$ and $CaCO_3$ was only 11% effective in treatment of drainage water due to the slow rate of reaction of $MgCO_3$.

Investigations into open limestone channels have indicated that the accumulation of sediment over the limestone, preventing contact of limestone with acidic water, was the greatest problem impacting the treatment in its first year of operation. Removal of metals from the water was due to the increase in pH produced by limestone dissolution in addition to sorption reactions of the existing coating which had natural microbial activity (Green et al., 2008a). It is considered that such an operation (i.e. channel treatment) would be unlikely within the Lakes setting, although the study demonstrates that at a geochemical level, the neutralisation and water quality adjustment can be achieved.

C – Proof of concept established in Lower Lakes environments and environs

Score: 'Probable' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Neutralisation trials have been conducted within the tributaries of the Lower Lakes using limestone addition to neutralise acid soils. This was undertaken over several months and comprised the following:

- Limestone addition in the form of three temporary barriers in mid and lower Currency Creek;
- Application of limestone slurry to dose pooled acidic water in Currency Creek; and
- Aerial dispersal of limestone via aircraft between Currency Hill and Currency Creek.

Water monitoring of the tributaries following addition of limestone was considered to have addressed much of the acid formed, and the majority of the tributaries have a pH within a suitable range, with the exception of one or two area that remain a high risk (DEH, 2009b).

Whilst preliminary results suggest a positive outcome, the definitive results are currently not available and, as such, a lower score has been attributed to this criterion.

3.5.3. Implemented successfully before acidification of the Lakes occurs.

A1: On large scale

Score: 'Probable' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Potential complexities identified for neutralisation to be successfully implemented on a large scale and the general reactive nature of this technology to achieve a suitable pH. Data gaps exist in relation to sourcing of sufficient quantities of material to neutralise the entire Lake Albert environment. For example, whilst active treatment systems have been noted to be capable of treating a large acidity flux (particularly using hydrated lime) the treatment system may require regular addition of reagent and the dosing of hydrated lime may be particularly difficult to control (Green et al., 2006), in addition to the logistical difficulties associated with such an application. Treatment should be closely managed to prevent adverse aquatic impacts due to overdosing. However, trials of distribution via aircraft indicate that large scale application of this technique may be applicable to large areas.

A2: On a localised scale.

Score: 'Yes' alignment with the criteria, with a ''high' level of confidence in this score.
Justification: As discussed in Study 9 and through a number of examples where neutralisation has been successfully implemented, a high degree of certainty has been attributed that this option can successfully be implemented on a localised scale. It is considered that small scale localised dosing is much more operationally manageable.

3.5.4. Costs to Government (State and Federal)

3.5.4.1. Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)

A - Capital / Establishment costs are minimal

Score: 'Unlikely' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: A number of data gaps exist in relation to actual costs of implementing this option. There is a need to commission a study to estimate costs associated with the 'neutralisation' option for Lake Albert (and Lower Lakes environment) to clarify this score.

Aglime is the cheapest neutralising agent and is generally not harmful to plants, livestock, humans and most aquatic species. The limitation of its application is its insolubility in water, although it is more soluble in strongly acid water. Using aglime to increase the pH of water can be slow and costly.

B – Operational / Maintenance costs are minimal

Score: 'Probable' alignment with the criteria, with a 'low' level of confidence in this score.
Justification: A number of data gaps exist in relation to actual costs of maintaining this option, or the requirement for maintaining the option i.e. is follow-up work required over time after initial treatment? This component could be assessed more accurately following spatial heterogeneity investigation results. Also, the additional costs such as agency project management would need to be factored into the costings.

C – Decommissioning costs are minimal

Score: 'Probable' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: It is considered probable that decommissioning costs may be minimal. However, it is worth noting that some infrastructure may be recommended depending on the delivery process. Earth Systems have previously suggested that slurry could be added to the water, via select process points. This infrastructure would require decommissioning.

3.5.4.2. Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)

A - Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region)

Score: 'No' alignment with the criteria.
Justification: Obtaining sufficient neutralising agents to successfully implement this option on the scale required for Lake Albert is likely to result in impacts external the Lower Lakes environment. An example includes the need to quarry and transport sufficient limestone material (reuse of non-renewable resource) and the carbon footprint associated with transportation and processing of neutralisation agent into the system. Some data gaps exist in relation to sources and required quantities of neutralising agents, which has been captured by a moderate confidence weighting to this score.

B - Maximises the indirect benefits experienced in the wider Lower Lakes region (e.g. tourism, agriculture, wine, lifestyle)

Score: 'Unlikely' alignment with the criteria, with moderate confidence.
Justification: It is considered unlikely that this option would benefit the wider region on an indirect basis, and is not considered likely to improve amenity value or resource value of the system.

3.5.5. Adjustments

Preventative or Treatment: this option is regarded as a 'treatment' approach.
Risk of Negative Impacts: Data gaps have been identified relating to a full identification of the potential impacts associated with the addition of large volumes of limestone to an environment. However, the following impacts are likely to occur with an unknown extent of severity:

- Flora impacts associated with addition of large volumes of neutralising agents, including smothering inhibition of photosynthesis; and
- Fauna impacts, primarily aquatic species, associated with addition of large volumes of neutralising agents, including increased turbidity and associated impacts to fish and invertebrate populations.

Additionally, the following impacts would be anticipated:

- loss of freshwater environment and associated flora and fauna impacts and significant species loss;
- salinisation of lake basin as water levels recede;
- potential for eutrophication to occur as water levels recede; and
- ecological disturbance impacts during neutralisation material addition and ongoing management and monitoring.

Note that Study 9 (Appendix D) provides an in-depth review of potential impacts to the environment from liming and indicates that overall, the impacts are predominately positive, given the alternatives, although also states that further knowledge in this area is required with respect to the Lakes systems.

Therefore the option is regarded as having the following risk matrix inputs:

- **Likelihood:** Possible
- **Severity:** Moderate

Resulting in a '**HIGH**' risk in terms of adverse impacts.

3.6. Option: Provision of Freshwater Flows (via buy-backs)

The provision of freshwater option comprises the sediments identified as being potentially acid sulfate generating being saturated (not necessarily inundated) with freshwater to maintain a low redox environment and prevent pyrite oxidation. This option differs from the bioremediation option in that it is preventative rather than a treatment and is resourced by buy-backs and/or re-allocation.

The issues register for this option is presented as Table VI, Appendix E.

The MCA Scoring Assessment is presented as Table 006.

3.6.1. Freshwater SMART review

The SMART review for the freshwater inundation option is presented in Appendix A.

3.6.2. Technically feasible and achievable in practice on the scale required

3.6.2.1. Technically feasible (theoretically, will it work?)

A – Successful implementation of option is theoretically possible.

Score: 'Yes' alignment with criteria, with a 'high' level of confidence in this score.
Justification: Re-instatement of water levels to submerge PASS and ASS has been identified in a number of studies to be a feasible option (Study 18). However as a stand-alone option, this treatment may not be sufficient to treat (neutralise) acidic (oxidised) sediments. The treatment may disperse via evaporation before treatment occurs in the summer months, and it is unlikely that freshwater would have requisite buffering capacity. Also, it is considered that the rate of inundation must at least match evaporation (the lower pump rates associated with the more available pumps may not meet evaporation). Inundation must be constant, accurate and effective, a fluctuating inundation may be worse than no inundation at all, and may exacerbate pyrite oxidation (via increase in optimum moisture for oxidation via Fe(III)) and flushing. Lake seiching may then amplify and transport acidification to water body (Macdonald et al., 2007).

B– Technically feasible on the scale required.

Score: 'Yes' alignment with criteria, with a 'low' level of confidence in this score.
Justification: Re-instatement of water levels to submerge PASS and ASS has been identified in a number of studies to be a feasible option. However freshwater resource is potentially scarce (low confidence) and potentially unlikely to supplement the Lakes water budget, although may supply enough to inundate in terms of maintaining ASS saturation.

3.6.2.2. Achievable in practice (has it been proven to work?)

A – Generic Proof of Concept established

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Generic proof of concept known from numerous studies into ASS and provision of freshwater flows. The current state of thinking in the ASS research area is that avoidance of disturbance of ASS, followed by inundation is perhaps the most effective method of prevention.

B – Proof of Concept established in similar (representative) environments

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Generic proof of concept known from numerous studies into ASS and provision of freshwater inundation (DEC, 2009).

C – Proof of concept established in Lower Lakes environments and environs

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Proof of concept accepted from specific studies into ASS and provision of freshwater flows within Lower Lakes. However it is potentially less likely that level maintenance of waters could be sourced and applied. Inundation may work although the acquisition of the freshwater resource required may be challenging.

3.6.3. Implemented successfully before acidification of the Lakes occurs.

A1: On large scale

Score: 'Unlikely' alignment with the criteria, with a 'low' level of confidence in this score.
Justification: Under the current climatic conditions, and in light of political pressures with regards to water allocations and quotas, the volumes of water required to inundate the Lakes are considered unlikely within the timeframes proposed. However, a low level of confidence has been attributed to this score, due to the unknown political pressures involved in securing adequate water allocations. To some extent, the unknown climatic conditions in the short to medium term have also reduced the confidence attributed to this score.

A2: On a localised scale.

Score: 'Probable' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Partial inundation of system, whereby sufficient water is secured without completely inundating the Lakes is considered probable, as lesser volumes of water would need to be purchased. A moderate level of confidence has been attributed to this score due to some unknowns concerning the volumes of water required, and unknown political drivers in securing sufficient water allocations.

3.6.4. Costs to Government (State and Federal)

3.6.4.1. Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)

A - Capital / Establishment costs are minimal

Score: 'No' alignment with the criteria.
Justification: The purchase of large volumes of water allocations for the Lakes is currently in the high order of capital magnitude. Whilst the anticipated costs associated with this option are considered in the high order of magnitude, a number of data gaps exist in relation to the level of acceptable costs associated with addressing acidification. Political pressures are anticipated to play an important role in defining acceptable costs associated with this option. As such a low confidence has been attributed to this score as political drivers surrounding Lake Albert are unknown at this time.

B – Operational / Maintenance costs are minimal

Score: 'Unlikely' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: A number of variables are associated with securing sufficient water to inundate the Lakes and maintain water levels over time. These include data gaps relating to the duration of drought conditions and the availability of water within the River Murray, commodity rises and potential fluctuations in purchasing water allocations and political issues concerning the acceptability of purchasing large volumes of water for Lake Albert.

C – Decommissioning costs are minimal

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: This option is not considered to be unduly infrastructure heavy. The costs relate more to assumed costs with respect to water purchase, and the agreements required therein.

3.6.4.2. Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)

A - Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region)

Score: 'Unlikely' alignment with the criteria, with a' high' level of confidence in this score.
Justification: Potential impacts to environments in the Murray Darling Basin, including the River Murray and associated wetlands in South Australia may occur. These may result due to the water allocation purchase for Lake Albert limiting the availability of environmental flows in other areas of the Murray Darling Basin.

B - Maximises the indirect benefits experienced in the wider Lower Lakes region (e.g. tourism, agriculture, wine, lifestyle)

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Potentially, the increased flow of fresh water into the Lakes is considered to warrant a maximum score for indirect benefits associated with the Lakes as a resource.

3.6.5. Adjustments

Preventative or Treatment: This option is regarded as a 'preventative' approach.
Negative Impacts: Low impacts have been identified for this option. Whilst there are potential issues relating to:

- the mobilisation of acidified sediments;
- initial turbidity increases; and
- salinisation (in the medium to long term through evaporation), these are considered to be relatively low at this time.

Of key importance is the retention/re-establishment of a freshwater environment within Lake Albert.

Also, as mentioned previously, if inconsistent inundation is undertaken, leading to wildly varying water levels, this may exacerbate the oxidation of pyrite and generation of acidity. Consideration may be given to prior neutralisation of oxidised sediments to prevent export of acidity and metals via flushing during re-flooding (e.g. Study 4, Macdonald et al., 2007).

Therefore the option is regarded as having the following risk matrix inputs:

- **Likelihood:** Unlikely
- **Severity:** Moderate

Resulting in a '**Moderate**' risk in terms of adverse impacts.

3.7. Provision of freshwater (environmental allocations)

As with the option discussed in Section 3.6, the provision of freshwater option comprises saturating (not necessarily inundating) the sediments identified as being potentially acid sulfate generating with freshwater to maintain a low redox environment to prevent pyrite oxidation. This option differs from the bioremediation option in that it is preventative rather than a treatment and is resourced by environmental re-allocation (rather than buy-backs). Thus the significant difference between freshwater (buy-backs) and freshwater (environmental allocations) is predominantly cost based.

The issues register for this option is presented as Table VII, Appendix E.

The MCA Scoring Assessment is presented as Table 007.

3.7.1. Freshwater SMART review

The SMART review for the freshwater inundation option is presented in Appendix A (note that buy-backs and environmental allocation are considered essentially the same for this purpose, and thus ‘buy-backs’ is not replicated for environmental allocations.

3.7.2. Technically feasible and achievable in practice on the scale required

3.7.2.1. Technically feasible (theoretically, will it work?)

A – Successful implementation of option is theoretically possible.

Score: ‘Yes’ alignment with criteria, with a ‘high’ level of confidence in this score.
Justification: Re-instatement of water levels to submerge PASS and ASS has been identified in a number of studies to be a feasible option (Study 18). However as a stand-alone option, this treatment may not be sufficient to treat (neutralise) acidic (oxidised) sediments. The treatment may disperse via evaporation before treatment occurs in the summer months, and it is unlikely that freshwater would have requisite buffering capacity. Also, it is considered that the rate of inundation must at least match evaporation (the lower pump rates associated with the more available pumps may not meet evaporation). Inundation must be constant, accurate and effective. A fluctuating inundation may be worse than no inundation at all, and may exacerbate pyrite oxidation (via increase in optimum moisture for oxidation via Fe(III)) and flushing. Lake seiching may then amplify and transport acidification to the water body (Macdonald et al., 2007).

B– Technically feasible on the scale required.

Score: ‘Yes’ alignment with criteria, with a ‘low’ level of confidence in this score.
Justification: Re-instatement of water levels to submerge PASS and ASS has been identified in a number of studies to be a feasible option. However freshwater resource is potentially scarce (low confidence) and potentially unlikely to supplement the Lakes water budget, although enough freshwater may be supplied to inundate in terms of maintaining ASS saturation.

3.7.2.2. Achievable in practice (has it been proven to work?)

A – Generic Proof of Concept established

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Generic proof of concept known from numerous studies into ASS and provision of freshwater flows. The current state of thinking in the ASS research area is that avoidance of disturbance of ASS, followed by inundation is perhaps the most effective method of prevention.

B – Proof of Concept established in similar (representative) environments

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Generic proof of concept known from numerous studies into ASS and provision of freshwater inundation (DEC, 2009).

C – Proof of concept established in Lower Lakes environments and environs

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Proof of concept accepted from specific studies into ASS and provision of freshwater flows within Lower Lakes. However it is potentially less likely that level maintenance of waters could be sourced and applied. Inundation may work although the acquisition of the freshwater resource required may be challenging.

3.7.3. Implemented successfully before acidification of the Lakes occurs.

A1: On large scale

Score: 'Unlikely' alignment with the criteria, with a 'low' level of confidence in this score.
Justification: Under the current climatic conditions, and in light of political pressures with regards to water allocations and quotas, the volumes of water required to inundate the Lakes are considered unlikely within the timeframes proposed. However, a low level of confidence has been attributed to this score, due to the unknown political pressures involved in securing adequate water allocations. To some extent, the unknown climatic conditions in the short to medium term have also reduced the confidence attributed to this score.

A2: On a localised scale.

Score: 'Probable' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Partial inundation of system, whereby sufficient water is secured without completely inundating the Lakes is considered probable, as lesser volumes of water would need to be purchased. A moderate level of confidence has been attributed to this score due to some unknowns concerning the volumes of water required, and unknown political drivers in securing sufficient water allocations.

3.7.4. Costs to Government (State and Federal)

3.7.4.1. Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)

A - Capital / Establishment costs are minimal

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence.
Justification: The re-allocation of large volumes of water for the Lakes is currently not considered to be high in the order of capital magnitude. Re-allocation of existing quotas / volume is not considered to potentially incur significant establishment costs, due to the majority of infrastructure likely to be already present.

B – Operational / Maintenance costs are minimal

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Although a number of variables are associated with securing sufficient water to inundate the Lakes and maintain water levels over time, it is assumed that these technical and physical obstacles are surmountable. Thus the operational / maintenance costs are considered to be not necessarily significant, given that the majority of the infrastructure required to maintain flow / input is present, and the re-allocation is effectively a return to 'normal' operating conditions.

C – Decommissioning costs are minimal

Score: 'Yes' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: This option is not considered to be infrastructure heavy. As discussed in the above parameter, the provision of re-allocation is likely to be a return to the status quo for the system and thus decommissioning should not be a significant issue.

3.7.4.2. Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)

A - Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region)

Score: 'Probable' alignment with the criteria, with a' high' level of confidence in this score.
Justification: As with the buy-back option, there are potential impacts to environments in the Murray associated wetlands of South Australia with this option. These impacts may result due to the water re-allocation limiting the availability of environmental flows in other areas of the Murray Darling Basin. However, it is SKM's current understanding that wetland specific risk assessments are likely to be undertaken by the SA Government, which would mitigate potential impacts associated with re-allocation.

B - Maximises the indirect benefits experienced in the wider Lower Lakes region (e.g. tourism, agriculture, wine, lifestyle)

Score: 'Yes' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: Potentially, the increased flow of freshwater into the Lakes is considered to warrant a maximum score for indirect benefits associated with the Lakes as a resource.

3.7.5. Adjustments

Preventative or Treatment: This option is regarded as a 'preventative' approach.
Negative Impacts: Low impacts have been identified for this option. Whilst there are potential issues relating to:

- the mobilisation of acidified sediments;
- initial turbidity increases; and
- salinisation (in the medium to long term through evaporation), these are considered to be relatively low at this time.

Of key importance is the retention/re-establishment of a freshwater environment within Lake Albert.

Also, as mentioned previously, if inconsistent inundation is undertaken, leading to wildly varying water levels, this may exacerbate the oxidation of pyrite and generation of acidity. Consideration may be given to prior neutralisation of oxidised sediments to prevent export of acidity and metals via flushing during re-flooding (e.g. Study 4, Macdonald et al., 2007).

Therefore the option is regarded as having the following risk matrix inputs:

- **Likelihood:** Unlikely
- **Severity:** Moderate

Resulting in a '**Moderate**' risk in terms of adverse impacts.

3.8. Use of seawater inundation – Lake Albert exclusively

This option would not involve flooding the Lake with seawater, but allowing just enough water into the Lake to maintain the level of the Lake above the trigger level of -0.75 metres below sea level. Note that we have only considered transfer of water from the Coorong, and not from the ocean, in line with the recommendations provided in Tonkin (2008).

The issues register for this option is presented as Table VIII, Appendix E. The MCA Scoring Assessment is presented as Table 008.

3.8.1. SMART Review of seawater – Lake Albert

The SMART review for the seawater inundation option of Lake Albert (via pumping) is presented in Appendix A.

3.8.2. Technically feasible and achievable in practice on the scale required

3.8.2.1. Technically feasible (theoretically, will it work?)

A - Successful implementation of option is theoretically possible

Score: 'Probable' alignment with criteria, with a 'Medium' level of confidence in this score.
Justification: As discussed previously in Section 3.3 (see discussion therein), theoretically, the inundation of ASS with seawater can be an effective strategy in preventing acidification.

B– Theoretically viable on the scale (spatial) required

Score: 'Probable' alignment with criteria, with a 'medium' level of confidence in this score.
Justification: As discussed previously in Section 3.3, theoretically, inundation will be as effective on a large scale as on a local scale, assuming a significant environmental homogeneity. As noted in Section 3.3, should the option be required to be used to treat localised extremities, then land-forming of the lake bed and / or construction of dams may be required to retain the water. However these costs have not been considered here due to the requirement of the option to maintain Lake levels at a static elevation (and in addition, other options may be more viable for localised treatment, depending on scale etc).

3.8.3. Achievable in practice (has it been proven to work?)

A - Generic Proof of Concept established

Score: 'Maximum' alignment with the criteria, with a high level of confidence in this score.
Justification: The application of this option has proved to be effective in a number of settings, although it is worth considering that the generic proof of concepts are generally on a different scale – see below. Application of seawater to acidic sediments has generally proven successful at the East Trinity site (Martens et al., 2004; Ahern et al., 2009), and thus it is considered that a generic proof of concept is available, although the variation in environments and technique (i.e. East Trinity used lime assisted tidal exchange) must be considered.

B - Proof of Concept established in similar (representative) environments

Score: 'Probable' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: Whilst the option has proven to be effective in estuarine acid sulfate soil environments throughout Australia (e.g. White et al., 1997; Indraratna et al., 2002, Johnston et al., 2005), there are no documented cases where saline water (with a salinity higher than seawater) has been used to inundate a previously freshwater environment (i.e. East Trinity was a previous brackish estuarine environment that was already totally environmentally degraded). See Section 3.3 for further discussion.

C – Proof of concept established in Lower Lakes environments and environs

Score: 'Probable' alignment with the criteria, with a 'moderate' level of confidence in this score.
Justification: In 2008 to 2009, water was pumped from Lake Alexandrina into Lake Albert, which was considered to successfully prevent any acidification of Lake Albert (Study 18). However it is noted that water sourced from the Coorong is vastly different water than that previously sourced from Lake Alexandrina and there may be unforeseen consequences in terms of its ability to prevent acidification. For instance, water from the Coorong is hyper-saline and has elevated levels of sulfate which may limit the potential for sulfide precipitation (with respect to available concentrations of Fe required for formation of FeS). Previous research has focussed on the application of seawater to already acidified sediments (Johnston et al., 2009b), therefore the buffering / neutralisation of sediments that are not fully oxidised would appear to be achievable, and the inundation in terms of preventing oxidation is certainly achievable as a preventative measure. However, previous inundation research has generally used un-diluted lime assisted seawater. The seawater applied to the Lakes water bodies may be diluted by the remaining fresh water and the current option does not include lime assistance with respect to dosing the inflow.

The influx of seawater and lack of flushing may lead to a hyper-saline environment in the Lake, due to undiluted inflow (no net outflow) of saline water plus evaporation over time.

3.8.3.1. Implemented successfully before acidification of the Lakes occurs

A1 – on a large scale

Score: 'Unlikely' alignment with the criteria, with a 'low' level of confidence in this score.
Justification: A pre-feasibility study of pumping from the Coorong to Lake Albert indicated a 12-15 month lead time to acquire the necessary pumps (Tonkin, 2008). Such a timeframe suggests the option will not be operational and effective by December 2010. There is also uncertainty associated with pumping such a large volume of water from the Coorong – e.g. potential scouring issues and time delays associated with acquiring the necessary approvals to source water from a wetland of national significance. Additionally, previous studies have indicated that sediment buffering / neutralisation has occurred over a period of at least 17 months (depth and location dependant) (see Ahern et al., 2009) and therefore it is not clear that unassisted seawater (with potential for dilution) may effectively buffer / or neutralise acidic sediments. This is of specific focus to sediment that has undergone oxidation. Where the option is

designed primarily to inundate as an anti oxidation measure, then a reasonable level of success could be expected.

A2 – on a localised scale

Score: 'Probable' alignment with the criteria, with a 'low' level of confidence in this score.
Justification: It is likely that lower rates of pumping may be more feasible to implement in the timeframe identified. Lower pumping rates could be used to saturate, but not necessarily inundate ASS. However there is still some uncertainty related to sourcing water from a wetland of national significance.

3.8.4. Costs to Government (State and Federal)

3.8.4.1. Direct lifecycle costs (dollar costs directly apportioned to the entire lifecycle of the option.)

A - Capital / Establishment costs are minimal

Score: 'No' - alignment with the criteria.
Justification: A potentially significant capital outlay of $20.9 million (ex. GST, +/- 30%) is required to implement the option (Tonkin, 2008).

B – Operational / Maintenance costs are minimal

Score: 'Unlikely' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: The costs of the option are considered to be potentially significant although the majority of the expenditure is considered to be associated with the capital / implementation costs.

C – Decommissioning costs are minimal

Score: 'Unlikely' alignment with the criteria, with a 'high' level of confidence in this score.
Justification: The decommissioning costs are likely to be significant, therefore not minimal

3.8.4.2. Indirect or environmental costs & benefits (limited to impacts that Government may be liable for through the application of the option)

A - Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes region)

Score: 'Probable' alignment the criteria, with a 'moderate' level of confidence in this score.
Justification: There is likely to be a big carbon footprint associated with this option, and there may also be costs to the Coorong associated with water removal, hence the reduced alignment and moderate confidence.

B - Maximises the indirect benefits experienced in the wider Lower Lakes region (e.g. tourism, agriculture, wine, lifestyle)

Score: 'Unlikely' alignment the criteria, with a 'moderate' level of confidence in this score.
Justification: It is currently considered unlikely that this option would maximise indirect benefits to the wider region given the intrusive nature of the infrastructure required for pumping, and associated noise pollution.

3.8.5. Adjustments

Preventative or Treatment: Option is regarded as a 'preventative' approach.
Negative Impacts: Even if it is assumed that the option is effective in treating the acidification of the Lower Lakes, there is a risk that the following adverse impacts could eventuate as a result of implementing the option:

- The primary risk, as discussed previously in Section 3.3, is the risk of incorrectly timing the inundation of acidic sediments, using seawater. For the inundation to work effectively, it must be applied prior to the sediments turning acidic, otherwise there is a risk of mobilising both acidity and heavy metals;
- the salinisation of a freshwater resource (with the potential to become hyper-saline due to lack of flushing regime), which has no refuge habitat for fish;
- potential generation of hydrogen sulfide gas due to high quantities of sulfate in water from the Coorong that could result in an imbalance between sulphur and available iron; and
- risk of adverse impacts on the Coorong and Murray Mouth associated with altered flow dynamics.

It is also important to consider:

- Risk to infrastructure from adverse extreme drawdown increasing the possibility of air entrapment in pipework; and
- Sediment accumulation in pump outlet.

Therefore the option is regarded as having the following risk matrix inputs:

- **Likelihood:** Possible
- **Severity:** Critical

Resulting in an '**Extreme**' risk, in terms of adverse impacts based on the misapplication of seawater to oxidised sediments.

4. Local Application of Options

Consideration of potential impacts resulting from implementation of an option at a local scale (i.e. hotspot management) is discussed below in Section 4.5 onwards, following a discussion of the assessment process. Where differences between the local and the entire Lower Lakes environment were not identified these are not discussed below to avoid repetition. The discussions presented below are identified in relative terms to the impacts predicted.

4.1. Hotspot Management above -1.0 m AHD

Current mapping information and data developed by CSIRO / DEH as part of the ASS spatial heterogeneity project (Grealish et al., 2009) were used to identify management area size with respect to the concentration of net acidity above an elevation of -1.0m AHD for Lake Albert (Table 11) and Lake Alexandrina (Table 12). With respect to Lake Albert, a total of 57.32 km^2 of sediment above -1.0 m AHD is predicted to have a 'HIGH' net acidity (i.e. > 50 mol H^+/t). A similar figure is predicted for Lake Alexandrina (53.13 km^2).

- **Table 11 - Areas of Net Acidity above -1.0 m AHD - Lake Albert**

Net Acidity (mol H^+/t)	Km^2
<0	10.90
0 - 25 Low	2.69
25 - 50 Medium	3.51
50 - 100 High	6.70
100 - 500 High	34.86
500 - 1000 High	15.34
> 1,000 High	0.42
Total	**74.42**

- **Table 12 - Areas of Net Acidity above -1.0 m AHD: Lake Alexandrina**

Net Acidity (mol H+/t)	Km^2
<0	29.45
0 - 25 Low	8.66
25 - 50 Medium	8.88
50 - 100 High	18.66
100 - 500 High	52.19
500 - 1000 High	0.94
Total	**118.78**

The initial assessment of management of hotspots is based on the assumption that water level can be maintained at -1.0m AHD in each of the Lakes. As water level declines below -1.0m AHD, significant areas of sediment become exposed, especially in Lake Albert (see Table 2 - Net Acidity Statistics: Lake Albert), which indicates a 'hotspot' management approach would become increasingly more complex and potentially less effective, due to the significantly large area of sulfidic rich clay sediment becoming exposed. For Lake Alexandrina, the level at which hotspot management becomes ineffective is somewhat lower, approximately -1.5 to -2.0 m AHD (Table 4 - Zonal Statistics on the Net Acidity (all values are mol H+/t unless otherwise stated)).

4.2. Hotspot Management below -1.0 m AHD

Sediments below -1.0 m AHD generally exhibit higher net acidity when compared with areas above -1.0 m AHD. With respect to areas of the lakes below -1.0 m AHD, local scale (hotspot) management has been defined as an area(s) comprising:

- Acid neutralising capacity (equivalent % $CaCO_3$) less than 50;
- Net acidity (mol H^+/t)greater than 50 (with further identification of areas >600); and
- pH of water less than 5.

These areas are generally restricted to the central portion of Lake Alexandrina, and the north western and south eastern areas of Lake Albert, which are areas predominantly comprised by clays (see Section 4.4).

4.3. Adoption of Standard Hotspot Area

A benchmark area size (as hectares) for the relative assessment of hotspot application of options was set as 16 km^2, which is an approximate size area to Loveday Bay. The actual size of each hotspot that may require treatment will vary significantly, and so 16 km^2 was considered to accurately represent any one uniform area that may be affected by acidification (e.g. such as Loveday Bay). The scale of implementation of management options to areas above -1.0 m AHD is dependent on at what level the net acidity management threshold is set. For the purposes of this assessment, it is assumed that the lowest 'HIGH' net acidity (i.e. > 50 mol H^+/t) threshold would be adopted.

4.4. Hotspot Management and Soil Type

The effectiveness of any management option is considered to be associated with soil type, with the general premise being that sands are more amenable to management option effectiveness in comparison to clays. The principle reason for this is that clays have a reduced hydraulic conductivity over that of sands (Table 13). A lower hydraulic conductivity may result in a reduced effectiveness for any management option that relies on a sufficient recharge of water to encourage saturation (i.e. bioremediation).

- **Table 13 – Range of Hydraulic Conductivities for Sediments - (m/day) values from published sources**

Material	Fetter, 2000		Domenico and Schwartz, 2008		Freeze and Cherry, 1979	
	Min.	Max.	Min.	Max.	Min.	Max.
Clay	8.6×10^{-7}	8.6×10^{-4}	8.6×10^{-7}	4.1×10^{-4}	-	-
Silt, sandy silts	8.6×10^{-4}	8.6×10^{-2}	8.6×10^{-5}	1.7	8.6×10^{-5}	0.9
Silty sand or fine sands	8.6×10^{-3}	0.9	1.7×10^{-2}	17	8.6×10^{-3}	86
Well-sorted or medium sands	0.9	86	7.8×10^{-2}	43	-	-
Coarse or clean sand	-	-	7.8×10^{-2}	518	8.6×10^{-2}	864
Well-sorted gravel	8.6	864	26	2,592	86	86,400

The soil type above -1.0 m AHD (to old shoreline) in both lakes has been assessed by Grealish et al., 2009 (Table 14).

- **Table 14 - Soil Type above -1.0 m AHD**

NAME	Texture	Km^2	% of area
Lake Albert	Clay	28	38 (of Lake Albert)
Lake Albert	Sand	45	62 (of Lake Albert)
Lake Alexandrina	Clay	22	19 (of Lake Alex)
Lake Alexandrina	Sand	95	81 (of Lake Alex)
	Total	**210**	-

Lake Albert generally comprises a larger proportion of clay than Lake Alexandrina (note that Table 14 relates to above -1.0 m AHD although this composition is considered to be generally representative of the whole lakes, Figure F4) which supports the consideration that the application of management options in a 'hotspot' fashion below -1.0 m AHD in Lake Albert may become increasingly less effective with regards to acidification mitigation. Hotspot management zones based on soil type and net acidity were plotted across the lakes, as per the following categories:

1. Sand lithology with low net acidity (i.e. net acidity greater than 0 mol H^+/t and assumed to be represented by areas demonstrating less than 50 equiv % $CaCO_3$ acid neutralising capacity - current mapping provided in Grealish et al (2009) bands Net acidity between 0 and 250 mol H^+/t only);

2. Sand lithology with high net acidity (i.e. net acidity of > 0 mol H^+/t and no acid neutralising capacity);

3. Clay lithology with low net acidity (as for sand, but in clay areas);

4. Clay lithology with high net acidity (i.e. net acidity of > 0 mol H^+/t and no acid neutralising capacity).

Certain areas of the lakes were excluded where < 0 mol H^+/t net acidity was indicated. These four categories are presented on Figures F9 to F12. A composite of each category was then prepared by layering the respective zones on to one plan (Figure F13). The composite was used to determine the most potentially appropriate management options per soil type and net acidity level, based on the assessment presented in Sections 4.5 to 4.11.

The outcomes for the local scale (hotspot) scoring assessment are provided below, conservatively based on implementation of an option on areas below -1.0 m AHD, as these are considered worst case scenarios. The Scoring Matrices for the Local Scale Application are presented in Appendix G.

4.5. Option: Do Nothing

The SMART review for the do nothing option is presented in Appendix A. No differences have been identified between local and large scale for the purpose of assessing this option. Not treating ASS in a hotspot scenario may have a less significant environmental impact overall (i.e. to the entire system), but is still considered to cause significant localised impacts (e.g. the effects of acidification at Loveday Bay).

4.6. Option: Vegetation

The SMART review for the Vegetation option is presented in Appendix A. These SMART criteria are considered applicable for both local and large scale application of this option. Key differentiators between the scales are noted below.

Vegetation would only occur within hotspot areas of acidity as defined previously above. This would significantly reduce the area of Vegetation required, resulting in reduced costs for planting, maintenance and infrastructure to establish the Vegetation program. A lesser degree of complexity would also be attributed to implementing this option at a local scale, which is anticipated to increase the success of this option.

4.6.1. TECHNICALLY FEASIBLE (theoretically, will it work?)

The lack of proof of concept for plants actually directly mitigating acidity (i.e. the uptake of acidity or neutralisation of acidic sediments), even at a local scale, reduces the value of using this option to treat acidification. However, a variation of the implementation of the use of vegetation in the form of wetlands (See earlier discussion in Section 3) might be implemented to treat acidic drainage from localised hotspots. This manner of implementation is somewhat different from the mass planting on a system scale. However, it is considered that tactically located wetlands are unlikely to be able to ameliorate acidic groundwater formed through drawdown of the water table, unless a thorough groundwater collection / drainage infrastructure was developed, based on accurate delineation of the hotspot. This option does not however, solve the problem of the potential impact of acid migration following seiching or, on a larger scale, a raising of Lake water levels associated with improved environmental flow / precipitation. Therefore the technical feasibility of this option is considered to not differ significantly from the whole system implementation assessment.

4.6.2. Implemented successfully before acidification of the Lakes occurs – Dependant on Lakes recharge

A ‘Probable’ score with a ‘Moderate’ confidence (compared with ‘Unlikely’ with a ‘High’ confidence) has been identified. This score reflects the reduced complexity of establishing vegetation over a smaller area. This includes establishing and maintaining vegetation, which is considered more feasible at a local scale (this assumes that the option is technically robust).

4.6.3. DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option)

Higher confidences were considered with respect to the capital / establishment costs and also operational / maintenance costs ('Moderate' for the entire lower lakes). However the confidences have remained unchanged to reflect some uncertainty in the establishment and maintenance costs over time. However, it is considered that a reduced quantity of plants would be required and thus lower costs are potentially apparent associated with establishment and maintenance of plant stock health.

It is also noted that the implementation of such a program is likely to have significant socio-economic benefits to the local communities and on a wider regional scale.

4.7. Option: Bioremediation

The SMART review for the bioremediation option is presented in Appendix A. These SMART criteria are considered applicable for both local and large scale application of this option. Key differentiators between the scales are noted below.

Bioremediation would only occur within hotspot areas of acidity as defined previously. This may not necessarily include all areas of ASS. This would significantly reduce the area of bioremediation required, resulting in reduced costs for establishing suitable conditions for bioremediation to occur. This includes reduced infrastructure to obtain water for the creation of sub-oxic environments and to distribute water to areas of bioremediation treatment. As such, a lesser degree of complexity would also be attributed to implementing this option at a local scale, which is anticipated to increase the success of this option.

4.7.1. Implemented successfully before acidification of the Lakes occurs – Dependant on Lakes recharge.

Implementation of this option at a local scale has been attributed a high score (Yes) with a 'Moderate' confidence level (compared with 'Unlikely' with a 'High' level of confidence for large scale). This reflects the lower complexity required to implement this option, and assumes that water could be obtained from sources other than groundwater (note the low yield available to the system on any scale, SKM, 2009). A moderate confidence has been allocated to this criterion due to data gaps relating to implementing this option at a local scale, and the requirement for the option to not be reliant on groundwater. Assumptions for implementing this option at a local scale were largely derived from a study into bioremediation potential scenarios in Lake Albert (Study 18, Appendix D). It is noted that in-situ bioremediation of sediments is likely to occur following inundation (i.e. not as an active management approach).

One drawback to the application of this option is the immediate performance / effectiveness in clay strata, given that the application of water to create a sub-oxic environment may be affected by the reduced hydraulic continuity of clays.

4.7.2. DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)

4.7.2.1. Capital / Establishment costs are minimal

‘Probable’ alignment with the capital/establishment costs criteria was identified, in line with the score for large scale implementation. Costs for hotspot management are considered relative to that for a large scale approach, in orders of magnitude. The ongoing requirement for water in order to create sub-oxic environments is an unknown quantity, although tactical distribution on a local scale benefits the scoring of this option at the local scale. It is assumed that environmental allocations would be the most effective source of water, given the poor forecast for groundwater yield.

4.7.3. INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option):

4.7.3.1. Maximises the indirect benefits experienced in the wider Lower Lakes Region (e.g. tourism, agriculture, wine, lifestyle)

On a local scale, it is considered that greater indirect benefits can be identified (‘Probable’ compared with ‘Unlikely ‘at a large scale). This relates to the assumptions made regarding that this option is more feasible in terms of (effective) resource usage on a local scale than on a system wide scale.

4.8. Option: Neutralisation

The SMART review for the neutralisation option is presented in Appendix A. These SMART criteria are considered applicable for both local and large scale application of this option. Neutralisation would entail management of acidity at hotspot location (as defined previously) for both large scale and local scale, Therefore no significant differences were taken into account with respect to the SMART criteria for the purpose of assessing this option.

4.8.1. Technically feasible and achievable in practice on the scale required

C – Proof of concept established in Lower Lakes circumstances

With respect to a local scale implementation, neutralisation has been considered as a ‘Yes’ alignment with this criteria with a high level of confidence (compared with ‘Probable’ with ‘Moderate’ level of confidence). This reflects preliminary positive results from the use of in-situ neutralisation trials undertaken within the Lower lakes (i.e. within Currency and Finniss Creeks).

4.8.2. Implemented successfully before acidification of the Lakes occurs – Dependant on Lakes recharge.

A higher score has been attributed to the criteria with respect to local scale implementation (‘Probable’ with a ‘Moderate ‘confidence, compared with ‘Unlikely’ with a ‘Moderate’ level of confidence at a large scale). Significantly reduced quantities of neutralising agents would be required at a local scale. Therefore, the likelihood of sourcing and applying sufficient neutralising agents is considered greater at a local scale (however the cost associated with neutralising a 16 km^2 area is still considered to be significant).

Additionally, this option may be described as a reactive approach, with varying concentrations of neutralising agents required, depending upon specific acidity levels within a location. As such, the process of predicting and successfully applying this option is considered to be more efficient at a local scale.

4.8.3. DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)

4.8.3.1. Capital / Establishment costs are minimal, and Operational / Maintenance costs are minimal

'Probable' alignment with the capital/establishment and Operational/Maintenance costs criteria was identified, compared with 'Unlikely' for large scale implementation, as a result of the decreased volume of neutralising agent required and the associated resources required to implement. An increased confidence was also allocated to the Operational/Maintenance score at a local scale, as a reflection of the more manageable resources required with respect to attending to hotspots. However, only a 'Moderate' confidence was identified due to data gaps regarding accurate economics of implementing this option.

4.8.4. INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option):

4.8.4.1. Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)

'Unlikely' alignment with the criteria with a 'High' level of confidence, compared with 'No' alignment with a 'Moderate' confidence for large scale. The higher alignment with the criteria reflects a reduced quantity of neutralising agent required to be sourced from external environments and transported to the Lower Lakes for application, although the in-situ net acidity of any respective hotpot may still require a significant volume of neutralising agent.

4.8.5. Adjustments: Severity of negative impacts

A reduced severity of impact is predicted at a local scale ('Slight', compared with 'Moderate for a large scale). This score captures the reduced quantities of neutralising agent that would be required to be added to the lower lakes environment, and thus the reduced opportunity for 'overshooting' the rate and volume of application of Aglime (i.e. leading potentially to a alkaline environment). Potential impacts resulting from the addition of neutralising agents are discussed previously in Section 3.5. If a different neutralising agent were to be used (e.g. sodium hydroxide, NaOH) then the risk of excessive alkalinity may be avoided. The assessment made here considered the most readily available and complex of the neutralising agents (Aglime).

4.9. Option: Use of salt water released via the barrages to inundate the Lower Lakes

The SMART review for the seawater inundation option is presented in Appendix A. These SMART criteria are considered applicable for both local and large scale application of this option. Key differentiators between the scales are noted below.

The potential to install irrigation infrastructure (pipework and pumping equipment) could be undertaken to undertake a hotspot management approach within the Lower Lakes. This would require large volumes of water to inundate the lower lakes, although not in its entirety. Detailed information or feasibility studies are not available for this approach. As such, this option may also be regarded as unfeasible at a local scale. This is due to the nature of inundating hotspot areas which generally occur within the elevated margins of the lake environments, and the technical requirements of applying seawater discretely to localised zones.

4.9.1. Technically feasible and achievable in practice on the scale required

B– Theoretically viable on the scale (spatial) required

'Unlikely' alignment with the criteria compared with 'Probable' at a large scale. This reflects the significant data gaps present relating to implementing this option at a local scale.

4.9.2. Implemented successfully before acidification of the Lakes occurs – Dependant on Lakes recharge.

A reduced score ('Probable') with a 'Low' confidence has been allocated to this option, compared with 'Yes' alignment with a 'Moderate' level of confidence. This reflects the significant data gaps present relating to implementing this option at a local scale, as discussed above.

4.9.3. DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)

4.9.3.1. Capital / Establishment costs are minimal, and Operational / Maintenance costs are minimal

Probable alignment with the capital/establishment and Operational/Maintenance costs criteria was identified compared with 'Yes' for large scale implementation. This reflects anticipated infrastructure required to distribute seawater to hotspot locations within Lake Albert and Lake Alexandrina, as discussed above. A reduced level of confidence was also allocated to both these criteria ('Low') at a local scale, as significant data gaps still exist regarding the economics of implementing this option.

4.9.4. Adjustments: Severity of negative impacts

'Moderate' severity of impact has been identified for the criteria, compared with 'Critical' at large scale. Reduced severity of risk is anticipated at a local scale, due to the lower volumes of saltwater required, resulting in potentially lower salinity within the Lower Lakes environment. This is dependent upon the specific nature of implementing this option at a local scale. However, the potentially significant negative effects of seawater on ASS would still be prevalent.

4.10. Option: Provision of Freshwater Flows via Buyback

The SMART review for the seawater inundation option is presented in Appendix A. These SMART criteria are considered applicable for both local and large scale application of this option. Key differentiators between the scales are noted below.

The potential to install irrigation infrastructure (pipework and pumping equipment) could be undertaken to undertake a hotspot management approach within the Lower Lakes. For the purpose of this document this assumes provision of freshwater flows into Lake Alexandrina through 'buy back' government purchases of water from the River Murray. This water would then be distributed to hotspot locations. This would require sufficiently large volumes of water to inundate the lower lakes, although not in its entirety. Detailed information or feasibility studies are not available for this approach. As such, this option may also be regarded as unfeasible at a local scale. This is due to the nature of inundating hotspot areas which generally occur within the elevated margins of the lake environments.

4.10.1. Implemented successfully before acidification of the Lakes occurs – Dependant on Lakes recharge.

'Yes' alignment with the criteria compared with 'Unlikely' for large scale implementation. This score captures the increased likelihood of sourcing sufficient water to implement a hotspot management approach, where significantly less volumes of water are likely to be required. It has been assumed that sourcing sufficient water through buy back is more likely than sourcing sufficient water through re-allocation. A 'Moderate' confidence has been allocated due to data gaps present regarding transfer of water to hotspot areas.

4.10.2. DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)

4.10.2.1. Capital / Establishment costs are minimal

An 'Unlikely' alignment was given for this criteria with a 'Moderate' level of confidence, compared with 'No' alignment with a 'High' level of confidence for large scale. The criteria scores higher at a local level as a reduced volume of water will be required to implement hotspot management approach for this option. Therefore, lower financial costs will be required to secure the water required. However, a lower confidence has been attributed due to data gaps regarding how water will be distributed to hotspot areas, particularly within elevated margins of the lakes.

4.10.2.2. Operational / Maintenance costs are minimal

A 'Probable' alignment with the criteria, with a 'Moderate' level of confidence, compared with Unlikely' alignment with a 'High' level of confidence for large scale implementation of the option. The criteria scores higher at a local level as a reduced volume of water will be required to implement hotspot management approach for this option. Therefore, lower financial costs will be required to secure the water required. However, a lower confidence has been attributed due to data gaps regarding how water will be distributed to hotspot areas, particularly within elevated margins of the lakes.

4.10.3. Adjustments

The *likelihood of negative impacts* occurring at a local scale was scored 'Likely' compared with 'Unlikely' at a large scale. This reflects the significantly lower volumes of freshwater within in the Lower Lakes should a hotspot management approach be adopted. Whilst the local scale would aim to address potential acidification risks, a number of impacts would result from drying of large areas of the Lower Lakes, as discussed in Section 3.1.

4.11. Option: Provision of Freshwater Flows via Re-allocation

The SMART review for the seawater inundation option is presented in Appendix A. These SMART criteria are considered applicable for both local and large scale application of this option. Key differentiators between the scales are noted below.

The potential to install irrigation infrastructure (pipework and pumping equipment) could be undertaken to undertake a hotspot management approach within the Lower Lakes. For the purpose of this document this assumes provision of freshwater flows into Lake Alexandrina through reallocation of water within the River Murray environment. This water would then be distributed to hotspot locations. This would require sufficiently large volumes of water to inundate the lower lakes, although not in its entirety. Detailed information or feasibility studies are not available for this approach. As such, this option may also be regarded as unfeasible at a local scale. This is due to the nature of inundating hotspot areas which generally occur within the elevated margins of the lake environments.

4.11.1. Implemented successfully before acidification of the Lakes occurs.

Probable alignment with this criteria with a 'Moderate' level of confidence, compared with 'Unlikely' with a 'Low level of confidence for a large scale. This score captures the increased likelihood of sourcing sufficient water to implement a hotspot management approach, where significantly less volumes of water are likely to be required. A 'Moderate' confidence has been allocated due to data gaps present regarding transfer of water to hotspot areas.

4.11.2. DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)

4.11.2.1. Capital / Establishment costs are minimal, and Operational / Maintenance costs are minimal

'Probable' alignment with these criteria with a moderate level of confidence, compared with 'Yes' alignment with a 'High' confidence for large scale. It is assumed that negligible financial costs are associated with obtaining water through re-allocation. However, anticipated costs to distribute water to hotspot locations have resulted in a lower score at a local scale. Information gaps regarding implementation of this option at a local scale is captured by a reduced confidence weighting, compared with large scale.

4.11.3. Adjustments

The *likelihood of negative impacts* occurring at a local scale was scored 'Likely' compared with 'Unlikely' at a large scale. This reflects the significantly lower volumes of freshwater within in the Lower Lakes should a hotspot management approach be adopted. Whilst the local scale would aim to address potential acidification risks, a number of impacts would result from drying of large areas of the Lower Lakes, as discussed in Section 3.1.

5. Summary of Results

Complete tabulation of the scoring results along with sensitivity analysis on the results for the entire system assessment is presented as Table 009.

At the default setting of 50/50 contribution from each of costs and technical stream, and applying the adjustment parameters, the freshwater (allocations) option appears to be ranked as the highest scoring option. Table 15 below presents the 50/50 rankings when the adjustment parameters are applied.

- **Table 15 - Ranking of adjusted options at 50/50 costs vs. technical contribution – Entire system**

50/50 Ranking	Option	50/50 Score
1	Provision of freshwater (allocations)	399
2	Vegetation	288
3	Bioremediation	243
4	Provision of freshwater (buybacks)	233
5	Seawater inundation (barrages)	222
6	Neutralisation	188
7	Do Nothing	120

When each of the following adjustment parameters is removed:

- Prevention vs. treatment
- Risk of negative impacts

the ranking changes, indicating the significance of the adjustment parameters upon the actual initial score, depending on the considered ‘benefit’ of being a preventative measure vs. treatment, and the likelihood and severity of negative environmental impacts (‘risk’).

Table 16 below presents the 50/50 rankings when the adjustment parameters are removed.

- **Table 16 - Ranking of non-adjusted options at 50/50 costs vs. technical contribution – Entire system**

50/50 Ranking	Option	50/50 Score
1	Provision of freshwater (allocations)	712
2	Seawater inundation (barrages)	610
3	Vegetation	451
4	Neutralisation	450
5	Do Nothing	443
6	Bioremediation	434
7	Provision of freshwater (buybacks)	416

Thus the non-adjusted ranking at 50/50 contribution indicates that the provision of freshwater (allocations) option achieves the highest score.

These scores can be broken down further to provide rankings based on the relative contributions of technical feasibility (Table 17) and costs (Table 18).

- **Table 17 - Ranking of non-adjusted options based on technical contribution (50/50) – Entire System**

50/50 Ranking	Option	50/50 Score
1	Provision of freshwater (allocations)	272
2	Provision of freshwater (buybacks)	272
3	Neutralisation	247
4	Bioremediation	220
5	Seawater inundation (barrages)	215
6	Do Nothing	79
7	Vegetation	68

- **Table 18 - Ranking of non-adjusted options based on cost contribution (50/50) – Entire System**

50/50 Ranking	Option	50/50 Score
1	Provision of freshwater (allocations)	440
2	Seawater inundation (barrages)	396
3	Vegetation	383
4	Do Nothing	364
5	Bioremediation	214
6	Neutralisation	203
7	Provision of freshwater (buybacks)	144

The provision of freshwater (allocations) ranks as the highest scored non-adjusted option in the technical contribution, and in the cost contribution, when the ratio of contributions is 50/50.

As discussed previously in Section 2.0, the MCA scores were developed across a sliding scale of change in contribution from each of the two heading criteria (technical and costs) in order to present the potential change in option ranking depending on the required contribution from cost vs. technical / practical feasibility. This contribution scale based on option ranking is presented as Figure F5. Note that the scale accounts for adjusted values (i.e. preventative vs. treatment and risk of negative impact). The actual scores used to produce the contribution scale are presented as a score scale in Figure F6.

The variation in option ranking over this scale is based on the change in contribution from heading criteria and not the sub and base criteria weighting (Appendix B). The contribution ranking scale (Figure F5) indicates the following:

- freshwater (allocations) is ranked as number 1 across all contribution ratios'
- the freshwater (buy-backs) option also shares the number one ranking with 'allocations' when cost contribution is placed at 0%;
- Bioremediation generally scores well (between ranks 3 and 4) across all contributions;
- the 'do nothing' option is ranked low across all contributions generally.

5.1. Lake Albert

Potential alternative options for Lake Albert were reviewed as discussed above for the entire system, with the inclusion of the seawater inundation option (Lake Albert exclusively). At the default setting of 50/50 contribution from each of costs and technical stream, and applying the adjustment parameters, the freshwater (allocations) option appears to be ranked as the highest scoring option. Table 19 (below) presents the 50/50 rankings when the adjustment parameters are applied.

Table 19 - Ranking of adjusted options at 50/50 costs vs. technical contribution – Lake Albert

50/50 Ranking	Option	50/50 Score
1	Provision of freshwater (allocations)	399
2	Vegetation	288
3	Bioremediation	243
4	Provision of freshwater (buybacks)	233
5	Seawater inundation (barrages)	222
6	Neutralisation	188
7	Do Nothing	120
8	Use of seawater – Lake Albert only	112

Note that the use of seawater as an option is ranked at number 8 (of 8). The non-adjusted ranking shows seawater use to be ranked 8 also (Table 20). The technical ranking (non-adjusted) places the seawater option for Lake Albert at number 4, whereas the cost ranking is number 8.

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▪ **Table 20 - Ranking of non-adjusted options at 50/50 costs vs. technical contribution – Lake Albert**

50/50 Ranking	Option	50/50 Score
1	Provision of freshwater (allocations)	712
2	Seawater inundation (barrages)	610
3	Vegetation	451
4	Neutralisation	450
5	Do Nothing	443
6	Bioremediation	434
7	Provision of freshwater (buybacks)	416
8	Use of seawater – Lake Albert only	238

5.2. Local Scale Assessment

The scores allocated with respect to the implementation of the options at a local scale were reviewed as discussed previously, with consideration given to the spatial heterogeneity of ASS and in-situ soil lithology. The results are presented as Figure F7 (ranks) and F8 (scores).

At the default setting of 50/50 contribution from each of costs and technical stream, and applying the adjustment parameters, both freshwater options (reallocations and buyback) appear to be ranked as the highest scoring options, with buyback marginally higher by one point. Table 21 (below) presents the 50/50 rankings when the adjustment parameters are applied.

- **Table 21 - Ranking of adjusted options at 50/50 costs vs. technical contribution - Local Scale**

50/50 Ranking	Option	50/50 Score
1	Provision of freshwater (buybacks)	244
2	Provision of freshwater (allocations)	243
3	Vegetation	233
4	Bioremediation	178
5	Neutralisation	147
6	Seawater inundation (barrages)	134
7	Do Nothing	121
8	Transfer of seawater to Lake Albert	86

Bioremediation ranked 4th at a 50 / 50 split, with a significant gap between scores for the other options. The scores for the top 3 ranked options were also relatively close to each other, with only 1 point differentiating the two freshwater options (buyback and reallocation). The non adjusted scores sees a similar result except bioremediation scores higher than Vegetation, and neutralisation slips a position, due to the relief of environmental impacts from the do nothing option (Table 22).

- **Table 22 - Ranking of non-adjusted options at 50/50 costs vs. technical contribution - Local Scale**

50/50 Ranking	Option	50/50 Score
1	Provision of freshwater (buybacks)	580
2	Provision of freshwater (allocations)	578
3	Bioremediation	484
4	Vegetation	476
5	Do Nothing	447
6	Neutralisation	399
7	Seawater via barrages	318
8	Transfer of seawater to Lake Albert	246

6. Discussion

6.1. Technical vs. Costs

Based on adjusted parameters, the freshwater (allocations) option is ranked as the number 1 option across 90% of the costs contribution. When the contribution from costs becomes less important, the freshwater (buybacks) option also becomes number 1 (i.e. at 0% costs), in line with the potentially significant costs factors associated with the buy-back process of freshwater (ranked at 7 in terms of costs contribution, Table 18). The freshwater (allocations) option scores well on both contribution streams, and the perceived risks to the environment are also relatively low, as indicated by the overall rank (adjusted) at 50/50 contribution (rank 1, Table 15 - *Ranking of adjusted options at 50/50 costs vs. technical contribution*).

Although the Vegetation option ranks at number 2 across the 0/100 and 60/40 split (technical and costs respectively), it actually scores poorly when considering the technical contribution alone (ranked 7 of 7, Table 17), although a combination of high marks on the costs contribution, coupled to a mild adjustment when processed through the adjustment parameters, is sufficient to raise the option above the other considered options (which by definition must collectively score poorly on both costs and the adjustment options, i.e. risks to the environment). The Vegetation option is however likely to have alternative benefits with respect to soil stabilisation and prevention of further erosion of Lake beds. Additionally, the seasonal die-back of vegetation is potentially likely to benefit bio-remediation processes and / or potentially assist in the maintenance of reducing conditions within sediments, thereby potentially preventing some sulfide oxidation.

The bioremediation option itself scores generally well across the contribution scale, and the overall rank (adjusted) at 50/50 contribution is high (rank 3, Table 15). Bioremediation scores relatively low in both pre-adjustment technical and costs contribution (rank 4 and 5, technical and costs respectively) although makes up ground on the low risks to the environment following adjustment, which raises the overall adjusted ranking to 3. It is considered that there are some data gaps in the technical contribution of this option, notably:

- Direct evidence of SRB activity and capacity within the Lower Lakes sediments; and
- Sufficient information relating to groundwater yield with respect to mounding of groundwater to encourage bioremediation to occur.

These gaps have been reflected in the current scoring. It is considered that the technical contribution scores for this option would require review following the completion of data gaps. However, it is worth noting that the bioremediation option currently scores poorly on the theoretically viable on the scale required criterion, due to the likely requirement for broad scale inundation (see discussion above). Hence this option may prove to be more beneficial as a ‘hotspot’ option in combination with other options.

The neutralisation option scores reasonably well on technical contribution, pre adjustment (rank 3, Table 17), although is scored quite low on cost contribution (both direct and indirect) given the material input required for this option. This is evident from the increase in rank as costs contribution becomes less important. The application of this option over a large scale was determined to be 'unlikely'. However, the results indicate that as a localised treatment measure where reduced costs may be apparent, the neutralisation option is likely to be of some merit.

6.2. Environmental risks

A summary of the potential environmental risks per option is presented in Table 23.

The options that fare well in the adjusted assessment are generally the options that have perceived low environmental risks:

- Vegetation (0.64 multiplier);
- Bioremediation (0.56); and
- Provision of freshwater allocations / buybacks (0.56).

If the risks adjustment is ignored, then the ranking at 50/50 contribution is un-altered, and the number 1 option remains freshwater allocations.

Focussing on the non-adjusted contributions, the seawater option is ranked 5 for technical contribution and 2 for costs, indicating that (if applied correctly) the option does have potential to prevent acidification of sediments (but should not be used as a treatment). Consideration could be given to using a combination of options (neutralisation and inundation) to negate risks, based on predictive mapping. The high scores awarded in the direct costs criteria indicate that the option would not require significant outlay in terms of capital (implementation and ongoing maintenance).

■ **Table 23 – Summary of potential environmental risks for each of the options**

Option	Combined Ranking @ 50/50	Likelihood of Negative Impact	Severity	Risk of Negative Impact		Summary Impact Comments
Do Nothing	6	0.6	0.6	Extreme	**Negative**	▪ Significantly lower lake levels (including a completely dry Lower Lakes environment); ▪ Increased salinity due to a lack of flushing and evaporative concentration; ▪ Dust generation and erosion of exposed lake beds; ▪ Pyrite oxidation and mobilisation of acidity and metals through Lake seiching and flushing from rainfall events ; ▪ Eutrophication as water levels recede; and ▪ Anoxic conditions developing.
					Positive	▪ Low implementation cost option ▪ Relative ease of returning Lower Lakes to pre-action state upon re-flooding
Seawater via Barrages	4	0.7	0.5	Extreme	**Negative**	▪ Salinisation of a fresh water resource (with the potential to become hyper-saline due to lack of flushing regime). ▪ Potential generation of hydrogen sulfide gas due to high quantities of sulfate in water from the Coorong that could result in an imbalance between sulphur and available iron ▪ Risk of adverse impacts on the Coorong and Murray Mouth associated with altered flow dynamics ▪ Potential loss of freshwater connection to the Coorong and with particular impacts upon diadromous fish species ▪ Disconnection of Murray Mouth to River Murray, with particular impacts upon fish diadromous fish species (this

						▪ assumes fish passage is not possible for the proposed weir at Pomanda Island) ▪ Mobilisation studies have indicated that seawater mobilises a significant amount of acidity and heavy metals / nutrients during inundation, if sulfidic sediments have oxidised.
					Positive	▪ The provision of a refuge environment within the AMLR tributaries (Currency Creek and Finniss Creek) presents significant ecological safeguards should the Lower Lakes become a saltwater environment. ▪ Barrages management could allow more natural estuarine environment to develop in the Lower Lakes ▪ High rainfall events could be managed to provide flushing flows within Lake Alexandrina to reduce salt levels ▪ Installation of fish passages at the proposed weir near Wellington could allow connection to the freshwater environment of the River Murray), important for diadromous fish species. ▪ Creation of a saltwater environment, potentially providing habitat for marine fish species ▪ Aesthetic benefits through provision of inundated Lower Lakes environment
Bioremediation	2	0.7	0.8	Moderate	**Negative**	▪ Suitable redox conditions must be maintained to prevent acid re-generation ▪ Loss of freshwater environment and associated flora and fauna impacts and significant species loss ▪ Salinisation of lake basin as water levels recede ▪ Potential for eutrophication to occur as water levels recede ▪ Ecological disturbance impacts during installation of infrastructure and ongoing management and monitoring ▪ Potential disturbance of PASS and ASS environments which may create acidification issues

					Positive	▪ Relative ease of returning Lower Lakes to pre-action state upon re-flooding ▪ Some opportunities for feeding bird species (primarily wading species)may develop, arising from Vegetation works
Vegetation	1	0.8	0.8	Low	**Negative**	▪ Loss of freshwater environment and associated flora and fauna impacts and significant species loss ▪ Salinisation of lake basin as water levels recede ▪ Potential for eutrophication to occur as water levels recede ▪ Ecological disturbance impacts during installation of infrastructure and ongoing management and monitoring ▪ Introduction of mono-cultures of non-native vegetation species, loss of diversity and potential longer term weed management issues ▪ Potential disturbance of PASS and ASS environments which may create acidification issues
					Positive	▪ Relative ease of returning Lower Lakes to pre-action state upon re-flooding ▪ Some opportunities for feeding bird species (primarily wading species)may develop

Neutralisation	5	0.7	0.7	High	**Negative**	▪ Flora impacts associated with addition of large volumes of neutralising agents, including smothering and inhibition of photosynthesis ▪ Fauna impacts, primarily aquatic species, associated with addition of large volumes of neutralising agents, including increased turbidity and associated impacts to fish and invertebrate populations ▪ Loss of freshwater environment as waters recede and associated flora and fauna impacts and significant species loss ▪ Salinisation of lake basin as water levels recede ▪ Potential for eutrophication to occur as water levels recede; and ▪ Ecological disturbance impacts during neutralisation material addition and ongoing management and monitoring.
					Positive	▪ Relative ease of returning Lower Lakes to pre-action state upon re-flooding
Provision of water via freshwater buy backs	3	0.8	0.7	Moderate	**Negative**	▪ Potential mobilisation of acidified sediments; ▪ Initial turbidity increases; and ▪ Relatively low level salinisation (in the medium to long term through evaporation) ▪ Inconsistent inundation may exacerbate the oxidation of pyrite and generation of acidity
					Positive	▪ A secure water supply maintaining adequate water levels within the Lower Lakes will provide significant benefits to the ecology of the area

Lake Albert seawater use exclusively	7	0.7	0.5	Extreme	**Negative**	▪ High chance of ineffective treatment as inundation must be accurately timed prior to the sediments turning acidic, to reduce the risk of mobilising both acidity and heavy metals; ▪ Salinisation of a fresh water resource (with the potential to become hyper-saline due to lack of flushing regime), which has no refuge habitat for fish; ▪ Potential generation of hydrogen sulfide gas due to high quantities of sulfate in water from the Coorong that could result in an imbalance between sulphur and available iron; ▪ Risk of adverse impacts on the Coorong and Murray Mouth associated with altered flow dynamics. ▪ Loss of freshwater environment and associated ecosystem, including large scale loss of existing fish populations within Lake Albert ▪ Lake Albert would become a closed system, with no connection with freshwater or marine species.
					Positive	▪ An initial water connection into Lake Alexandrina may allow existing fish populations an exit route as Lake Albert fills with saltwater reducing the impact of this option with regard to fish. ▪ In the longer term a saltwater environment would develop at Lake Albert which could provide habitat for marine fish species if able to colonise, or where stocking activities occur; ▪ Aesthetic benefits through provision of inundated Lake Albert

6.3. Lake Albert & Seawater

It is recognised that the seawater inundation option is considered an option of last resort. However the assessment has shown that if it is required, then the technical contribution may be sufficient to prevent acidification (subject to conditions on application to sediments). This may be of benefit particularly to Lake Albert where it may be imperative to maintain inundation over the central area of the Lake, which is comprised of clay bearing high acidity that may not be treated by any other means (noting that the technical contribution is rank 4). The costs (direct) associated with the pumping of saltwater from the Coorong into the Lake are considered potentially significant, and so the option scores poorly on the direct cost criteria. As an overall adjusted score, in comparison to the other options, the pumping of saltwater from the Coorong into Lake Albert is ranked at 8 (of 8), predominantly due to the direct and indirect costs involved. Note that the ranking of this option does not improve when the adjustments are removed, due to the significant cost associated. As in indicator, when cost contribution is reduced, the ranking of this option would improve to rank 4 at 0% technical contribution / 100% cost.

6.4. The 'do nothing' option

The assessment indicates that the 'do nothing' option scores very low overall, both before and after adjustment is applied (ranks 5 and 7 respectively). Further analysis indicates that the non-adjusted technical contribution is low (rank 6), whereas the cost contribution is slightly higher (rank 3), mainly as a result of the direct costs scoring highly (i.e. no infrastructure required etc).

The perceived environmental risks then applied during adjustment derive the low overall ranking (7) which increases to 5 as the importance of technical contribution is reduced.

6.5. Local Scale Assessment of Options

Considerations of potential impacts resulting from implementation of an option at a local scale are discussed below, based on the assumptions outlined in Section 4.4 and assuming the following:

- Acid neutralising capacity (equivalent % CaCO3) less than 50;
- Net acidity (mol H^+/t) greater than 50, with further identification of >600; and
- pH of water less than 5.

The following discussions consider adjusted scores only (note that these results are presented on Figure F7 and F8).

Potential environmental risks (as discussed in Section 6.2) are considered comparable to those identified previously in Table 23. An additional risk considered relevant at a local scale is:

- Requirements of additional infrastructure to distribute freshwater (or seawater) to hotspot locations have not been investigated. As such, installation and construction of infrastructure may not be feasible or achievable at a local scale.

Provision of freshwater (buyback) is ranked the highest option (1) where 50% to 100% technical contribution is considered. This falls significantly to ranking 5 at 100% cost contribution, reflecting the significant financial resources required to implement this option. This pattern is also evident at a large scale.

The provision of freshwater (environmental allocations) is ranked as the number 2 option across all cost contributions. Provision of freshwater (allocation) is the most stable ranked option irrespective of cost contribution. A similar pattern is also evident for this option at a large scale, although this option scores 1 ranking lower at a local scale. This is due to considered lower costs associated with provision of water through buyback at a local scale where lower water volumes are required, and the increased confidence / security of obtaining the required volume via purchase rather than revised management of allocations.

Vegetation is ranked as the number 1 option between 100% and 60% of the cost contribution. However, where cost becomes less of a concern this option falls to ranking 3 at 50% and decreases in rank where costs become progressively less important. Where 0% costs are taken into account this option is ranked number 6. This pattern reflects this options relatively low financial cost, yet lower success in respect to technical feasibility and achievable in practice. A similar pattern is also evident on a large scale.

Bioremediation is ranked 6 where costs of 100% are considered. However, this increases to ranking 4 / 3 at 50% onwards to technical contribution of 100%. Whilst a comparable rank was also attributed for large scale application of this option, a lower rank is evident for local scale where costs are considered with a greater weighting.

Neutralisation is ranked the lowest (7) at 100% to 50% cost contribution due to the perceived costs (both direct and indirect) associated with the requirement for neutralising a 16 km^2 area. However the ranking increases to 3 where 100% technical contribution is considered, emphasising this options strong technical aspect (note that it ranks at 2 for technical contribution). A similar pattern is evident for the entire Lower Lakes rankings. This is to be expected, as both local scale and the entire Lower Lakes assessments take into account a hotspot management approach, as discussed within SMART criteria descriptions for these options (see Appendix A).

Saltwater inundation (via barrages) generally ranks low between number 5 and 6 where 80% to 20% cost contribution is considered. Note an increase of one ranking (4) where 100% cost contribution is considered. The general pattern identifies lower rankings at a local scale (compared to entire Lower Lakes) which reflects the additional infrastructure required to distribute seawater to hotspot areas within the Lower Lakes.

The ‘Do nothing’ option has been ranked number 3 where costs are 100%. This significantly falls to ranking number 6 where 50% costs are attributed and then falls to the lowest ranked option where 70% to 100% technical contribution is considered alone. This reflects the significant impacts and risks associated with this option. This pattern differs when considering the do nothing option at a large scale, which generally ranks low regardless of consideration of costs. This occurrence of higher rankings at increased cost contribution reflects the significant costs (including for example the infrastructure required to redistribute water to hotspot locations) associated with implementing seawater inundation and freshwater inundation (buy back) at a local scale.

Note that the transfer of saltwater from the Coorong into Lake Albert was ranked the lowest at all contributions due to the combined effect of poor environmental performance (i.e. impacts) and significant cost loadings (both direct and indirect).

Figure F14[5] presents the potential management options per unit in order of scores with respect to both adjusted (i.e. prevention vs. treatment weighting, environmental impacts) and non-adjusted scores. The effectiveness of hotspot management may be affected below a water level of -1.0 m AHD, especially with respect to Lake Albert, due to the following:

- Generally higher net acidity in sediments; and
- Increased clay content of sediments.

Therefore the potential range of options is considered to become reduced when considering clay lithology of high net acidity. Figure F14 denotes that either freshwater inundation (prevention or treatment), or neutralisation (assuming cost concerns are ignored) are potentially the most effective management options should these sediments become at risk of exposure.

6.6. Preliminary Assessment - Blanket Options

Based on the spatial extent and acid flux information, the appropriate selection of options (i.e. building on the preliminary assessment provided here at a Local Scale) as a combination approach is potentially likely to be of beneficial use over a blanket homogeneous approach using one option.

It should be noted that this alternative options assessment is a preliminary step in assessing potential alternative options for the management of acid sulfate soil related environmental acidification. The options assessed are of a 'blanket nature' and require further detailed assessment to determine applicability to the Lakes environment in terms of local scale management.

Thus this assessment should be treated as a preliminary live document (i.e. Stage I) that is not written with the intent of being able to support decision making on the use of alternative options. Stage II of the process is crucial to the assessment of alternative options and will be undertaken pending the completion of additional studies and suitable advancement of the Environmental Impact Statement.

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[5] Note that this is a high level assessment and does note factor in significant variables such as pyrite oxidation rate and acid flux.

7. Conclusions

The assessment currently indicates that the freshwater (allocations) option is the general number 1 ranked option.

Further analysis of the scores indicates that the Vegetation option (although ranked at number 2 for several technical / cost contributions) scores poorly on a technical basis (i.e. in terms of acidification management), but is kept high in the rankings due to high scores awarded on the costs contribution, coupled to a high multiplier for the perceived low environmental risks.

The freshwater (buy-backs) option scores well on the technical and environmental risks areas, but the cost component reduces its ranking as the cost contribution increases (although it does share number 1 spot with 'allocations' when costs contribution is set to 0% .

The bioremediation option scores in the mid-range generally, although should require further assessment / revision following the completion of additional studies.

The seawater inundation (via barrages) for the Lakes system ranks at number 3 when the cost contribution is increased (i.e. >70%), as it a low cost option. It does not score highly on the technical contribution as a preventative measure, and is downgraded by its potentially high environmental risk, associated with inundating oxidised sediments.

The freshwater options may be affected by the same potential risk, although it is considered that more buffering capacity would be available when using freshwater over that available when using seawater. In addition, consideration could be given to pre-neutralisation of oxidised sediments using neutralising agents, prior to inundation.

With respect to Lake Albert, the pumping of saltwater from the Coorong is ranked low overall, based on the cost contribution, both pre and post adjustment. However the mid ranking of the technical contribution indicates that the option may be of merit as a preventative last resort measure for certain areas of the Lake.

The 'do nothing' option scores poorly overall, with a low technical ranking, but its ranking is marginally increased when considering maximum cost contribution, as expected from an option that has no significant direct costs.

With respect to local scale application of options for the management of 'hotspots' of net acidity, the hotspot application of options was scored with respect to application to the areas of the lakes with significant net acidity (i.e. below -1.0m AHD) as a conservative measure that is also valid for areas above -1.0 m AHD. The soil type (e.g. sands, clays) was considered during the assessment of option feasibility, and the presence of clays, particularly in Lake Albert, below -1.0m AHD was considered to have a potential effect on the effectiveness of those options dependent on a relatively high hydraulic conductivity (i.e. bioremediation). The local scale assessment resulted in the provision of freshwater (buyback) being ranked the highest option (1) where 50% to 100% technical contribution is considered. This ranking falls significantly to 5 at 100% cost contribution, reflecting the significant financial resources required to implement this option. This pattern is also evident at a large scale. The higher scores for ‘buy-back’ versus ‘environmental allocation’ at lower cost contribution are attributable to the increased confidence in obtaining the required volume via purchasing, over that of re-allocation from other sources.

An assessment of potentially suitable hotspot management options based on soil type and net acidity indicates that freshwater inundation (either buy-backs or allocations) and neutralisation (ignoring cost contribution) are the most suitable for the sulfidic rich clay units. The more peripheral lower net acidity areas may be amenable to less cost intensive options, such as bioremediation or Vegetation.

There is likely to be overlap between a number of options after implementation, for example Vegetation and bioremediation are intrinsically linked, and would require some freshwater inundation, and perhaps some pre-neutralisation to reduce pH. Therefore a combination of options is likely to be relevant, and these will be assessed in Stage 2 of the assessment.

The Stage I assessment presented here is considered to be a preliminary ‘live’ document which may require adjustment / updating as an iterative process as events occur (e.g. environmental recharge of the water bodies).

In addition, this document should not be read out of context (i.e. Stage I of a two Stage process). Stage 2 is crucial to the accurate assessment of the alternative options, and will be completed following the concomitant completion of the additional studies and suitable advancement of the Environmental Impact Statement for Barrage opening.

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9. Limitations

This report has been prepared by Sinclair Knight Merz Pty Limited ("SKM") for the sole use of the SA Water ("the Client") and in accordance with the scope of services outlined in the proposal prepared for the client dated 16 June 2009.

All reports and conclusions that deal with environmental and / or sub-surface conditions are based on interpretation and judgement and as a result have uncertainty attached to them. You should be aware that this report contains interpretations and conclusions which are uncertain, due to the nature of the assessment / investigations. No study can completely eliminate risk, and even a rigorous assessment and/or sampling programme may not detect all problem areas within a system / site. The following information sets out the limitations of the Report.

This Report should only be presented in full and should not be used to support any objective other than those detailed within the Agreement. In particular, the Report does not contain sufficient information to enable it to be used for any use other than the project specific requirements for which the Report was carried out, which are detailed in our Agreement. SKM accepts no liability to the Client for any loss and/or damage incurred as a result of changes to the usage, size, design, layout, location or any other material change to the intended purpose contemplated under this Agreement.

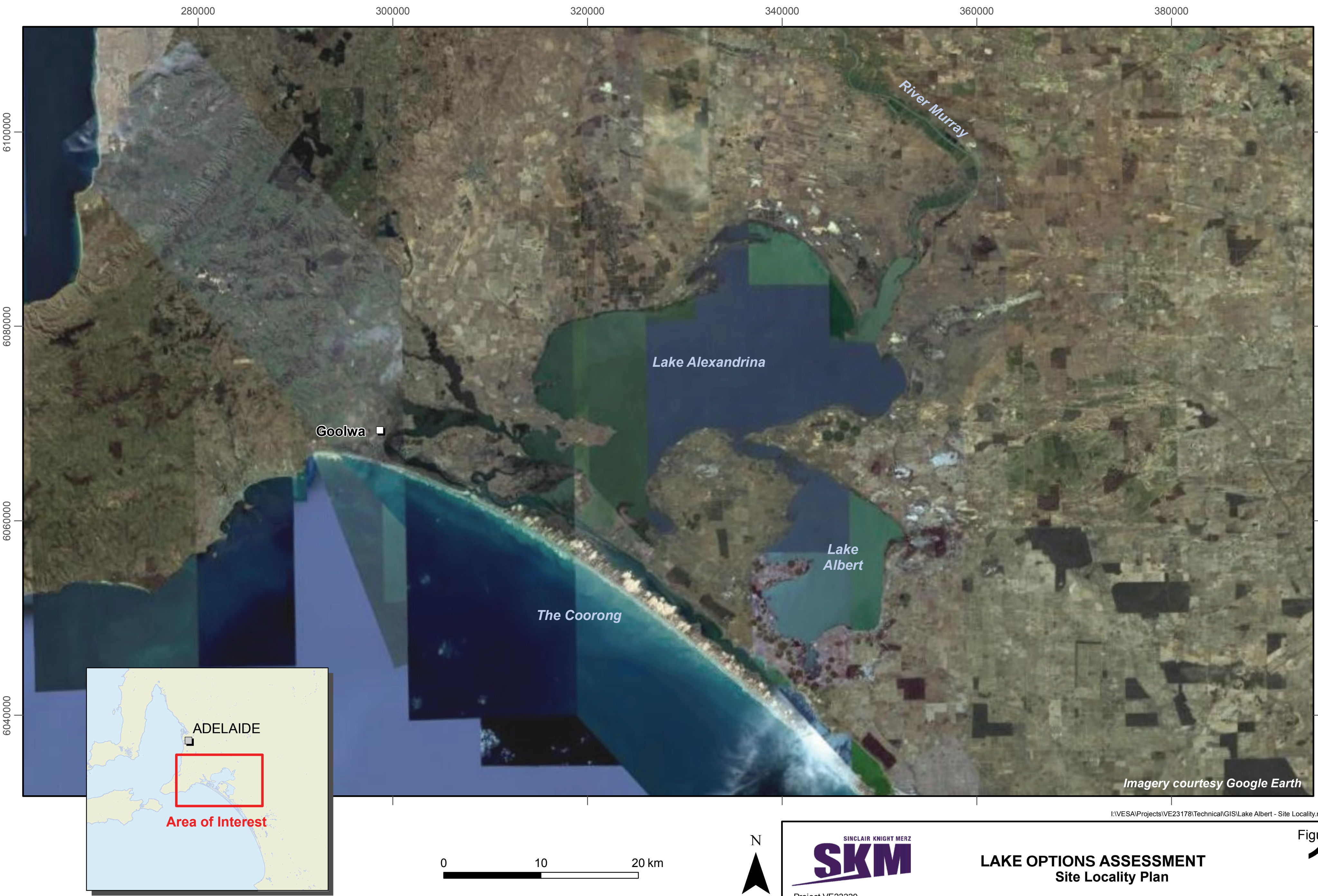
It is imperative to note that the Report only considers the site conditions current at the time of assessment, and to be aware that conditions may have changed due to natural forces and/or operations on or near the site. Any decisions based on the findings of the Report must take into account any subsequent changes in site conditions and/or developments in legislative and regulatory requirements. SKM accepts no liability to the Client for any loss and/or damage incurred as a result of a change in the site conditions and/or regulatory/legislative framework since the date of the Report.

The Report is based on an interpretation of factual information available and the professional opinion and judgement of SKM. Unless stated to the contrary, SKM has not verified the accuracy or completeness of any information received from the Client or a third party during the performance of the services under the Agreement, and SKM accepts no liability to the Client for any loss and/or damage incurred as a result of any inaccurate or incomplete information.

The Report is based on assumptions that the site conditions as revealed through selective sampling and / or modelling are indicative of conditions throughout the site. The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and (to the best of our knowledge) they represent a reasonable interpretation of the current conditions on the site. However, these interpretations and assumptions cannot be substantiated until specifically tested and the Report should be regarded as preliminary advice only.

Any reliance on this report by a third party shall be entirely at such party's own risk. SKM provides no warranty or guarantee to any third party, express or implied, as to the information and/or professional advice indicated in the Report, and accepts no liability for or in respect of any use or reliance upon the Report by a third party.

Figures



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SINCLAIR KNIGHT MERZ
SKM
Project VE23239

LAKE OPTIONS ASSESSMENT
Site Locality Plan

Figure
1

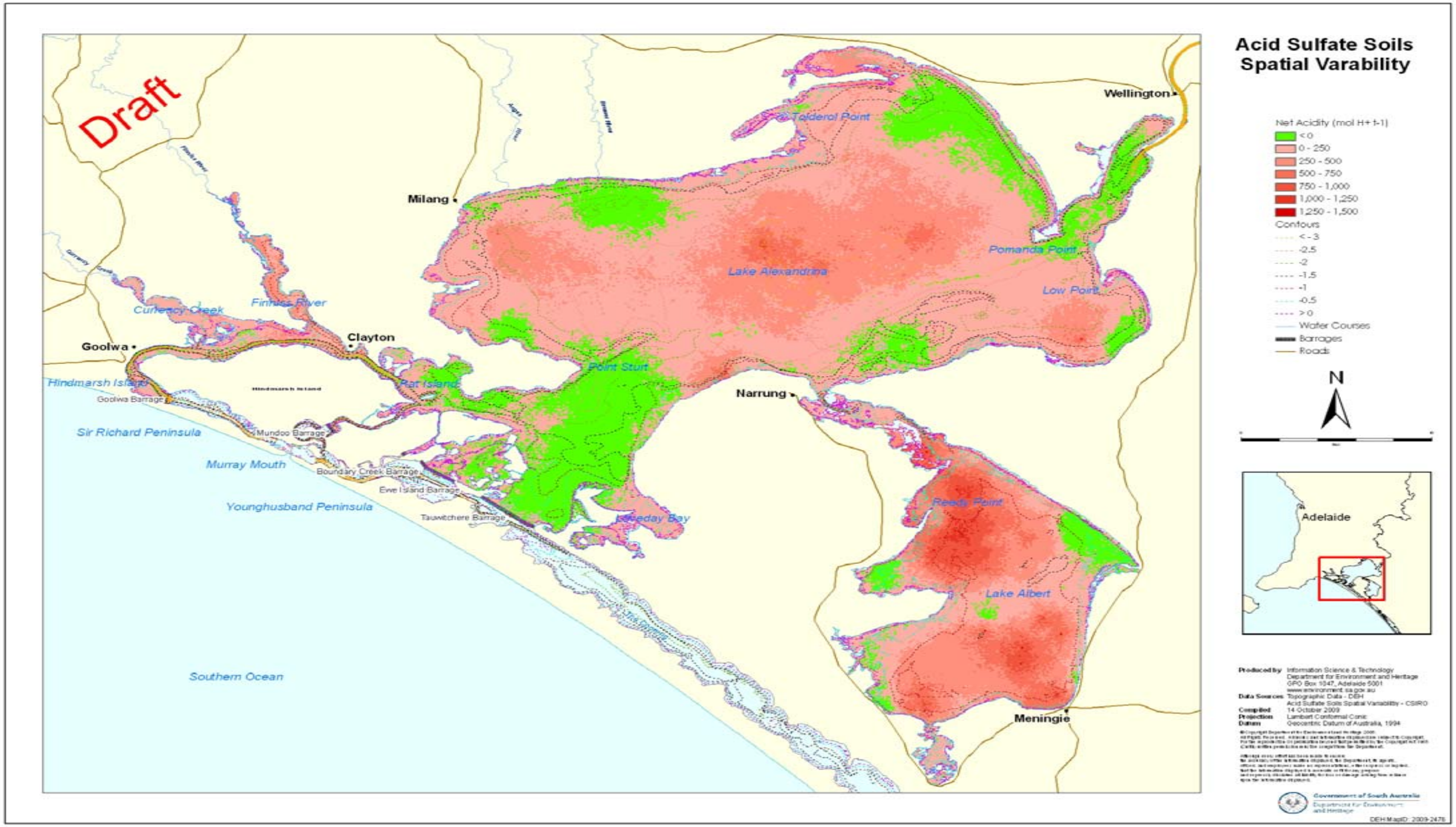

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FIGURE

Lower Lakes Alternative Options Analysis - Lower Lakes Net Acidity (after Grealish et al., 2009)

F2

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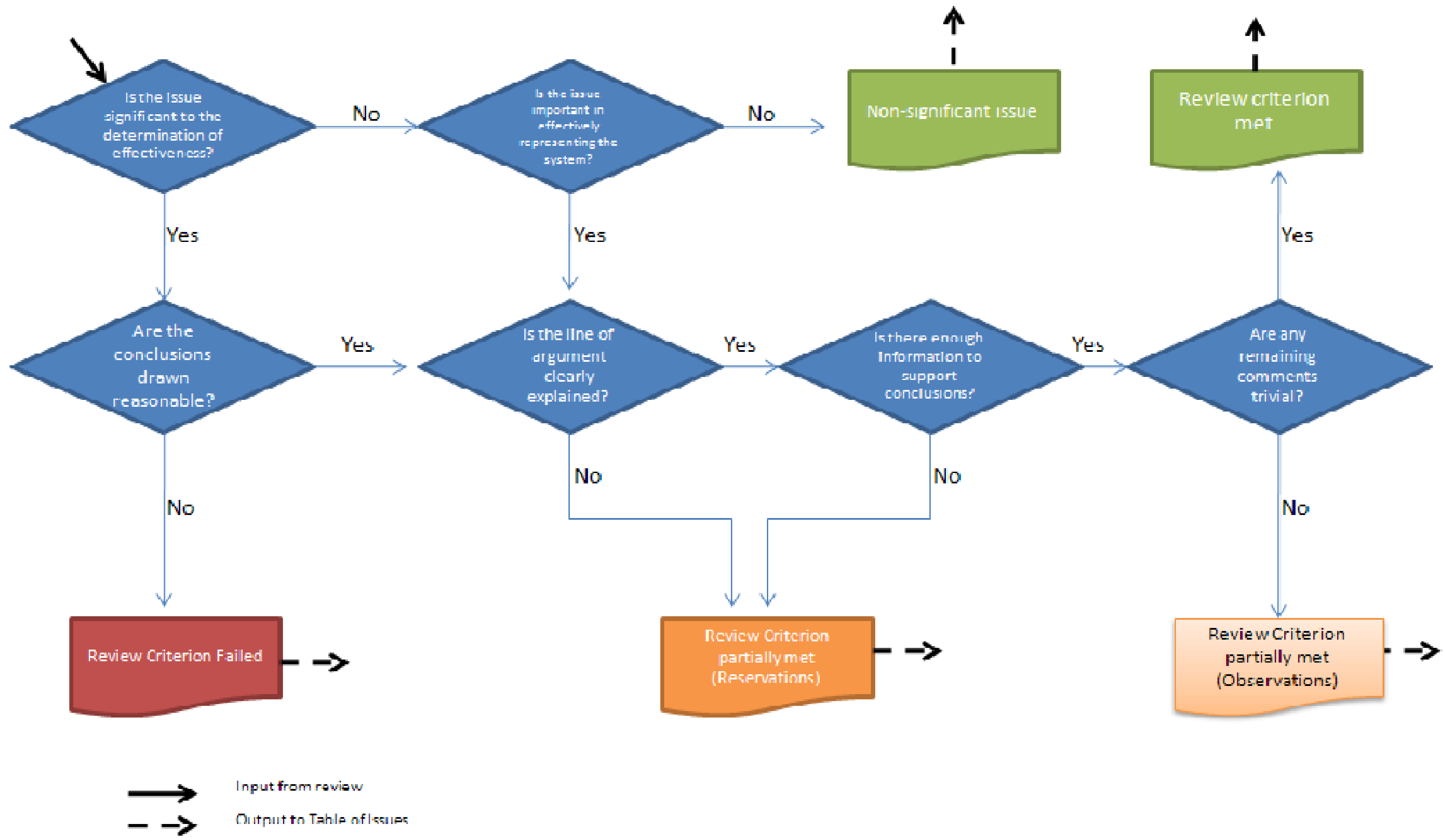

SKM SINCLAIR KNIGHT MERZ

Lower Lakes Alternative Options Analysis - Issue Decision Process

FIGURE

F3

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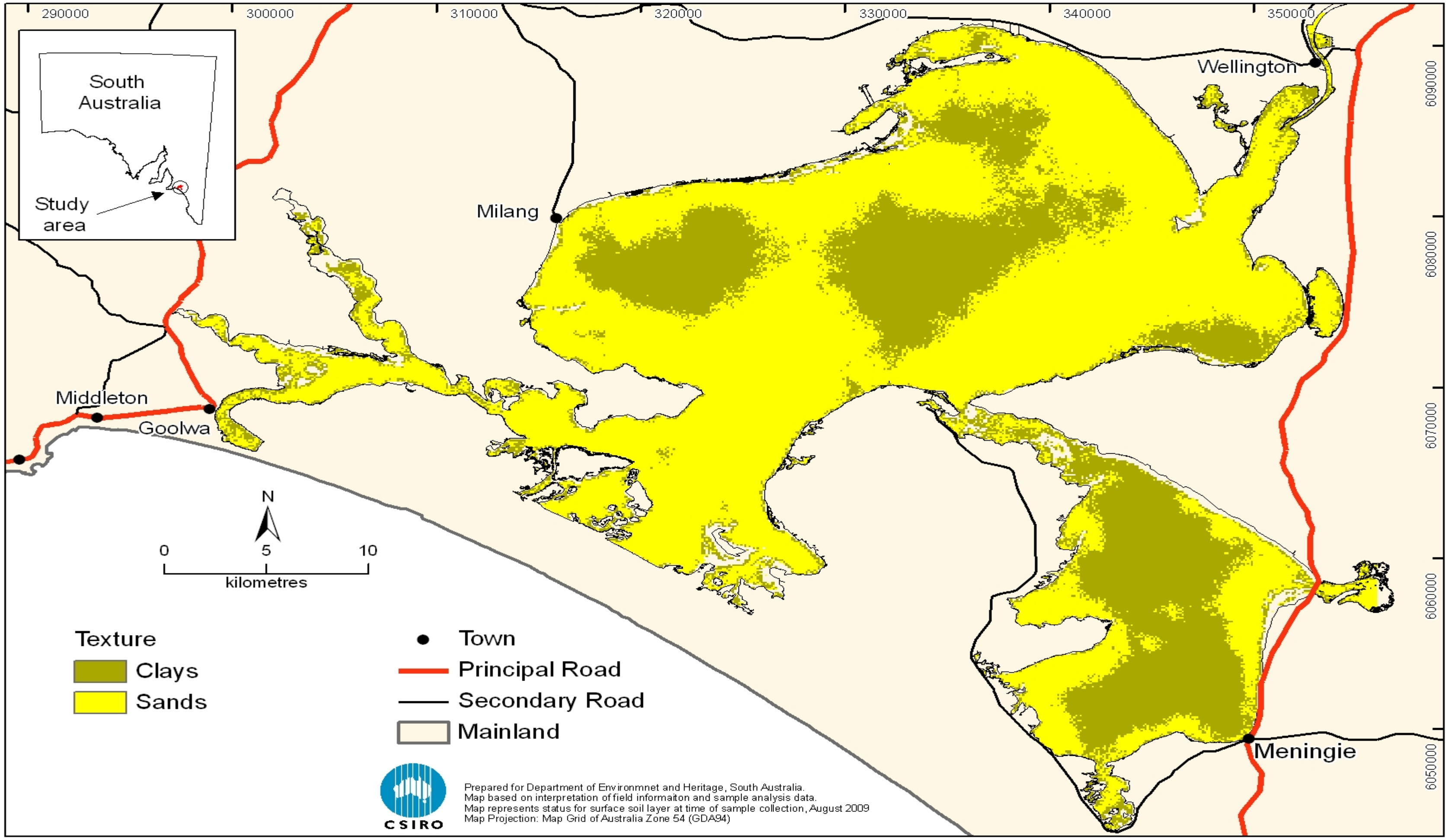

SINCLAIR KNIGHT MERZ SKM

Lower Lakes Alternative Options Analysis - Soil Texture (after Grealish et al., 2009)

FIGURE

F4

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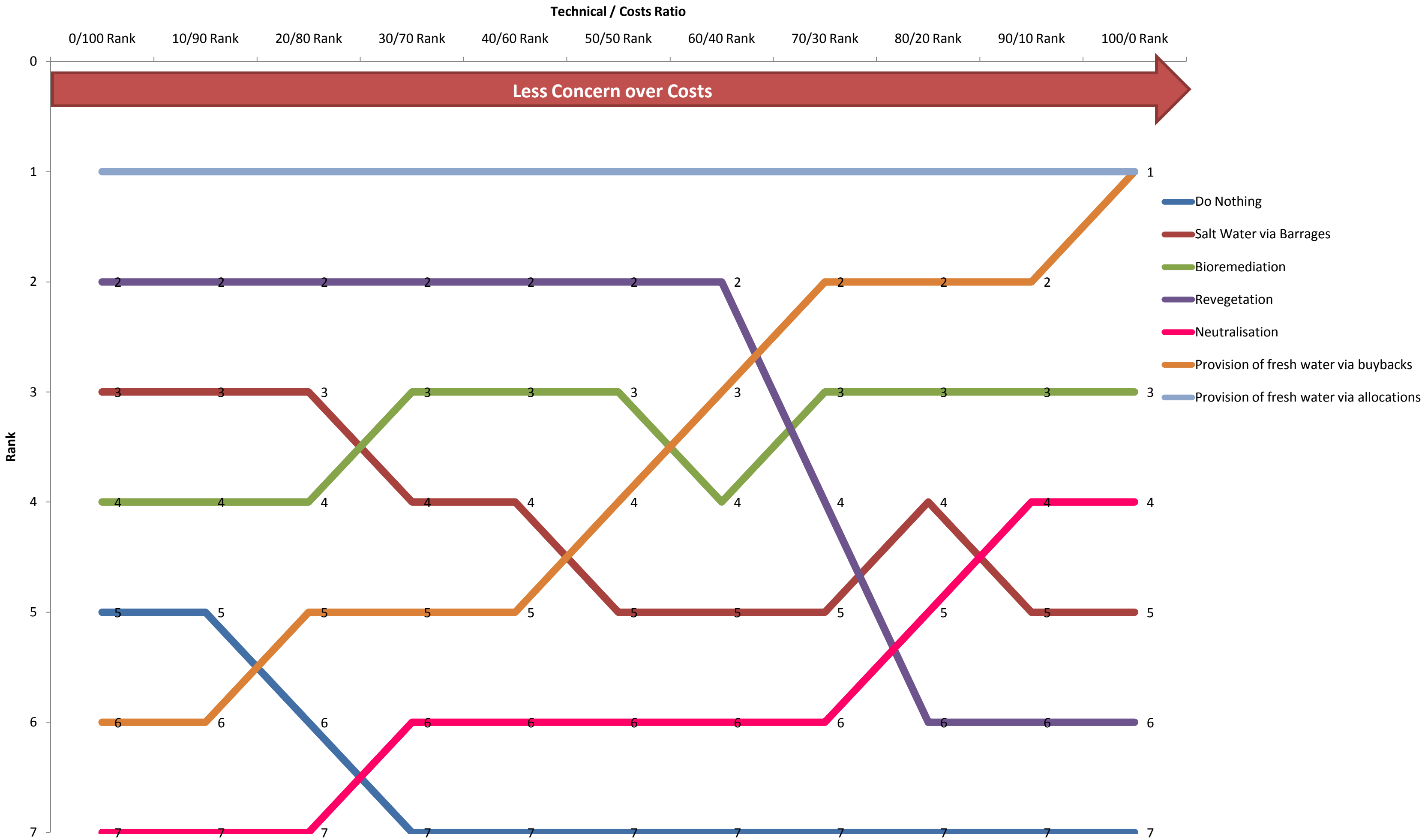

Please note that this figure is provided as a summary only and should not be used out of context from the accompanying text. This figure should not be used for decision making purposes and is a result of preliminary assessment of option s only.

Illustration Purposes Only

SKM SINCLAIR KNIGHT MERZ

Lower Lakes Alternative Options Analysis - Contribution Ranking Scale of Options based on technical / practical feasibility and high level cost assumptions - Entire System

FIGURE

F5

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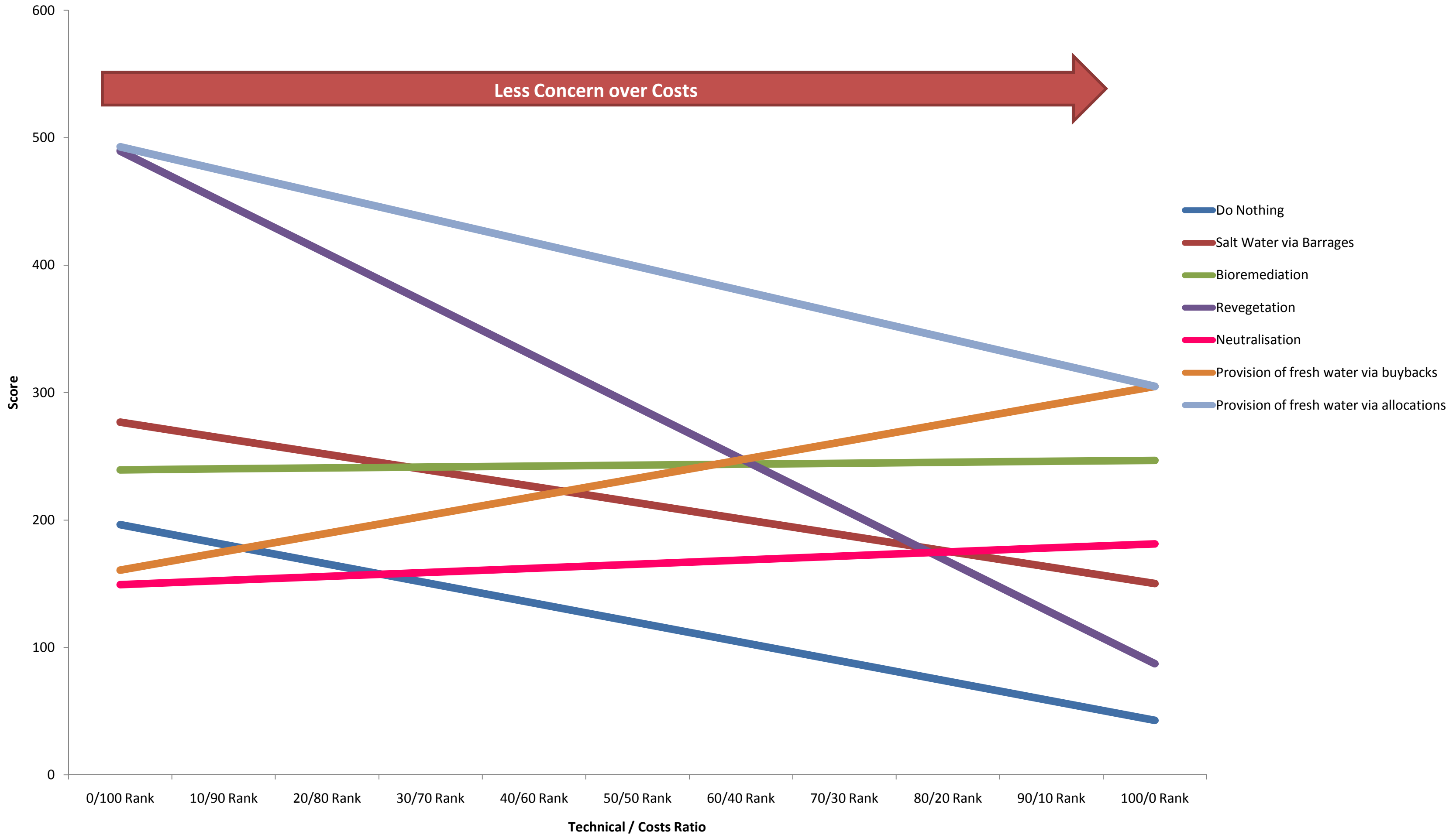

Please note that this figure is provided as a summary only and should not be used out of context from the accompanying text. This figure should not be used for decision making purposes and is a result of preliminary assessment of option s only.

Illustration Purposes Only

SINCLAIR KNIGHT MERZ SKM

Lower Lakes Alternative Options Analysis - Contribution Scoring Scale of Options based on technical / practical feasibility and high level cost assumptions - Entire System

FIGURE

F6

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Please note that this figure is provided as a summary only and should not be used out of context from the accompanying text. This figure should not be used for decision making purposes and is a result of preliminary assessment of option s only.

Illustration Purposes Only

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Lower Lakes Alternative Options Analysis - Contribution Ranking Scale of Options based on technical / practical feasibility and high level cost assumptions - Local Scale

FIGURE

F7

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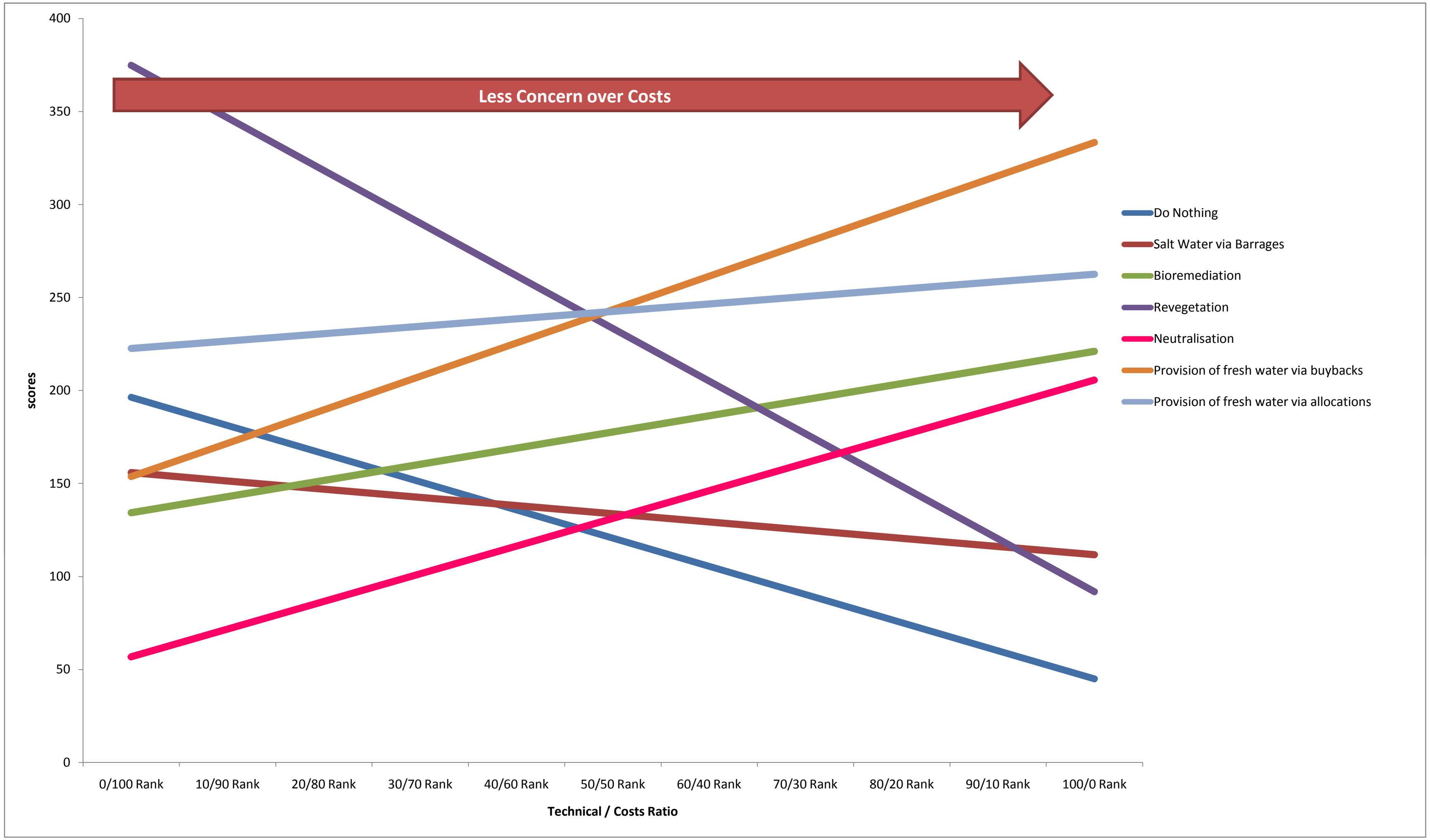

Please note that this figure is provided as a summary only and should not be used out of context from the accompanying text. This figure should not be used for decision making purposes and is a result of preliminary assessment of option s only.

Illustration Purposes Only

SINCLAIR KNIGHT MERZ SKM

Lower Lakes Alternative Options Analysis - Contribution Scoring Scale of Options based on technical / practical feasibility and high level cost assumptions - Local Scale

FIGURE F8

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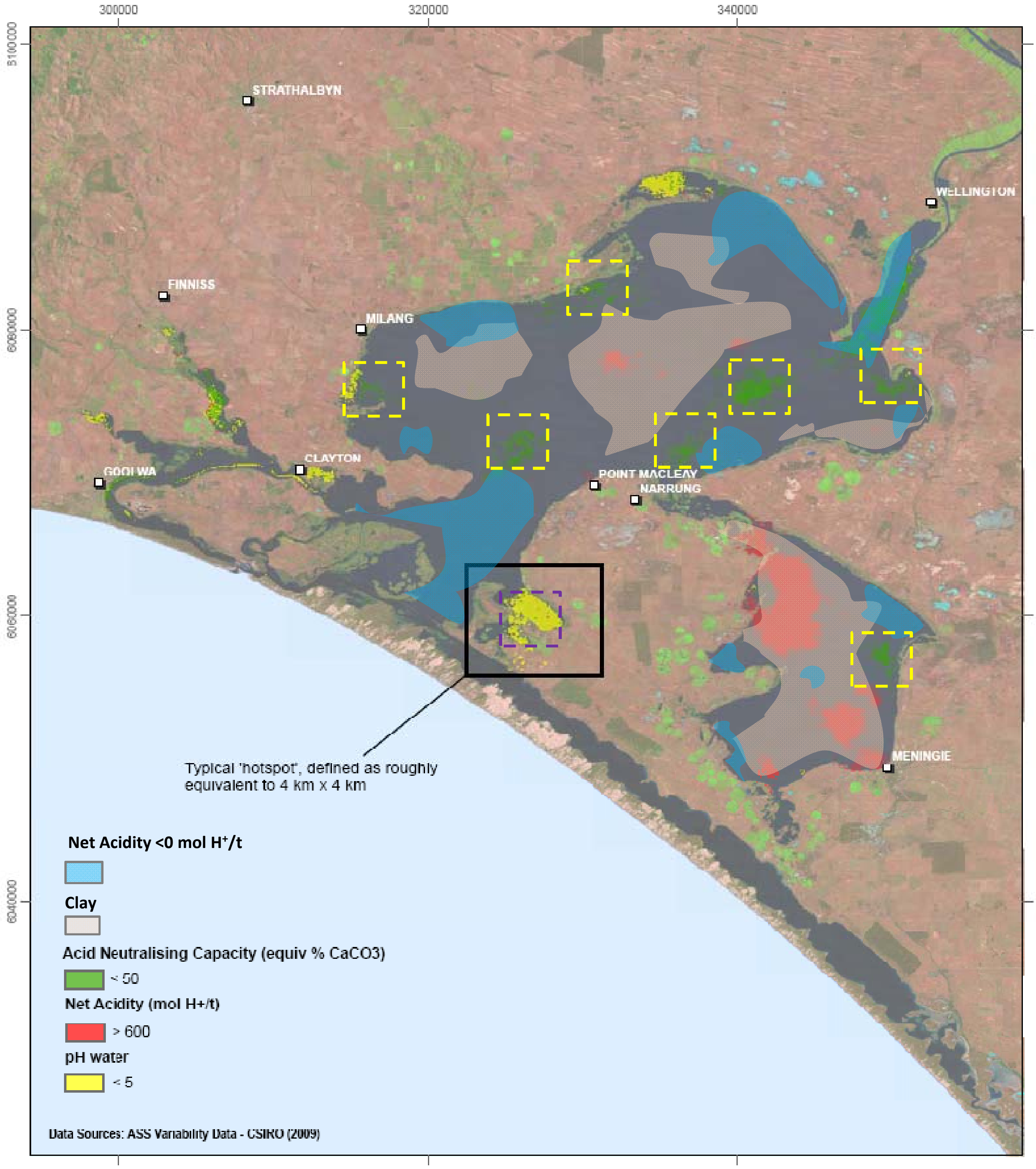
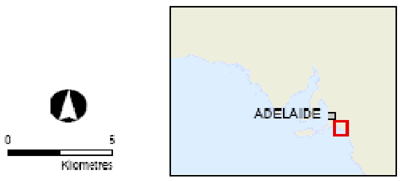


Approximate 16km² management area of sand lithology potentially demonstrating low net acidity (i.e. < 50 mol H⁺ / t) - based on presence of low acid neutralising capacity.



SKM

Lower Lakes Alternative Options Analysis
Hotspot Management - Sands with Low Net Acidity

FIGURE

F9

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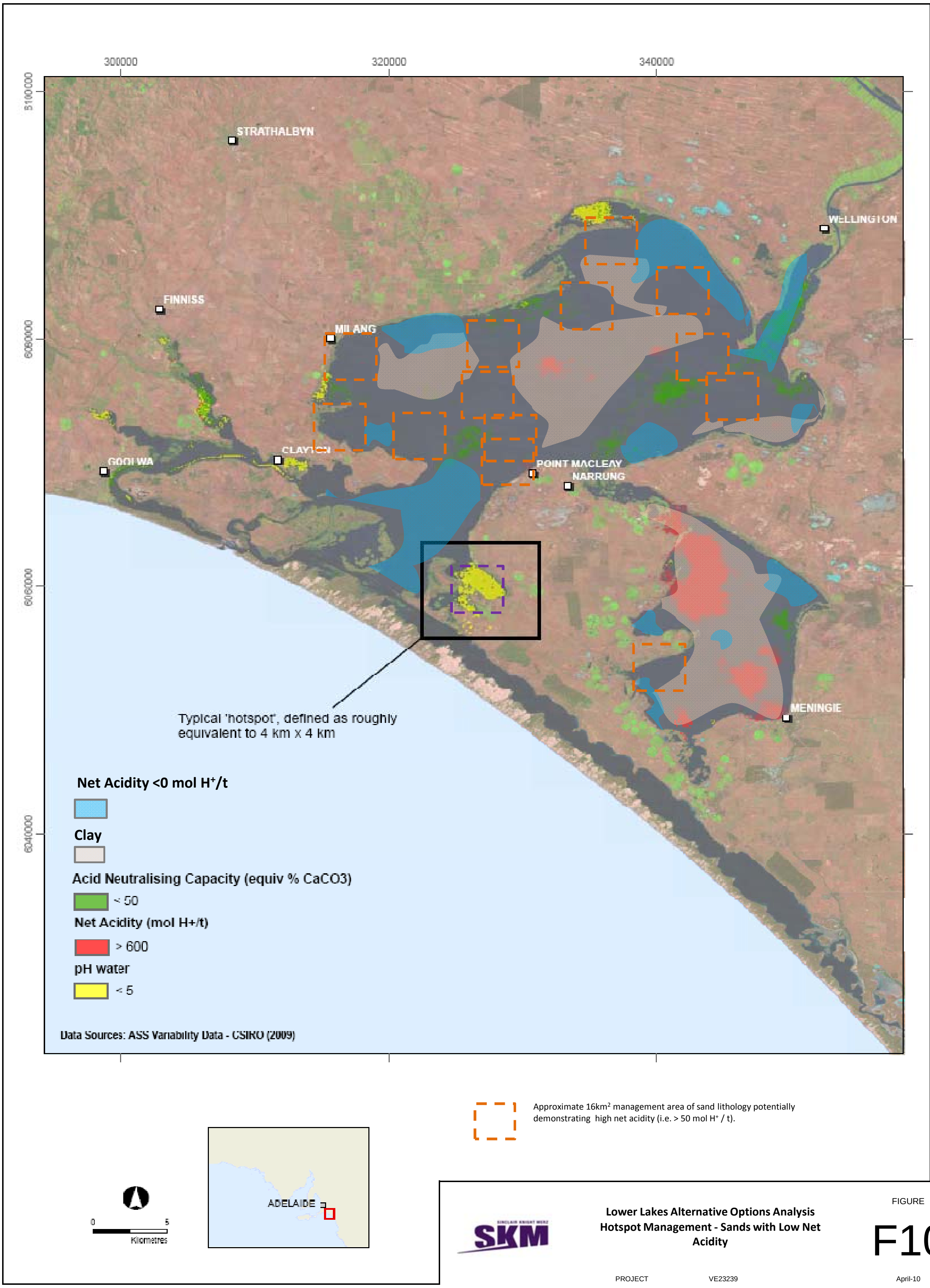

SKM

Lower Lakes Alternative Options Analysis
Hotspot Management - Sands with Low Net Acidity

FIGURE
F10

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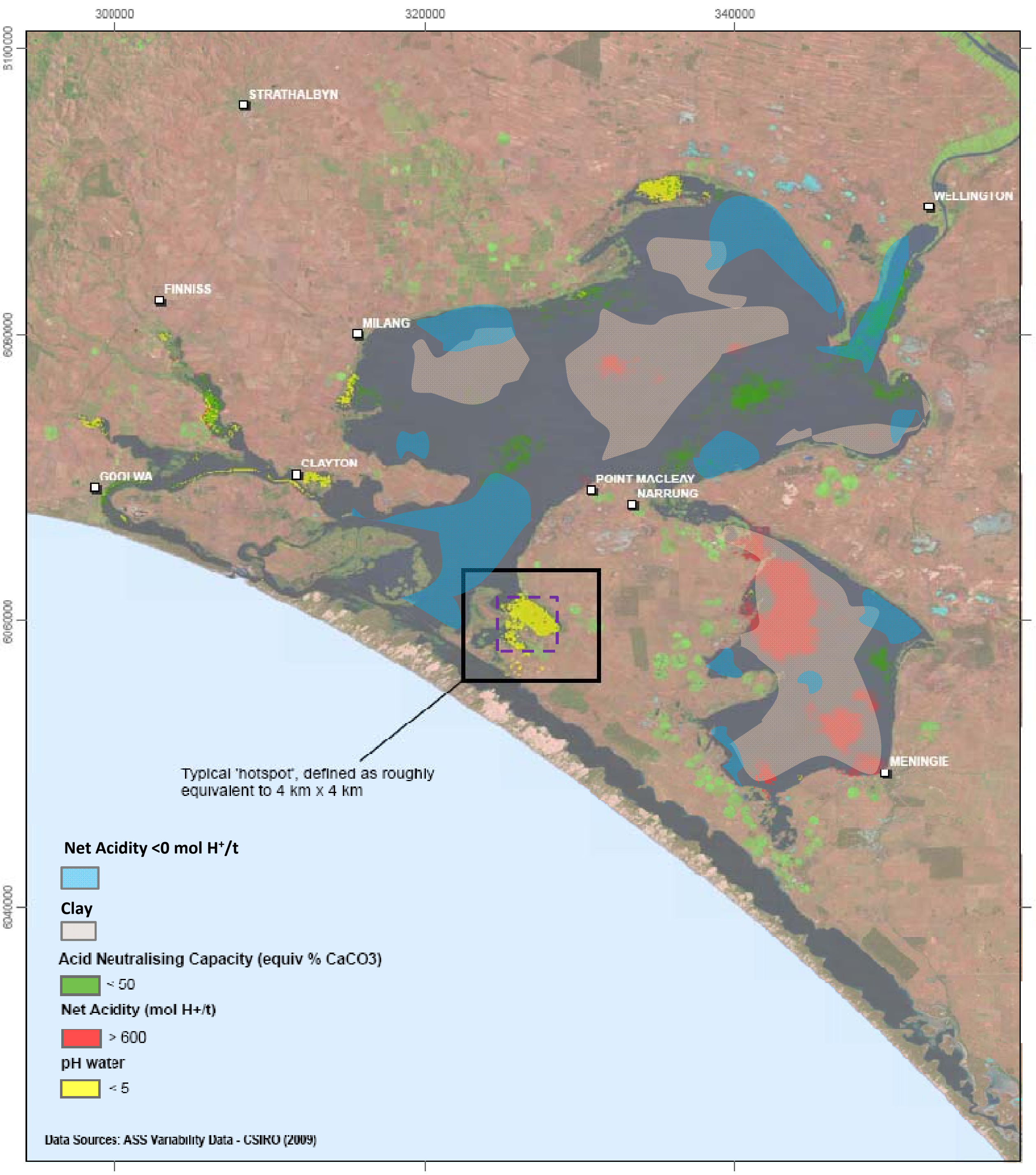
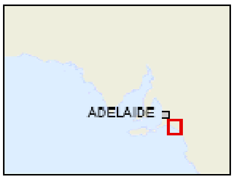
April-10



Approximate 16km² management area of clay lithology potentially demonstrating low net acidity (i.e. < 50 mol H⁺ / t).

0 5
Kilometres



SKM

Lower Lakes Alternative Options Analysis
Hotspot Management - Clays with Low Net Acidity

FIGURE

F11

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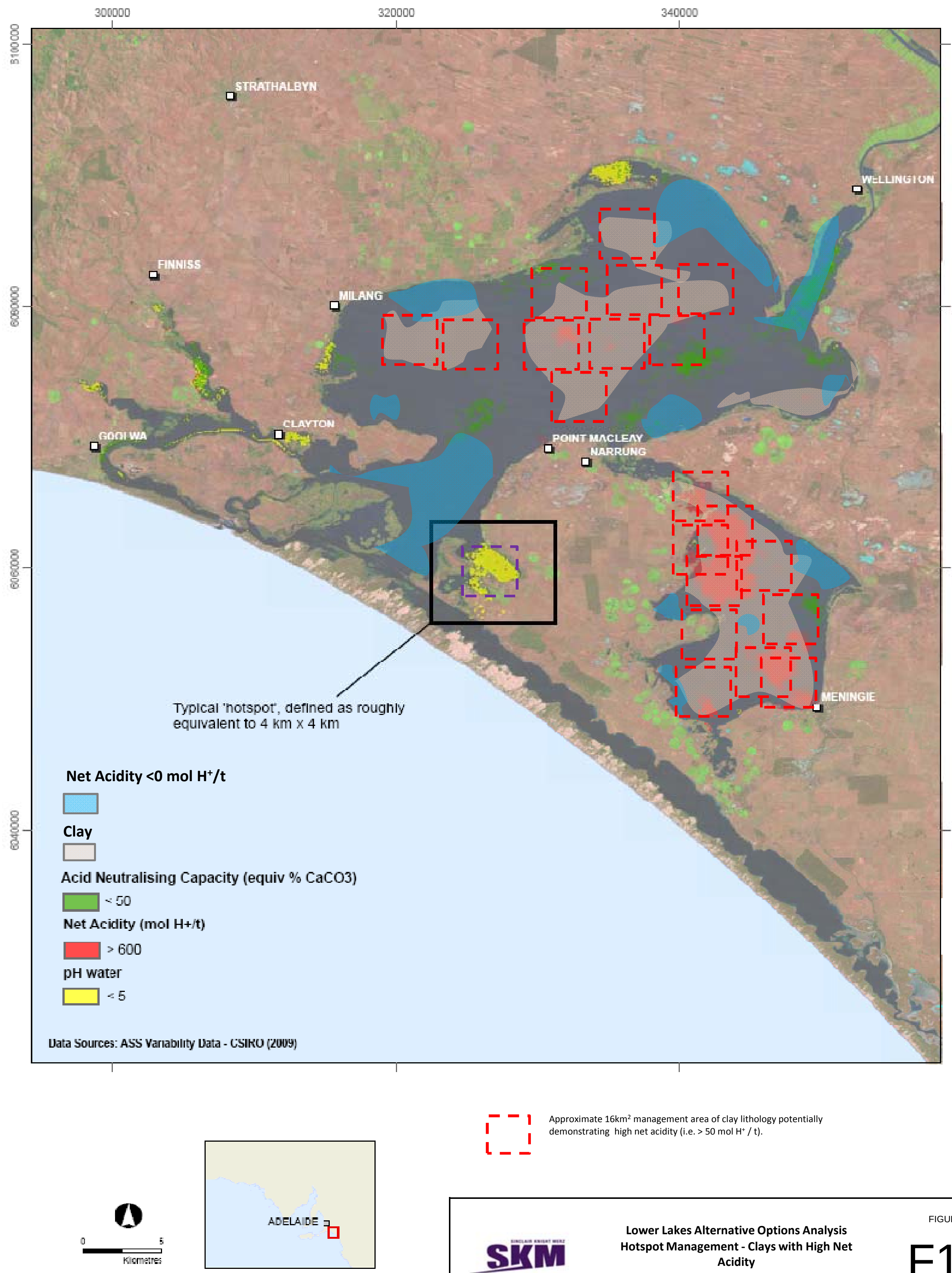
April-10



Approximate 16km² management area of clay lithology potentially demonstrating high net acidity (i.e. > 50 mol H⁺ / t).

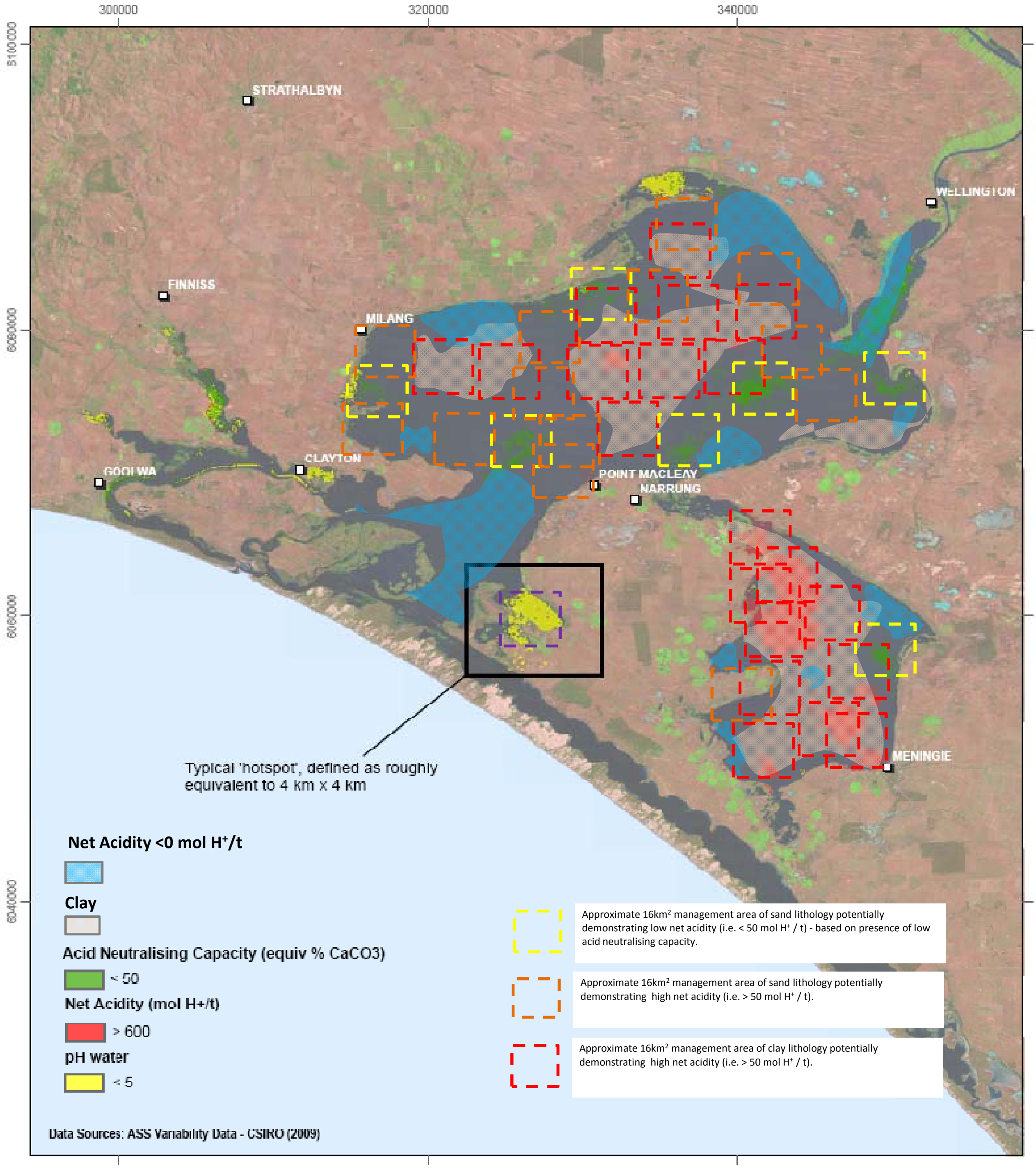
SKM

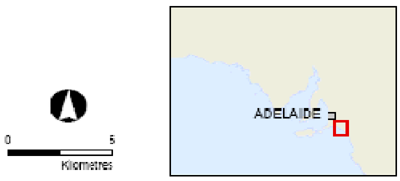
Lower Lakes Alternative Options Analysis
Hotspot Management - Clays with High Net Acidity

FIGURE
F12

PROJECT VE23239

April-10





SKM

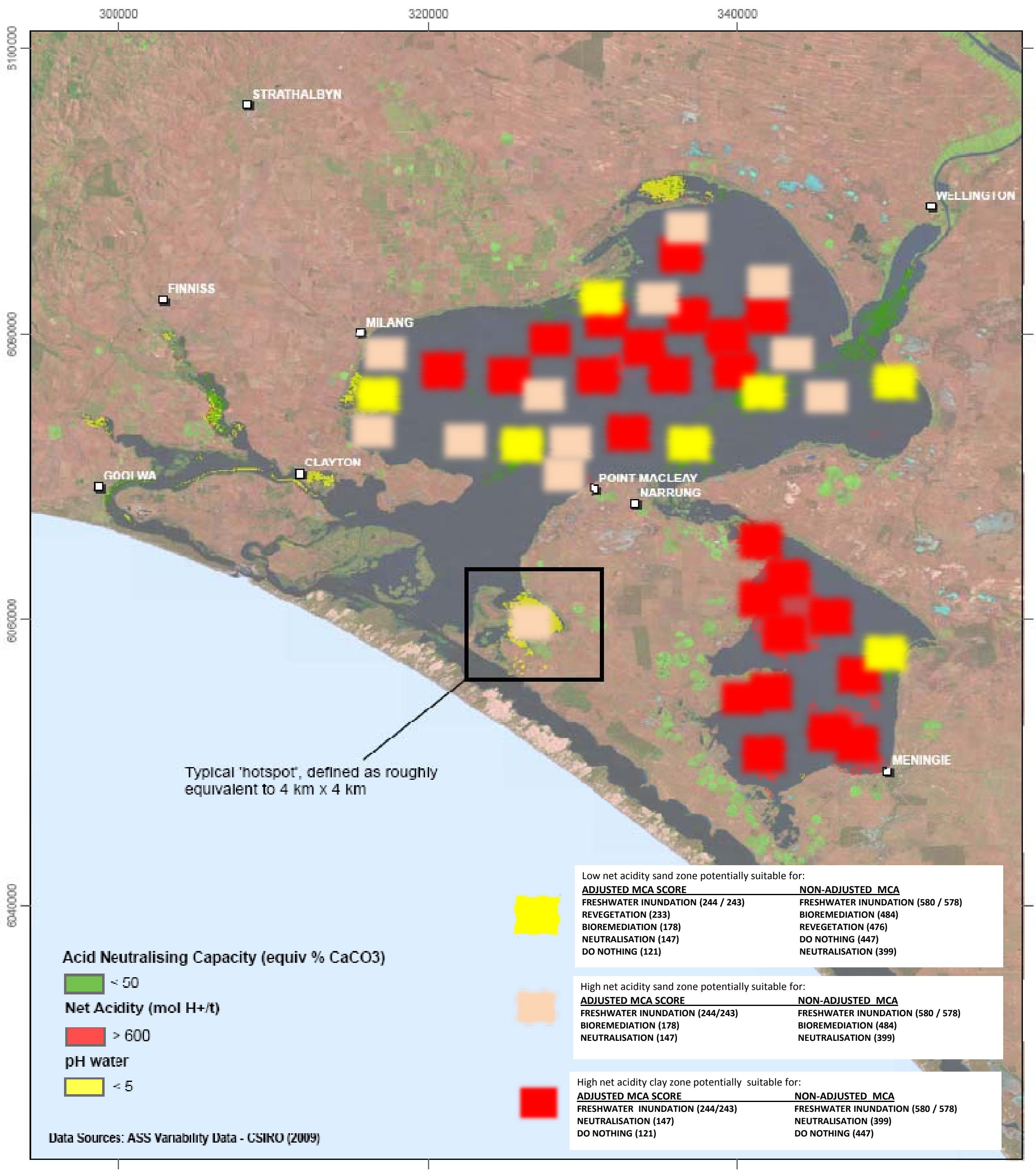
Lower Lakes Alternative Options Analysis
Hotspot Management - Composite of Management Zones

FIGURE

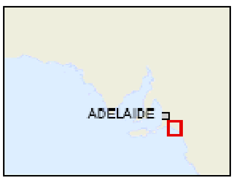
F13

PROJECT VE23239

April-10



Note that the options scores given are based on 50/50 technical / cost contribution. Inundation of sediments with seawater has not been included due to the considered risk of acid mobilisation following rewetting, based on numerous field and laboratory studies. This figure is provided as a summary only and should not be used out of context from the accompanying text. This figure should not be used for decision making purposes and is a result of preliminary assessment of options only.



0 5 Kilometres

SKM

Lower Lakes Alternative Options Analysis
Hotspot Management - Potential Management Options

FIGURE F14

PROJECT VE23239

April-10

Appendices

▪ Appendix A - SMART Interpretation of Options

SMART Options Interpretation

Option	Team Discussion Points	SMART
Do nothing option		
Specific	• Assumes no remedial action is taken; • Barrage operations continue as normal (under current operating rules for the drought conditions); • No additional weir structures are constructed – what about Pomander Island? (Wellington Weir) and also Clayton Regulator?	No active preventative management measures will be undertaken to address environmental acidification of the lower lakes, assuming that the Wellington Weir and the Clayton regulator will both be in place and operational.
Measureable	Potentially difficult to measure as many preventative actions have been implemented – such as pumping stopped into Lake Albert, weirs in place Currency/Finniss?	Measurable for this option include: • Water quality (lake health) • Soil pH
Achievable		Considered to be achievable
Relevant	Incorporates issues surrounding ecology, water quality and water chemistry. Does it also include visual and aesthetics (i.e. odour generation) Clarify extent of study area – To include Lake Alexandria, Lake Albert to the extent of the Barrages. Does not include the Coorong. Does it include Finniss and Currency Creek?	This is considered a control option and therefore is relevant to the environment.
Time bound	Should this take into account the D Day when acidification occurs?	Option span is indefinite here as no active management is being considered.

SMART Options Interpretation

Bio remediation		
Specific	Bioremediation refers to management approaches that aim to promote microbial activity (sulphate-reducing bacterial activity) in order to convert dissolved sulphate to sulphide minerals, while consuming acid. This essentially reverses the pyrite/iron monosulfide oxidation reactions that generated acidity in the first place. Essentially bioremediation involves promoting naturally occurring bacteria to return contaminated environments to a healthy state.	Bioremediation represents management approaches that aim to promote microbial activity (sulphate-reducing bacterial activity) via addition of organic matter in order to convert dissolved sulphate to sulphide minerals, while consuming acid.
Measureable	Specify Monitoring in relation to pH, vegetation and bio-remedial processes	Measurable include the standard criteria for water health plus the following: • Soil physics • Soil geochemistry • Soil microbiology
Achievable		Assumed to be achievable.
Relevant	Clarify extent of study area	Assumed to be relevant.
Time bound	Should this take into account the D Day when acidification occurs?	Proof of effectiveness prior to determined date of system acidification.

SMART Options Interpretation

Re-vegetation		
Specific	Below taken from Study 6 In the context of this project *revegetation* is the term used for covering with vegetation the soils affected by lack of water within the Lower Lakes system. The revegetation may include local native plant species, exotic annuals or exotic perennials identified as effective in covering soils to assist in the bioremediation of the area. Although biodiversity is extremely important in this region, the revegetation that is proposed does not have the sole purpose of improving biodiversity. Rather, the primary purpose of the initial revegetation is to provide ecosystem stability or resilience by immediate soil cover, stabilising moving sand to reduce the impacts on the natural ecosystem, individuals and communities. These actions are likely to have an effect on reducing soil acidification by assisting to maintain soil moisture in the short-term, and by providing longer-term benefits as part of a bioremediation process.	The revegetation option aims to stabilise the soils and prevent soil erosion around the Lower Lakes whilst also being effective in the management of acid sulfate soils in terms of minimising oxygen diffusion in the soil while water uptake by the plant reduces infiltration of water into the underlying minerals. Organic litter that eventually builds up also helps to buffer large fluctuations in water and oxygen movement into and out of the soil, so that cracking of soils and oxygen penetration is reduced.
Measurable		It is considered that the standard criteria of water health is required, plus the following: • Soil physics • Plant ecology (i.e. biomass survey) • Soil geochemistry
Achievable		Assumed to be achievable
Relevant		Assumed to be relevant
Timebound		Proof of effectiveness prior to determined date of system acidification.

SMART Options Interpretation

Neutralisation		
Specific	Rephrase to capture neutralisation process. Processes which act to increase alkalinity To include, but not limited to the following techniques: Limestoning...... Include soil and/or water column	The addition of a neutralising agent that is capable of buffering acid generated in the subsurface as a result of pyrite oxidation. This option includes the various types of neutralising agents available: • Limestone (dry, fine) • Limestone slurry • Caustic soda (NAOH)
Measureable	In relation to average pH over a certain area (as surely there will be a degree of variation depending on environmental conditions) Specify pH Monitoring	It is considered that the standard criteria would be required, plus the following criteria: • Localised monitoring where lime is applied (soil and groundwater)
Achievable		Assumed to be achievable
Relevant	Clarify extent of study area	Assumed to be relevant
Time bound	Should this take into account the D Day when acidification occurs?	Proof of effectiveness prior to determined date of system acidification.

SMART Options Interpretation

Provision of freshwater (via water purchase and/or re-allocation);		
Specific		
Measureable	Is there a quantity we need to cover off on? Clarify extent of inundation – is it to completely inundate, saturate soils, or combination of both depending on area of lower lakes. Specify Monitoring – stage boards?	The sediments identified as being potentially acid sulphate generating would be saturated (not necessarily inundated) with freshwater to maintain a low redox environment and prevent pyrite oxidation. Freshwater would be resourced from the following sources: • Water purchase; • Re-allocation of current licenses not required / used; • Provision of groundwater resources to provide saturation.
Achievable		Assumed to be achievable
Relevant	Clarify extent of study area	Assumed to be relevant
Timebound	Should this take into account the D Day when acidification occurs?	Proof of effectiveness prior to determined date of system acidification.

SMART Options Interpretation

Inundation of Lower Lakes with Saltwater		
Specific	Define extent of inundation and process of managing the barrages	Although the intent is to maintain fresh water in the Lower Lakes, if water levels and water quality drop below a critical point and acidification is imminent then allowing sea water into the Lower Lakes will need to be considered. This would not involve flooding the Lower Lakes with sea water, but allowing just enough water through the barrages to maintain the level of Lake Alexandrina above the trigger level of -1.5 metres below sea level.
Measureable	Specify Monitoring – stage boards?	Measurable are water quality and water levels
Achievable		Assumed to be achievable
Relevant		Assumed to be relevant
Time bound	Rainfall System allocation Lag time in system storage?	Until system returns to long term ‘stable’ natural conditions (i.e. cessation of drought conditions).

SMART Options Interpretation

Inundation of Lake Albert (exclusively) with Saltwater		
Specific	Define extent of inundation and process of managing the barrages	Although the intent is to maintain fresh water in the Lake Albert, if water levels and water quality drop below a critical point and acidification is imminent then allowing sea water into the Lake will need to be considered. This would not involve flooding the Lake with sea water, but allowing just enough water into the Lake to maintain the level of the Lake above the trigger level of -1.5 metres below sea level. The transfer of water into Lake Albert would be achieved via • pumping of water from the Coorong, or • establishment of a channel from the Coorong to the Lake
Measurable	Specify Monitoring – stage boards?	Measurable are water quality and water level
Achievable		Assumed to be achievable
Relevant		Assumed to be relevant
Time bound	Lag time in upper system storage? GL influx	Until system returns to long term 'stable' natural conditions (i.e. cessation of drought conditions)

Appendix B - Weighting Justification

Criteria Weighting Justification

Assessment Criteria	Weighting identified in MCA Tables	Criteria True Weighting %*	Justification
4 - Technically feasible and achievable in practice on the scale required	50	50	
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10	5	A low weighting has been attributed to this criterion due to the potentially large gap between theory and practical implementation of a particular option.
A - Option is theoretically viable	25	1.25	A low weighting has been attributed to this sub-criterion due to the potential large number of unknown variables involved in treating a system as complex as the Lower Lakes. An option which may be theoretically viable, yet cannot be proven to work presents a high risk action to address the potential acidification impacts.
B– Theoretically viable on the scale (spatial) required	75	3.75	Due to the large scale of the Lower Lakes environment, encompassing high spatial complexity, an option which can theoretically be implemented on the scale required has been attributed a higher allocation of this sub-criterion.
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45	22.5	A high weighting allocation has been attributed to this sub criterion where an option can be proven to address the potential acidification impacts.
A - Generic Proof of Concept established	15	3.375	This component of the sub-criterion receives a low weighting, due to the complexity of issues and spatial scales involved for the Lower Lakes system.
B - Proof of Concept established in similar (representative) environments	35	7.9	A moderate weighting has been allocated to this sub-criterion where an option has been proven to be success in addressing acidification in a similar environment. Some reservations remain due to the complexities and unique environments found within the Lower Lakes.
C – Proof of concept established in Lower Lakes circumstances	50	11.3	A high weighting has been allocated to this sub-criterion, where clear proof that an option has successfully addressed acidification in sections of the Lower Lakes, which can be confidently predicted to be practicable on the scale required.

4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45	22.5	Trigger acidification levels within sections of the Lower Lakes are anticipated to lead to further complexity surrounding implementation and the success of some of the options. In many cases, acidification may negate the success of an option, or lead to significant environment impacts. A high weighting has thus been attributed to capture the importance of these timeframes.
A1 – on a large scale	65	14.6	This sub-criterion has been attributed the highest relative weighting within criteria 4. Where an option can be implemented successfully before acidification occurs is considered the most important criterion with respect to an options' feasibility.
A2 – on a localised scale	35	7.9	A moderate weighting has been attributed to this sub-criterion to capture instances where an option may only be successfully implemented on a small scale within the Lower Lakes. As acidification risks often occur on a localised scale within the Lower Lakes, this would allow hotspot management to occur, using an option, or combination of options.
8 - Costs to Government (State or Federal)	50	50	
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70	35	Predicting life cycle costs is a significant factor in scoring each option. Costs are identified in 'orders of magnitude'.
Capital / Establishment costs are minimal	40	14	The initial financial costs associated with implementing an option have been attributed a high weighting to reflect the importance of securing financial funding to implement an option.
Operational / Maintenance costs are minimal	40	14	This criterion addresses on-going costs associated with maintaining the implementation of an option. This has been attributed a relatively high weighting, to reflect options which may have significant operational costs. This includes options which are considered 'reactive', such as the neutralisation option, where implementation occurs in combination with a continual monitoring program to identify when and how best to maintain a desired pH. As such, life cycle costs are difficult to accurately identify for reactive options.
Decommissioning costs are minimal	20	7	A moderate to low weighting has been attributed to this criterion weighting, which captures recoverable costs (such as re-saleable infrastructure) and direct costs associated removal of

			infrastructure. The costs associated with returning the Lower Lakes to a defined state following implementation of an option are not considered as part of this criterion. This weighting captures the lesser importance of decommissioning an option in life cycle cost planning and to reflect its lower relevance with respect to how government bodies secure funding to implement an option.
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30	15	
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60	9	Options which require resources to be sourced and transported to the Lower Lakes Region are assessed within this component. A moderate to high weighting has been attributed to identify significant external environmental impacts resulting in the implementation of an option. This assessment component considers physical impacts, such as mining/quarrying activities, together with the carbon footprint associated with transporting resources, such as pipeline and pumping infrastructure. This criterion also considers where an option impacts upon an environment where resources are no longer available, such as restricting water allocations to wetlands.
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40	6	A moderate to low weighting has been attributed to this criterion, which addresses beneficial outcomes of implementing an option, such as provision of water resources for tourism activities.

Key:

Main Criteria	
Sub Criteria Tier 1	
Sub Criteria Tier 2	

*True weighting refers to actual weighting calculation, presented as an actual percentage for Criteria 4 and 8.

Appendix C - Decision Confidence Assessment

Appendix C. - Summary of Confidence Determination

Assessment Criteria	Confidence Score Summary Justification		
	Low (0.5)	Moderate (0.75)	High (1)
4 - Technically feasible and achievable in practice on the scale required			
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)			
A - Option is theoretically viable	Limited information available, significant data gaps evident, draft findings only, significant limitations to study identified.	Documented evidence (generally excluding peer reviewed journal/documents) with reasonably sound scientific rigour applied to study. Some data gaps and limitations identified.	Study documented within a peer reviewed journal/document, sound scientific rigour, limited information gaps and absence of significant limitations.
B– Theoretically viable on the scale (spatial) required	As noted above, with significant data gaps relating to scalability	As noted above, with some limitations identified regarding scalability.	As noted above, with detailed information/ feasibility studies undertaken to identify scalability associated with implementing an option.
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)			
A - Generic Proof of Concept established	Limited or no information available, significant data gaps evident, only draft findings available, significant limitations to study identified.	• Documented evidence (excluding peer reviewed journal/documents) or draft document with reasonably sound scientific rigour applied to study. Some data gaps and limitations identified. • Study not identified, yet reasonable possibility it may have been undertaken and has not been sourced, as deemed by the study team.	Option documented within a peer reviewed journal/document, sound scientific rigour applied, limited information gaps and absence of significant limitations.
B - Proof of Concept established in similar (representative) environments	• Limited applicability of option to the Lower Lakes, although study may include proof of concept of acid sulphate treatment, e.g. within a	Draft findings only available at the time of assessment, studies with limitations or data gaps, studies undertaken in wetland environment (including lake environments), although in a distinctly	• Proof of concept established within a similar environment, such as a large shallow large, within a relatively comparable climatic region.

	terrestrial environment. • Study not identified, yet reasonable possibility it may have been undertaken and has not been sourced (as deemed by the study team).	different climatic region (e.g. acidic lakes in Scandinavia).	• Alternatively, the absence of a study can allow a high level of confidence to be attributed where no proof of concept has been established.
C – Proof of concept established in Lower Lakes circumstances	Draft findings only identified for the Lower Lakes environment. Small scale study.	Proof of concept identified for the Lower Lakes, although undertaken on a relatively small scale, with limitations present.	Proof of concept within the Lower Lakes on a reasonably scale, with no significant limitations identified. Alternatively, the absence of a study can allow a high level of confidence to be attributed where no proof of concept has been established.
4.3 - Implemented successfully before acidification of the Lakes occurs			
A1 – on a large scale	Limited or no information available or significant data gaps identified, regarding implementation of an option on a large scale.	Some information available regarding implementation of an option on a large scale. Some limitations identified, only draft study available, or data gaps identified.	Study undertaken with scientific rigour discussing implementation on a large scale. Absence of significant limitations or data gaps.
A2 – on a localised scale	Limited or no information available regarding implementation of an option on a localised scale.	Some information available regarding implementation of an option on a localised scale. Some limitations identified, only draft study available.	Study undertaken with scientific rigour discussing implementation on a localised scale. Absence of significant limitations or data gaps.
B – The Lakes can be returned to their pre-action trophic state			
C – A salinity of <1500EC is achievable in the long term			
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes			

8 - Costs to Government (State or Federal)			
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)			
Capital / Establishment costs are minimal	Detailed cost estimates are not available.	Cost estimates have been undertaken on comparable studies which can be extrapolated to some degree.	Detailed cost estimates have been prepared.
Operational / Maintenance costs are minimal	Detailed operational and maintenance costs are not available.	Operational and maintenance cost estimates have been undertaken on comparable studies which can be extrapolated to some degree	Detailed operational and maintenance costs have been prepared.
Decommissioning costs are minimal	Decommissioning costs (e.g. infrastructure and equipment) associated are not available.	• Decommissioning costs (e.g. infrastructure and equipment) cost estimates have been undertaken on comparable studies which can be extrapolated to some degree. • Draft document only available or assessment undertaken by non-recognised authority. Cost estimates undertaken by study team alone with some limitations.	Decommissioning costs (e.g. infrastructure and equipment) have been estimated by a recognised authority, or can be estimated by the study team with no significant limitations.
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)			
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	Absence of information relating to indirect costs in other environments.	Limited information, only draft information available, risks clearly identifiable by study team relating to indirect costs in other environments.	Studies undertaken to identify indirect costs to other environments by a recognised authority.
Maximises the indirect benefits experienced in the wider Lower Lakes region (eg/ tourism, agriculture, wine, lifestyle)	Absence of information relating to indirect benefits, which are not readily identifiable by the study team.	Indirect benefits identified by the study team where limited information is available.	Studies undertaken to identify indirect benefits to other environments by a recognised authority; or indirect benefits readily identifiable by the study team.

- **Appendix D - Lower Lakes Studies / Reports**

Doc ref/Hyperlink	Document Title	Corporate/ Agency Author	Year	Document Summary Description
Study 1.pdf	Acid, Metal and Nutrient Mobilisation Following Rewetting of Acid Sulfate Soils in the Lower Murray	CSIRO	2008	Acid sulphate soils: effects of re-wetting dried ASS. Results of soils testing study, including pH, and subsequent nutrient and heavy releases. Modelling results and interpretation of impacts upon ecology of Lower River Murray system.
Study 2.pdf	Acid, metal and nutrient mobilisation dynamics in response to suspension of MBOs in freshwater and to freshwater inundation of dried MBO and sulfuric soil materials	Southern Cross GeoScience (Centre for Acid Sulfate Soil Research)	2008	The acid, metal and nutrient mobilisation following rewetting of acid sulfate soils in the Lower Murray Project. Examines results of tests on Monosulfidic Black Oozes and ASS from lower lakes and mobilisation of contaminants. Specific discussion covering nutrients, metals and metalloids, and individual reactions to scenarios of ASS tests. No discussion of ecological impacts.
Study 3-Earth Systems.pdf	Acid sulfate soil (ASS) management strategy for Currency Creek, Finiss River and Goolwa Channel, and project critical work program for ASS management in the Lower Murray Lakes	Earth Systems	2009	Proposed approach/management strategy for the avoidance, minimisation and control of acid generation from acid sulfate soils for Currency Creek, Finniss River and Goolwa Channel. Builds upon previous feasibility studies by Earth Tech.
Study 4.pdf	Acid sulfate soils in subaqueous, waterlogged and drained soil environments in Lake Albert, Lake Alexandrina and River Murray below Blanchetown (Lock 1): properties, distribution, genesis, risks and management	CSIRO	2008	Explanation and predictions of ASS, prediction of impacts of further drought on ASS formation and decline in water quality, development of remediation and management options for specific ASS environments.
Study 5.pdf	Hydrodynamic and water quality model for the Lower River Murray – The 'Lower Murray HydroModel' Final Report	University of Adelaide & University of Western Australia	2009	Development of a high resolution, process-based, three-dimensional coupled hydrodynamic-biogeochemical-ecological modelling system used as a tool to understand how key water quality variables will respond to continued drought and engineering interventions, such as flow diversions, weirs, and pumping, including the do nothing option. Planned future applications of the model include investigation of the potential effects of seawater flooding of exposed acid sulfate soils in the Lower Lakes.
Study 6.pdf	Lower Lakes Rehabilitation Opportunity Review & Revegetation Plan. Draft Report	Rural Solutions/ SA DEH	2009	Draft report providing a review of the revegetation opportunities and process recommendations required to assist in the rehabilitation of the Lower Lakes. Results of revegetation trails undertaken within the Lower Lakes. Species selection, concept implementation and cost estimates for revegetation works.
Study 7-draft.pdf	The potential impacts of heavy metals and acidity on fish communities in the Lower Lakes and Coorong area, due to the exposure of acid sulfate soils: A literature review.	SARDI Aquatic Sciences	2009	Relatively brief Literature review of ASS, fishes within the lower lakes, impacts of heavy metals and low pH on fish communities.
Study 8.pdf	Inland acid sulfate soils in Australia: Overview and conceptual modelsINLAND ACID SULFATE SOILS IN AUSTRALIA: OVERVIEW AND CONCEPTUAL MODELS	CSIRO Land and Water/ CRC LEME, Adelaide, South Australia	2008	Comprehensive background information concerning ASS. Case studies include Lower Lakes.
Study 9.doc	Literature Review on the Impacts of Liming to Mitigate Acidification, Coorong, Lower Lakes & Murray Mouth Projects	Department for Environment and Heritage	Not dated	Discussion of ASS, use of liming techniques with specific reference to fish, macro-invertebrates, and vegetation. Methods for undertaking liming activities.
Study 11A NSW Acid Sulfate Manual Part 1.pdf	Acid Sulfate Soil Manual (Part 1)	New South Wales Acid Sulfate Soil Management Advisory Committee	2008	Comprehensive background information concerning ASS. Case studies do not include Lower Lakes.
Study 11B. NSW Acid Sulfate Manual Part 2.pdf	Acid Sulfate Soil Manual (Part 2)	New South Wales Acid Sulfate Soil Management Advisory Committee	2008	This part of the manual comprises separate guidance documents relating to Acid Sulfate Soils developed by ASSMAC (Acid Sulfate Soils Management Advisory Committee) including Groundwater Guidelines (1998), sampling techniques, laboratory analysis, and drainage guidelines.
Study 12.pdf	Numerical Assessment of Acid-Sulfate Soil Impact on the River Murray Lower Lakes During Water Level Decline	Centre for Water Research	2008	Prediction of ASS impact in Murray Lakes, 2008-2010. New acidity loading model in ELCOM-CAEDYM. Recommendations for management. Recommendations for water levels in Lake Albert be maintained above -1.0 mAHD to avoid significant effects of acidification.

Study 13-Aquaterra Peer Review.pdf	PEER REVIEW OF ACIDI FICAT ION THRESHOLDS FOR LAKE ALEXANDRINA AND LAKE ALBERT	Aquaterra Consulting	2008	Impartial technical peer review to provide independent advice to the Murray-Darling Basin Commission (MDBC) on the robustness of the identified acidification thresholds for Lakes Alexandrina and Albert ("the Lower Lakes"). Results presented in summary identifying limitations to studies within key elements. Documents/reports reviewed include some identified within this alternate options study.
Study 14 Reid ASS Discussion Paper.pdf	Plant-Based Strategies for Remediation of Acid Sulphate Soils Will they work?	School of Earth and Environmental Sciences, University of Adelaide	2009	Discussion paper on plant-based strategies for remediation of acid sulphate soils, with focus upon *P. australis*.
Study 15-Preliminary Assessment of ASS.pdf	Preliminary Assessment of Acid Sulfate Soil Materials in Currency Creek, Finniss River, Tookayerta Creek and Black Swamp region, South Australia	CSIRO	2009	Results of field investigations to assess the potential acidification risks and the extent of acid sulfate soils (ASS) in the lower reaches of Currency Creek and Finniss River, and at Tookayerta Creek and Black Swamp further upstream.
Study 16.pdf	Risk assessment of proposed management scenarios for Lake Alexandrina on the resident fish community	SARDI Aquatic Sciences	2009	Discussion of impacts upon fish within the lower lakes resulting from saltwater intrusion. Literature review of fish and life cycles within Lower Lakes, salinity models, findings of mitigating actions identified from a workshop. Additional document included within appendix: Literature review of the ecology of fishes of the Lower Lakes and Coorong and development of conceptual models for the risk assessment of proposed management options for the Lower Lakes, Bice (2008).
Study 17.pdf	Water Quality Screening Risk Assessment of Acid Sulfate Soil Impacts in the Lower Murray, SA	CSIRO	2008	The major objective of this project was to undertake a rapid screening level risk assessment to determine the potential impacts of ASS on aquatic ecosystems in the Lower River Murray below Lock 1 and Lakes Alexandrina and Albert. Water quality assessments presented in relation to SA Water river offtakes.
Study 18 Earth Systems Lake Albert.pdf	Draft: Preliminary management plan for acid sulphate soils in Lake Albert, South Australia	Earth Systems	2009	Preliminary management plan presenting an assessment of the acid sulphate soil strategies for Lake Albert, and a range of options to manage potential acidification. Four strategies are presented, which include semi quantitative assessments of risk, timeframes costs, and ease of implementation. A preferred option is discussed in detail, which includes a combination of options.

Appendix E - Issues Registers

Table I – Summary of Issues, Consequence and Sensitivity to Option Assessment – 001 – Do nothing					
Issue	**Parent Document**	**Summary**	**Consequence[1]**	**Comments**	**Potential Data Gap**
Comments					
1-1	Pers. Comm. D.mollison to jfox	Surface water	Review criterion partially met (observations)	Some surface water pH has been reported as low as pH 2 in isolated pools within Finniss / currency creek – is this symptomatic of system, is there a pathway to main water bodies? Sieching of water body would appear to be predominant risk here to acid soils – wind blown?	Potential. Further assessment of this issue may be available.
1-2	Study 1	Oxidation of PASS	Review criterion partially met (reservations)	Drying and cracking of sediment is expected – may potentially increase and magnify PASS generation – seiching to amplify.	Potential. Some discussion presented in Reid (2009) and CSIRO reports (Studies 1, 4, & 16), requires further clarification.
1-3	Study 13	Acid generation	Review criterion partially met (observations)	If soils are completely dry then risk of oxidation is lower, although risk of sieching is still apparent	No
1-4	Study 16	Water (and Soil) salinity	Review criterion partially met (observations)	Increase in salinity of water via increased ET and lack of flushing. This may be apparent with and without weir action (Wellington).	No
1-5	N/A	Return to freshwater	Review criterion	Relatively easy to return acid soil to	No (Pre

[1] Assessed with regards to Issue Decision Process.

		status	partially met (observations)	status prior to oxidation although the sediment would potentially require localised neutralisation prior to input of 'natural fresh water via normal inflow from Murray'.	neutralisation not discussed in any of the options)
1-6	Study 7	Acidity impacts upon fish	Review criterion partially met (observations)	Limited specific information of impacts on species found in Lake Albert to acidity	Yes. Information available for Lake Alexandrina (Bice & Ye, 2009) may be extrapolated to undertake high level review.
1-7	Study 7	Heavy metals in lower lakes	Review criterion partially met (observations)	Insufficient information regarding concentrations in lower lakes	Yes. Monitoring data likely available.
1-8	Study 7	Drought/prolonged absence of water on fish species within Lake Albert (and Lower Lakes)	Review criterion partially met (reservations)	Commission a study to identify impacts upon fish should drying of system occur.	Yes. Generic information regarding water requirements of Lake Albert fish species likely available.
1-9	Study 16	pH fatality fish impacts (<5, >10).	Review criterion partially met (reservations)	Do nothing approach resulting in acidic conditions below pH5 resulting in fish mortalities.	No
1-10	N/A	Further decline in lake Albert levels leading to further acidity	Review criterion partially met (observations)	Likely further decline in lake levels leading to likely generation of acidity.	Yes. Scenario modelling of lake levels relative to climate and RM extraction
1-11)	Study 12 as reviewed by	Uncertainty associated with acidification	Review criterion partially met	Current version of acidification model considered by peer review	Potential. Knowledge and data

	Study 13	model, in terms of both its conceptualisation and its lack of calibration/validation	(reservation)	(study 13) to be inadequate. Hence, it is uncertain how rapidly the Lower Lakes may acidify under the 'do nothing' scenario.	gaps currently being addressed/identified in alternative study
1-12	Study 18 (Earth systems Lake Albert report)	Hydrology of Lake Bed sediments poorly understood, with simple (often uniform) representations in conceptual and numerical models of lower lake levels	Review criterion partially met (reservations)	As water levels decline, rate of oxidation and acid discharge will be dependent on hydrology of bed sediments – i.e. how quickly they drain, moisture content profiles, extinction depths, and oxygen diffusion rates. Spatial variability likely to be significant across the site	Yes. Data requirements includes: hydraulic gradients, texture maps, permeability, transmissivity, ET, O_2 diffusion modelling
1-13	N/A	Further monitoring under this scenario will improve understanding of system and its response to changes in Lake Level	Review criterion partially met (reservation)	Oxidation rates, acid and metal flux rates and buffering capacity of system can be better understood	Potential.
1-14	N/A	No provision of refuge habitat in Albert	Review criterion partially met (reservation)	Lakes will segregate under do nothing option – i.e. there will be no pathway for fish to migrate	No.

Table II – Summary of Issues, Consequence and Sensitivity to Option Assessment – 002 – Bioremediation					
Issue	**Parent Document**	**Summary**	**Consequence[1]**	**Comments**	**Potential Data Gap**
Comments					
2-1	Study 18	Applicability of subsurface micro-organisms	Review criterion met (observations)	Although sulphate reducing bacteria are very ubiquitous – the absolute presence and application of SrB in LL to the issue in hand has not been explicitly investigated.	Yes
2-2	Study 13	Mobilisation of acidity and metals from lake margins	Review criterion met (observations)	Bioremediation requires anoxic conditions – anoxic conditions achieved in subsurface (immediate depths) via mounding with groundwater – availability of groundwater or otherwise is unknown. Immediate and direct influx of water may flush acid into the water body. Pre-neutralisation may be required prior to sediment inundation.	Yes
2-3	Study 2	Mobilisation of acidity and metals from lake margins –acid spike	Review criterion met (observations)	Bioremediation requires anoxic conditions – anoxic conditions achieved in subsurface (immediate depths) via mounding with groundwater – immediate application and drying out or migration of groundwater may cause localised WL variation and magnified oxidation – may require in-depth application of	Potential gap relating to implementation of option

[1] Assessed with regards to Issue Decision Process.

				hot-spot mgt.	
2-4	Study 18	Resource - groundwater	Review criterion met (reservations)	Groundwater resource scarce and unlikely to supplement the lakes water budget, although may supply enough to inundate in terms of maintaining ASS saturation?	Potential
2-5	Study 18	Resource – groundwater	Review criterion met (reservations)	Ability to maintain groundwater supply once committed? Variation in inundation may lead to uncertainty in ASS management?	Potential
2-6	Study 18	Resource – volume required (as GW)	Review criterion met (reservations)	Unlikely that level maintenance waters could be sourced and applied. Inundation may work although infrastructure required and drawdown rates (see below) may be inhibitive.	Potential
2-7	Study 18	Resource – volume required (other)	Review criterion met (observations)	Unlikely that level maintenance waters could be sourced (e.g. Lake Bonney) that would meet or exceed required volume for lake level maintenance (e.g. circa 1GL required for Lake Albert alone – this target cannot be met).	Potential – relating to water availability
2-8	Study 18	Usage of Fe in bio-stimulation	Review criterion met (observations)	The use of Fe in this sediment system must be closely assessed and monitored – if Fe(III) is applied to a sediment with <pH 4.5 then oxidation of Fe(II) (and subsequent acid generation may occur) and so direct blanket application of Fe(III) without prior assessment may be detrimental.	No
2-9	Study 18	Inhibition of Fe(II) oxidising bacteria	Review criterion met (observations)	Further application studies into co-inhibition may be useful to assess potential for limiting oxidation of pyrite by Fe(iii) during stimulation	Yes

				application.	
2-10	Study 18	Conditions may not be suitable across the whole site	Review criterion met (observations)	Likely to be high spatial variability in environmental variables, which are key for sulphate reducing bacteria to work. Therefore, approach may work in places but not ubiquitously.	Potential – relating to implementation
2-11				Generally accepted that SRB oxidise products of fermentative bacteria such as lactate, fatty acids, alcohols, some aromatic acids, a few amino acids and hydrogen.	Not outlined in the above.

Table III – Summary of Issues, Consequence and Sensitivity to Option Assessment – 003 –Seawater Into Lower Lakes System

Issue	Parent Document	Summary	Consequence[1]	Comments	Potential Data Gap
Comments					
8-1		Salinity increase		It is not clear what effect the increased water salinity would have on ecology but would likely change format?	
8-2	-	Treatment of currently oxidising lake margins		As a stand alone option, this treatment may not be sufficient to treat (neutralise) the oxidising margins of the lake. Previous research (Ahern et al., 2009) indicate that re-flooding of sediments is less effective furthest from marine source (i.e. northern edge of lake) and on slightly higher elevations. This issue is more relevant when considering the current pumping rates where given in April 2008. The water level is now lower within the lake and therefore more water maybe required to inundate the margins and maintain a higher level.	
8-3	-	Inundation effectiveness		The rate of inundation must at least match evaporation (the lower pump rates associated with the more available pumps may not meet evaporation). Inundation must be constant , accurate and effective, a	

[1] Assessed with regards to Issue Decision Process.

				fluctuating inundation may be worse than no inundation at all, and may exacerbate pyrite oxidation (via increase in optimum moisture for oxidation via Fe(III)) and flushing. Lake seiching may then amplify and transport acidification to water body.	
8-4	Study 2	Mobilisation of acidity and metals from lake margins		Immediate and direct influx of water may flush acid into the water body. Pre-neutralisation may be required prior to sediment inundation.	
8-5	Ahern et al 2009 (not in technical reports)	Neutralisation time frames		Previous research (Ahern et al., 2009) has indicated significant time lags associated with sediment pH increase and actual acidity increases with respect to se	
8-6	-	Acidity Neutralisation effectiveness		Previous seawater flooding options have used hyrdrated lime as a dose to seawater, with lime added into the seawater on tidal influx. Would be difficult to dose seawater on tidal influx? Actual alkalinity benefit of seawater on sediments of unknown Titratable actual acidity (and potential acidity) is tenuous.	
8-7	Study 14	Return to status		Ability of soil re-inundation to reverse oxidation	Yes (may be covered n ASS studies)
8-8	Study 14	Flooding with seawater option		Identify salinity tolerances for plant species should saline inundation option occur	Yes. Information desktop study required.

8-9	Study 7	Influence of seawater on fish species		Commission study to identify impacts on fish should lower lakes be flooded with seawater. Study needs to identify refuge habitats and connectivity between these environments. Length of time species can exist under stressed environments. Ability of system to recover in terms of re-colonisation.	No -see Risk assessment study
8-10	Study 16	Provision of refuge habitat to protect fish and provide source population upon reestablishment of freshwater environment in Lower Lakes.			
8-11	Study 16	Loss of fish species		Severe negative impact resulting from Saltwater intrusion to lower lakes	No
8-12	Study 16	Creation of refuge habitat through weir construction at Clayton.		Provision of freshwater refuge environment	Partial – absence of salinity modelling in refuge environment
8-13	Study 16	Impact on vegetation		Loss of vegetation for spawning and feeding opportunities	No
8-14	Study 16	Disconnection of lower lakes from EMLR tributaries		Important life cycle implications for diadromous fish species.	No

Table IV – Summary of Issues, Consequence and Sensitivity to Option Assessment – 004 – Re-vegetation

Issue	Parent Document	Summary	Consequence[1]	Comments	Potential Data Gap
Comments					
3-1F	Study 14 (Reid)	Window of opportunity for plant colonisation	Review criterion partially met (observations)	Window of opportunity for plant colonisation as solubilisation of Aluminium is considered likely to occur at <pH 4.5. This window is dependant on oxidation rates, which may be estimated from system modelling although would be difficult to determine in situ (time and expense?) unless field monitoring for pH was undertaken to determine the pH prior to seeding – i.e. <ph 4.5 may exclude seeding.	No
3-2F	-Study 14 and 6	Boundary around pH 4.5	Review criterion partially met (observations)	Potential boundary (margin) around pH 4.5 for aluminium toxicity i.e. what is colonisation time of chosen species (species depth) and can growth and colonisation occur over a time that would arrest decrease in pH. Prior neutralisation of acidity may be required.	Potential – risks need to be captured in implementation study (building upon Study 6)
3-3F	- Study 14 and 6	Colonisation time management	Review criterion partially met (observations)	Can colonisation time be actively managed?	Potential (see above: 3-2)
3-4F	- Study 14 and	Evapo-transpiration	Review criterion	Role of evapo-transpiration requires	Potential

[1] Assessed with regards to Issue Decision Process.

	6		partially met (observations)	better understanding with respect to large scale application of biomass, especially over summer months. Current DEH trials may provide more insight into this if they run over summer.	
3-5F	- Study 14 and 6	Biomass and ET	Review criterion partially met (reservations)	The mass of biomass may increase ET and lower water table while still regulating some portion of soil moisture which may increase ASS oxidation. This may occur as drawdown the water table which is recharged via rainfall (cyclical action) which may exacerbate oxidation.	Potential (some discussion in Study 14)
3-6F	N/A	Biomass and adjacent soil	Review criterion partially met (observations)	Not clear what role the biomass may have on adjacent (horizontal) water levels and may induce a certain level of cracking in adjacent soils which may then increase further oxidation.	Potential
3-7F	Study 14 Pg 6	Role of dead / decaying biomass	Review criterion partially met (reservations)	Not clear as to the role that the increase in dead / decaying biomass may have – it may be possible that the biomass may increase anoxic conditions directly beneath and increase MBO production (See study 2).	Potential
3-8F	Study 14 Pg 6	Rampant colonisation	Non significant issue	The chosen species may be invasive	No (Study 6 identifies weed management requirements)
3-9F	Study 14 Pg 6	Soil Type	Review criterion partially met (observations)	Success of chosen / selected species may be associated with the soil type so that any particular species may not	Potential (basic soil mapping undertaken in

				be suitable for a site wide application.	Study 6)
3-10F	Study 14 Pg 6	Water level fluctuation	Review criterion partially met (reservations)	Water level fluctuation is a variable that may influence uncertain biomass colonisation success.	Potential
3-11F	Study 14 Pg 6	Salinity	Review criterion partially met (reservations)	Soil salinity increases may disrupt biomass growth / colonisation success	Yes – identify salinity tolerances of selected plants (building on Study 6)
3-12F	Study 14 Pg 6	Theoretical evidence	Review criterion partially met (reservations)	No apparent theoretical evidence for application of plant species in acid soil management.	Yes. Definitive results of trial required.
3-13F	Study 14 Pg 7	Bacterial optimum pH	Review criterion partially met (observations)	Optimum ph for *T ferrooxidans* may be higher at around 3.5 – implications for application of plant remediation	No
3-14F	Study 14 Pg 9	Experimental data – soil pH	Review criterion partially met (observations)	Soil pH in the experiment is not related to root presence – i.e. no uptake of oxygen (see figure 1, sample S1) and pH as S2 (low / no vegetation) generally higher than S1 (good stand of grass).	No
3-15F	Study 14 Pg 9	Experimental data – replication	Review criterion partially met (reservations)	No replication / duplicate / triplicate on experimental data	Yes. Definitive results of trial required, as a minimum.)
3-16F	Study 14 Pg 10	Experimental data – heavy metals	Review criterion partially met (reservations)	Aluminium not assessed – key pH sensitive metal – toxicity would be a key factor here.	Yes
3-17F	Study 14 Pg 11	Soil type and pH	Review criterion partially met (reservations)	Sandy soil is generally more acidic (ASS) as it has little buffering capacity compared to clay soils - therefore	Yes

				plant and pH results could be skewed by soil type rather that plant performance.	
3-18F	Study 14 Pg 11	Plants vs no plants	Review criterion partially met (reservations)	No significant difference in surface soil pH between plants versus no plants	Potential
3-19F	Study 14 Pg 11	Relationship to moisture content	Review criterion partially met (observations)	The role of plant roots on soil moisture content is unclear	Yes
3-20	-Study 6	Implementation of planting	Review criterion partially met (reservations)	Limited discussion of complexities associated with establishing vegetation on a large scale, ie, no consideration for falling and rising water levels or periodic inundation where establishing plants will be difficult. This may not be a significant issue as water levels likely well away from lake edges already where plantings proposed	Yes/possible (Further information available from the DEH trials)
3-21	Study 6	Number of study sites	Review criterion partially met (observations)	800 study sites visited (very brief assessment)	No
3-22	Study 6	Weed control	Review criterion partially met (reservations)	General absence of discussion and reasoning	Yes
3-23	Study 6	Planting implementation	Review criterion partially met (observations)	Unclear if organisations recommended to undertake planting have given support/approval in timeframes required	Potential
3-24	Study 6	Planting implementation	Review criterion partially met (observations)	Absence of detailed timeframes	Yes
3-25	Study 6	Addition of iron to	Review criterion	Science behind this reasoning unclear	Potential

		system	partially met (observations)		
3-26	Study 14 and Study 6	Confidence associated with success of re-vegetation to maintain soil moisture and reduce soil acidification	Review criterion partially met (observations)	Statement made that the approach is “likely” to be successful. Poor confidence associated with this statement and lack of evidence to support this assumption.	Yes.
3-27	Study 6	Limited/no discussion of risk	Review criterion partially met (reservations)	Absence of discussion regarding potential risks, (such as weed establishment, impacts following re-flooding of system etc). Only mentions water draw down in brief.	Potential (Risks discussed in Study 14)
3-28	Study 6	Weed control	Review criterion partially met (observations)	Lack of specific information regarding techniques, timings	Potential
3-29	Study 6	Extent of re-vegetation	Review criterion partially met (observations)	Study identifies plan to solely re-vegetate borders of the lake (possibly where hot spots occur), not whole system	Potential
3-30	Study 6	Implementation (timing of planting)	Review criterion partially met (observations)	No timeframes proposed or discussed for planting	Yes (DEH trials may provide further information)
3-31	Study 6	Implementation of planting	Review criterion partially met (reservations)	Logistics of planting in timeframes required appear unlikely.	Potential
3-32	Study 6	Scientific rigour associated with Study 6	Review criterion partially met (reservations)	Relative lack of scientific justification for approach, including a lack of references in main body of document.	Potential
3-33	Study 6	Water balance model	Review criterion partially met (observations)	Water balance model recommended in study in relation to water consumption of proposed large scale planting	Yes (water balance model for the system incorporating

					planting approach required)
3-34	Study 6	Species selection and locations	Review criterion partially met (observations)	Limited information restricted to broad areas. May need further clarification and mapping	Yes/Potential
3-35	Study 6	Implementation (sourcing plant materials)	Review criterion partially met (observations)	Unclear if plant seed and tube stocks can be sourced in timeframes required.	Yes/Potential
3-36	Study 14	Risk of acidification inhibiting plant growth	Review criterion partially met (observations)	No plant specific assessment – Need for specific acidic tolerances for proposed plant species	Yes
3-37	Study 14	Risk identified relating to practicalities of planting	Review criterion partially met (reservations)	Small window present where plants can establish following partial drying, yet prior to acidification process occurs.	Yes – in relation to a detailed specific planting schedule needs to be developed in line with current predictions
3-38	Study 14	Implementation of planting	Review criterion partially met (observations)	Risk of ability to establish plants in different soil types present within Lower Lakes. Need to identify specific soil requirements for proposed plant species in relation to Lower Lakes.	Yes/Potential (building upon Study 6)
3-39	Study 14	Implementation of planting	Review criterion partially met (reservations)	Risk of plants to establish and survive in fluctuating water levels	Yes – identify water requirements and inundation ranges for plant species

3-40	Study 14	In relation to flooding the system and existing stands of *P. australis*.	Review criterion partially met (reservations)	Risk of saltwater inundation of *P. australis* and production of Monosidic black ooze	Yes
3-41	Study 14	Implementation of planting	Review criterion partially met (observations)	Limited evidence that plants can reduce acidity in their own right	Yes
3-42	Study 14	Data Gap	Review criterion partially met (observations)	pH profiles of ASS for established plants	Yes
3-43	Study 14	Data Gap	Review criterion partially met (observations)	pH requirements and tolerances for plant species proposed for lower lakes re-vegetation	Yes
3-44	N/A	Water Balance model	Review criterion partially met (reservations)	Plants will lower soil oxygen diffusion rates and dampen variability in soil moisture contents, but trade-off is higher ET to potentially lower the watertable. Not clear yet as to whether plants will improve or exacerbate acid generation	Yes – Water balance model required for Lake Albert under this option

Table V – Summary of Issues, Consequence and Sensitivity to Option Assessment – 005 – Neutralisation					
Issue	**Parent Document**	**Summary**	**Consequence[1]**	**Comments**	**Potential Data Gap**
Comments					
4-1	Study 9	Cannot be applied effectively everywhere	Review Criterion Partially Met (Reservations)	Parts of the Lake system may be inaccessible or require too much disturbance	Yes – Relating to implementation of this option (Not discussed)
4-2	Study 9	De-oxygenation issues	Review Criterion Partially Met (Observations)	May not be able to treat problems associated with de-oxygenation?	Yes/Potential (Not discussed)
4-3			Review Criterion Partially Met (Observations)	Knowledge gap exist when treating a large area, such as ability to treat deep acidification within the soil profile.	

[1] Assessed with regards to Issue Decision Process.

Table VI – Summary of Issues, Consequence and Sensitivity to Option Assessment – 006 – Freshwater Allocation / Purchase					
Issue	**Parent Document**	**Summary**	**Consequence[1]**	**Comments**	**Potential Data Gap**
Comments					
5-1		Treatment of currently oxidising lake margins	Review criterion partially met (reservations)	As a stand alone option, this treatment may not be sufficient to treat (neutralise) acidic sediments. The treatment may disperse via evaporation before treatment occurs.	Potential (Discussed)
5-2	Aquaterra study	Inundation effectiveness	Review criterion partially met (reservations)	The rate of inundation must at least match evaporation (the lower pump rates associated with the more available pumps may not meet evaporation). Inundation must be constant, accurate and effective, a fluctuating inundation may be worse than no inundation at all, and may exacerbate pyrite oxidation (via increase in optimum moisture for oxidation via Fe(III)) and flushing. Lake seiching may then amplify and transport acidification to water body.	(Discussed)
5-3	Study 2	Mobilisation of acidity and metals from lake margins	Review criterion partially met (observations)	Immediate and direct influx of water may flush acid into the water body. Pre-neutralisation may be required prior to sediment inundation.	Potential (Not Discussed)
5-4		Resource - groundwater	Review criterion partially met	Groundwater resource scarce and unlikely to supplement the lakes water	Potential (Discussed)

[1] Assessed with regards to Issue Decision Process.

			(reservations)	budget, although may supply enough to inundate in terms of maintaining ASS saturation?	
5-5		Resource – groundwater	Review criterion partially met (reservations)	Ability to maintain groundwater supply once committed? Variation in inundation may lead to uncertainty in ASS management?	No (Discussed)
5-6		Resource – volume required (as GW)	Review criterion partially met (observations)	Unlikely that level maintenance of waters could be sourced and applied. Inundation may work although infrastructure required and drawdown rates (see below) may be inhibitive.	No (Volumes not discussed)
5-7		Resource – volume required (other)	Review criterion partially met (reservations)	Unlikely that level maintenance waters could be sourced (e.g. Lake Bonney) that would meet or exceed required volume for lake level maintenance (e.g. circa 1GL required for Lake Albert alone – this target cannot be met).	Potential (Not discussed)
5-8	Study 14	Return to status	Review criterion partially met (observations)	Ability of soil re-inundation to reverse oxidation	Yes/Potential (Not discussed)
5-9	Study 12 as reviewed by Study 13	Uncertainty associated with acidification model, in terms of both its conceptualisation and its lack of calibration/validation	Review criterion partially met (reservation)	Current version of acidification model considered by peer review (study 13) to be inadequate. Hence, it is uncertain how the Lower Lakes may respond to changes in water level associated with provision of fresh water.	Knowledge and data gaps currently being addressed in alternative study (Not discussed)
5-10	Study 18 (Earth systems Lake Albert report)	Hydrology of Lake Bed sediments poorly understood, with simple (often uniform)	Review criterion partially met (reservations)	Effectiveness of targeted applications of fresh water dependent on accurate understanding of hydrology of bed sediments – i.e. how quickly they	Hydraulic gradients, texture maps, permeability,

		representations in conceptual and numerical models of lower lake levels		recharge, moisture content profiles, extinction depths, and oxygen diffusion rates. Spatial variability likely to be significant across the site	transmissivity, ET, O_2 diffusion modelling (Not discussed)

Table VII – Summary of Issues, Consequence and Sensitivity to Option Assessment – 007 – Pumping of Seawater Into Lake Albert					
Issue	**Parent Document**	**Summary**	**Consequence[1]**	**Comments**	**Potential Data Gap**
Comments					
7-1	Lake Albert Investigation - Tonkin April 2008	Lead in time for infrastructure acquisition and commission	Review criterion partially met (reservations)	Commencement of pumping not achievable for 7 – 11 months depending on power supply issues and acquisition of pumps. Detailed design requires commencement ASAP.	Potential (Discussed)
7-2	- Lake Albert Investigation - Tonkin April 2008	Pump acquisition earlier but with lower capacity.	Review criterion partially met (reservations)	Pumps could be acquired sooner than stated above in 7-1 but would not be capable of pumping required 1Gl of water (can achieve c.800 ML) although still envisaged to supply a net influx (yearly), it would be below net evaporation in Jan and Feb (c. 950ML).	Potential (Not discussed)
7-3	- Lake Albert Investigation - Tonkin April 2008	Coorong as Source - salinity	Review criterion partially met (reservations)	Water from Coorong would potentially have higher salinity than the Ocean option as Coorong is hyper saline in sections. Absence of ecological assessment relating to hypersaline inundation	Yes (Discussed)
7-4	- Lake Albert Investigation - Tonkin April 2008	Coorong as Source – recharge of Coorong	Review criterion partially met (observations)	The report does not clearly state that there would be effective recharge of Coorong. The report ASSUMES that pumping from Coorong at >800 ML	Yes (Discussed)

[1] Assessed with regards to Issue Decision Process.

				day would draw in water from ocean via Murray Mouth – would hydrodynamic modelling be required to determine this process can occur? The report ASSUMES that inflow via Murray Mouth is sufficient to recharge based on calculations not supported by a bathymetric model.	
7-5	- Lake Albert Investigation - Tonkin April 2008	Coorong as Source – ecological implications	Review criterion partially met (reservations)	Report states that ecological implications on the Coorong are not considered within the report.	Yes (some discussion of potential impacts to fish within Lake Alexandrina in Study 16 (Not discussed in detail)
7-6	- Lake Albert Investigation - Tonkin April 2008	Coorong as Source – practicable land issues	Non-significant issue	Construction on preferred route may be hindered by agreement from landholder. Report states that construction space may be attainable on road reserve. It is possible that the road reserves are not wide enough.	Yes/Potential (Not discussed)
7-7	- Lake Albert Investigation - Tonkin April 2008	Coorong as Source – Practicable Environmental Nuisance	Non-significant issue	Potential for air and noise pollution from generators, Best practise would need to be adopted.	No (Not discussed)
7-8	Lake Albert Investigation - Tonkin	Salinity modelling	Review criterion partially met (observations)	Absence of modelling data, as undertaken in Lake Alexandria	Yes (Not discussed)

	April 2008				
7-9		Returning Lake Albert to freshwater Environment	Review criterion partially met (observations)	Detailed study and information of options not available. Clarification of how the closed system can be flushed	Yes (Discussed)
7-10		Increase in salinity through evaporation	Review criterion partially met (observations)	Hypersaline conditions expected to develop with Lake Albert	No - detailed salinity models required (Discussed)
7-11		Refuge habitat for freshwater fauna (primarily fish)	Review criterion partially met (observations)	Study to identify refuge habitat not undertaken. Practicalities of segregating Lake Albert would likely prevent this being explored further	Yes (Discussed)
7-12		Potential benefits to Coorong through removal of hypersaline water	Review criterion partially met (reservations)	The report does not clearly state that there would be effective recharge of Coorong. The report ASSUMES that pumping from Coorong at >800 ML day would draw in water from ocean via Murray Mouth – would hydrodynamic modelling be required to determine this process can occur? The report ASSUMES that inflow via Murray Mouth is sufficient to recharge based on calculations not supported by a bathymetric model.	Yes (Not discussed)
7-13		Absence of fish passage into Lake Alexandrina	Review criterion partially met (observations)	Re-connection of Lake Albert to Lake Alexandrina temporarily as saltwater pumped into system may allow fish to enter Lake Alex and prevent mass fish mortality.	Yes: Issue not discussed or raised in documents reviewed. (Not discussed)

7-14	Lake Albert Investigation - Tonkin April 2008	Coorong water into Lake Albert – Treatment of currently oxidising lake margins	Review criterion partially met (observations)	As a stand alone option, this treatment may not be sufficient to treat (neutralise) the oxidising margins of the lake. Previous research (Ahern et al., 2009) indicate that re-flooding of sediments is less effective furthest from marine source (i.e. northern edge of lake) and on slightly higher elevations. This issue is more relevant when considering the current pumping rates were given in April 2008. The water level is now lower within the lake and therefore more water maybe required inundating the margins and maintaining a higher level.	No (See Tonkin study
7-15	- Lake Albert Investigation - Tonkin April 2008	Coorong into Lake Albert - Inundation effectiveness	Review criterion partially met (observations)	The rate of inundation must at least match evaporation (the lower pump rates associated with the more available pumps may not meet evaporation). Inundation must be constant , accurate and effective, a fluctuating inundation may be worse than no inundation at all, and may exacerbate pyrite oxidation (via increase in optimum moisture for oxidation via Fe(III)) and flushing. Lake seiching may then amplify and transport acidification to water body.	No (See Tonkin study) (Discussed)
7-16	- Lake Albert Investigation -	Coorong into Lake Albert – Mobilisation of	Review criterion partially met	Immediate and direct influx of water may flush acid into the water body.	Yes

	Tonkin April 2008	acidity and metals from lake margins	(observations)	Pre-neutralisation may be required prior to sediment inundation.	
7-17	- Lake Albert Investigation - Tonkin April 2008	Seawater into Lake Albert – Neutralisation time frames	Review criterion partially met (observations)	Previous research (Ahern et al., 2009) has indicated significant time lags associated with sediment pH increase and actual acidity increases with respect to se	Potential
Tonkin report discounts the pumping of seawater from the ocean option. However, issues identified are detailed below for information.					
7-18	- Lake Albert Investigation - Tonkin April 2008	Ocean as Source – Practicable construction	Review criterion partially met (observations)	Construction would be difficult in sand dunes.	Potential (Not discussed)
7-19	- Lake Albert Investigation - Tonkin April 2008	Ocean as Source – increased plant size	Review criterion partially met (observations)	Increased plant may be required to deliver increased pumping rates (over that of Coorong as source) which would increase footprint.	No (See Tonkin study) (Discussed)
7-20	- Lake Albert Investigation - Tonkin April 2008	Ocean as Source – Potential NES Matters	Review criterion partially met (reservations)	Potential impact on NES matters as Young Husband Peninsula is a National Park – a referral to DEWHA may be required which would increase time criticality.	No (See Tonkin study) (Discussed)
7-21	Lake Albert Investigation - Tonkin April 2008	Ocean as Source – Risk to infrastructure	Review criterion partially met (reservations)	Potential risk to infrastructure from freak weather event (e.g. 1 in 100 year storm).	No (See Tonkin study) (Not discussed)
7-22	Lake Albert Investigation - Tonkin April 2008	Ocean as Source – Coast Dynamics and Intake	Review criterion partially met (observations)	Potential risk in terms of ongoing maintenance requirement of ocean intake due to silting up of intake and wear and tear due to dynamic wave action.	No (See Tonkin study
7-23	Lake Albert Investigation - Tonkin	Seawater into Lake Albert – Treatment of currently oxidising lake	Review criterion partially met (observations)	As a stand alone option, this treatment may not be sufficient to treat (neutralise) the oxidising	No (See Tonkin study) (Not

	April 2008	margins		margins of the lake. Previous research (Ahern et al., 2009) indicate that re-flooding of sediments is less effective furthest from marine source (i.e. northern edge of lake) and on slightly higher elevations. This issue is more relevant when considering the current pumping rates were given in April 2008. The water level is now lower within the lake and therefore more water maybe required inundating the margins and maintaining a higher level.	discussed)
7-20	- Lake Albert Investigation - Tonkin April 2008	Seawater into Lake Albert - Inundation effectiveness	Review criterion partially met (observations)	The rate of inundation must at least match evaporation (the lower pump rates associated with the more available pumps may not meet evaporation). Inundation must be constant , accurate and effective, a fluctuating inundation may be worse than no inundation at all, and may exacerbate pyrite oxidation (via increase in optimum moisture for oxidation via Fe(III)) and flushing. Lake seiching may then amplify and transport acidification to water body.	No (See Tonkin study) (Discussed)
7-21	- Lake Albert Investigation - Tonkin April 2008	Seawater into Lake Albert – Mobilisation of acidity and metals from lake margins	Review criterion partially met (observations)	Immediate and direct influx of water may flush acid into the water body. Pre-neutralisation may be required prior to sediment inundation.	Yes (Not discussed)
7-22	- Lake Albert	Seawater into Lake	Review criterion	Previous research (Ahern et al.,	Potential

	Investigation - Tonkin April 2008	Albert – Neutralisation time frames	partially met (observations)	2009) has indicated significant time lags associated with sediment pH increase and actual acidity increases with respect to se	(Discussed)

Appendix F - System MCA Matrices

Table	001	Sponsor / Owner	SA Water	Major Dependencies	See Text
Option Name	Do Nothing	Current Status	Draft	Issues Register Reference	Table I
Specific	Implement no acidification management option				
Measurable	Measure of: • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC)				
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability?				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	**50**								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	**10**								
A - Option is theoretically viable	25		5			125	6.3	1.00	6.3
B– Theoretically viable on the scale (spatial) required	75			2		150	7.5	1.00	7.5
Sub Total						275	13.8		13.8
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	**45**								
A - Generic Proof of Concept established	15		5			75	16.875	0.75	12.7
B - Proof of Concept established in similar (representative) environments	35			2		70	15.75	0.75	11.8
C – Proof of concept established in Lower Lakes circumstances	50				0	0	0	1.00	0.0
Sub Total						145	32.625		24.5
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	**45**								
A1 – on a large scale	65			2		130	29.25	1.00	29.3
A2 – on a localised scale	35			2		70	15.75	0.75	11.8
Sub Total						200	45		41.1
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**79.3**
8 - Costs to Government (State or Federal)	**50**								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	**70**								
Capital / Establishment costs are minimal	40	**10**				400	140.0	1.00	140.0
Operational / Maintenance costs are minimal	40	**10**				400	140.0	1.00	140.0
Decommissioning costs are minimal	20	**10**				200	70.0	1.00	70.0
Sub Total						1000	350		350.0
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	**30**								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60			2		120	18	0.75	13.5
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40				0	0	0	1.00	0.0
Sub Total						120	18		13.5
Sub-Total - Costs and Transparency									**363.5**
					Total		459		443

Adjustments			
	Preventative Measure or Treatment	After Event Treatment	
	Likelihood of negative impacts	Likely	
	Severity of negative impacts	Dangerous	
	Risk Multiplier	0.36	
	Score		120

Table	002	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Bioremediation	**Current Status**	Draft	**Issues Register**	II

Specific	Bioremediation - (Taken to be) addition of organic matter / substrate and Fe to acid generating soils in order to stimulate reduction of sulphate to sulphide (as FeS) and concomitantly consume acidity.
Measurable	• Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	50								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10								
A - Option is theoretically viable	25	10				250	12.5	1.00	12.5
B– Theoretically viable on the scale (spatial) required	75		5			375	18.8	0.75	14.1
Sub Total						625	31.3		26.6
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45								
A - Generic Proof of Concept established	15	10				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35		5			175	39.375	0.75	29.5
C – Proof of concept established in Lower Lakes circumstances	50		5			250	56.25	0.75	42.2
Sub Total						575	129.375		105.5
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45								
A1 – on a large scale	65			2		130	29.25	1.00	29.3
A2 – on a localised scale	35	10				350	78.75	0.75	59.1
Sub Total						480	108		88.3
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**220.3**
8 - Costs to Government (State or Federal)	50								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70								
Capital / Establishment costs are minimal	40		5			200	70.0	1.00	70.0
Operational / Maintenance costs are minimal	40		5			200	70.0	0.75	52.5
Decommissioning costs are minimal	20		5			100	35.0	1.00	35.0
Sub Total						500	175		157.5
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60		5			300	45	0.75	33.8
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40		5			200	30	0.75	22.5
Sub Total						500	75		56.3
Sub-Total - Costs and Transparency									**213.8**
					Total		519		434

Adjustments		
	Preventative Measure or Treatment	**Prevention**
	Likelihood of negative impacts	Possible
	Severity of negative impacts	Slight
	Risk Multiplier	0.56
	Score	**243**

Table	003	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Seawater Inundation	**Current Status**	Draft	**Issues Register Reference**	III
Specific	Transfer of seawater into Lake Alexandrina via Barrages to inundate sediments (Prevention).				
Measurable	• Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act) Plus • Sediment salinity				
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	**50**								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	**10**								
A - Option is theoretically viable	25		**5**			125	6.3	0.75	4.7
B– Theoretically viable on the scale (spatial) required	75		**5**			375	18.8	0.75	14.1
Sub Total						500	25.0		18.8
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	**45**								
A - Generic Proof of Concept established	15	**10**				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35			**2**		70	15.75	1.00	15.8
C – Proof of concept established in Lower Lakes circumstances	50			**2**		100	22.5	0.75	16.9
Sub Total						320	72		66.4
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	**45**								
A1 – on a large scale	65	**10**				650	146.25	0.75	109.7
A2 – on a localised scale	35		**5**			175	39.375	0.50	19.7
Sub Total						825	185.625		129.4
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**214.5**
8 - Costs to Government (State or Federal)	**50**								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	**70**								
Capital / Establishment costs are minimal	40	**10**				400	140.0	1.00	140.0
Operational / Maintenance costs are minimal	40	**10**				400	140.0	1.00	140.0
Decommissioning costs are minimal	20			**2**		40	14.0	0.75	10.5
Sub Total						840	294		290.5
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	**30**								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60	**10**				600	90	1.00	90.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40		**5**			200	30	0.50	15.0
Sub Total						800	120		105.0
Sub-Total - Costs and Transparency									**395.5**
					Total		697		610

Adjustments		
	Preventative Measure or Treatment	Prevention
	Likelihood of negative impacts	Possible
	Severity of negative impacts	Critical
	Risk Multiplier	0.35
	Score	214

Table	004	Sponsor / Owner	SA Water	Major Dependencies	See Text
Option Name	Revegetation	Current Status	Draft	Issues Register	IV
Specific	Re-vegetation – (Taken to be) plant based strategies for remediation of acid sulphate soil (Phytoremediation)				
Measurable	• Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)				
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	**50**								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	**10**								
A - Option is theoretically viable	25			2		50	2.5	0.75	1.9
B– Theoretically viable on the scale (spatial) required	75			2		150	7.5	1.00	7.5
Sub Total						200	10.0		9.4
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	**45**								
A - Generic Proof of Concept established	15				0	0	0	1.00	0.0
B - Proof of Concept established in similar (representative) environments	35				0	0	0	1.00	0.0
C – Proof of concept established in Lower Lakes circumstances	50				0	0	0	0.75	0.0
Sub Total						0	0		0.0
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	**45**								
A1 – on a large scale	65			2		130	29.25	1.00	29.3
A2 – on a localised scale	35		5			175	39.375	0.75	29.5
Sub Total						305	68.625		58.8
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**68.2**
8 - Costs to Government (State or Federal)	**50**								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	**70**								
Capital / Establishment costs are minimal	40	10				400	140.0	1.00	140.0
Operational / Maintenance costs are minimal	40	10				400	140.0	1.00	140.0
Decommissioning costs are minimal	20	10				200	70.0	0.75	52.5
Sub Total						1000	350		332.5
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	**30**								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60	10				600	90	1.00	90.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40		5			200	30	1.00	30.0
Sub Total						800	120		120.0
Sub-Total - Costs and Transparency									**452.5**
					Total		549		521

Adjustments	Preventative Measure or Treatment	Prevention	
	Likelihood of negative impacts	Unlikely	
	Severity of negative impacts	Slight	
	Risk Multiplier	0.64	
	Score		333

Table	005	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Neutralisation	**Current Status**	Draft	**Issues Register**	V
Specific	Treatment Option – acidity control / treatment within the lake sediments and/or water body via addition of alkaline amendment (e.g. limestone, hydrated lime or caustic magnesia).				
Measurable	• Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)				
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	50								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10								
A - Option is theoretically viable	25	10				250	12.5	1.00	12.5
B– Theoretically viable on the scale (spatial) required	75	10				750	37.5	0.75	28.1
Sub Total						1000	50.0		40.6
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45								
A - Generic Proof of Concept established	15	10				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35	10				350	78.75	1.00	78.8
C – Proof of concept established in Lower Lakes circumstances	50		5			250	56.25	0.75	42.2
Sub Total						750	168.75		154.7
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45								
A1 – on a large scale	65			2		130	29.25	0.75	21.9
A2 – on a localised scale	35		5			175	39.375	0.75	29.5
Sub Total						305	68.625		51.5
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**246.8**
8 - Costs to Government (State or Federal)	50								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70								
Capital / Establishment costs are minimal	40			2		80	28.0	1.00	28.0
Operational / Maintenance costs are minimal	40			2		80	28.0	0.50	14.0
Decommissioning costs are minimal	20		5			100	35.0	0.75	26.3
Sub Total						260	91		68.3
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60				0	0	0	0.75	0.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40			2		80	12	0.75	9.0
Sub Total						80	12		9.0
Sub-Total - Costs and Transparency									**77.3**
					Total		390		324

Adjustments		
	Preventative Measure or Treatment	**After Event Treatment**
	Likelihood of negative impacts	Possible
	Severity of negative impacts	Moderate
	Risk Multiplier	0.49
	Score	**119**

Table	006	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Freshwater	**Current Status**	Draft	**Issues Register**	VI

Specific
Taken to be:
• Buy-back allocations
And also
• Use of freshwater resources to mitigate acid generation in sediments (Prevention)

Measurable
Buy back:
• Lake water alkalinity (>25 mg/L)
• Lake water elevation (>1.5m AHD)
• Lake water salinity (EC< 1500 EC)
• Trophic state (oligotrophic)
Resource use on sediments
• Porewater geochemistry
• Groundwater quality
And
• Lake water alkalinity (>25 mg/L)
• Lake water elevation (>1.5m AHD)
• Lake water salinity (EC< 1500 EC)
• Trophic state (oligotrophic)
• Ecological component – impact on NES matters (Part 3 EPBC Act)

Achievable
• Volume FW resource required?
• Volume FW available?
• Long term availability?
• Theoretically possible?
• Is there proof of concept, trials etc

Relevant
Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)

Timebound
• When do we expect to see results?
• What is the effective lifespan of the treatment?
• How long are we measuring for?

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria Yes 10	 Probable 5	 Unlikely 2	 No/NA 0	Raw Value Score	Weighted Value Score	H=1 / M=0.75 / L=0.5 Value Confidence Score	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	50								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10								
A - Option is theoretically viable	25	10				250	12.5	1.00	12.5
B– Theoretically viable on the scale (spatial) required	75	10				750	37.5	0.50	18.8
Sub Total						1000	50.0		31.3
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45								
A - Generic Proof of Concept established	15	10				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35	10				350	78.75	1.00	78.8
C – Proof of concept established in Lower Lakes circumstances	50	10				500	112.5	0.75	84.4
Sub Total						1000	225		196.9
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45								
A1 – on a large scale	65			2		130	29.25	0.50	14.6
A2 – on a localised scale	35		5			175	39.375	0.75	29.5
Sub Total						305	68.625		44.2
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									272.3
8 - Costs to Government (State or Federal)	50								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70								
Capital / Establishment costs are minimal	40				0	0	0.0	1.00	0.0
Operational / Maintenance costs are minimal	40			2		80	28.0	1.00	28.0
Decommissioning costs are minimal	20	10				200	70.0	0.75	52.5
Sub Total						280	98		80.5
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60			2		120	18	1.00	18.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40	10				400	60	0.75	45.0
Sub Total						520	78		63.0
Sub-Total - Costs and Transparency									143.5
					Total		520		416

Adjustments			
	Preventative Measure or Treatment	**Prevention**	
	Likelihood of negative impacts	Unlikely	
	Severity of negative impacts	Moderate	
	Risk Multiplier	0.56	
	Score		**233**

Table	007	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Freshwater - allocations	**Current Status**	Draft	**Issues Register Reference**	VII

Specific	Taken to be: • Reallocation of water within the River Murray And also • Use of freshwater resources to mitigate acid generation in sediments (Prevention)
Measurable	Buy back: • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) Resource use on sediments • Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	H=1 / M=0.75 / L=0.5 Value Confidence Score	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	50								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10								
A - Option is theoretically viable	25	10				250	12.5	1.00	12.5
B– Theoretically viable on the scale (spatial) required	75	10				750	37.5	0.50	18.8
Sub Total						1000	50.0		31.3
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45								
A - Generic Proof of Concept established	15	10				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35	10				350	78.75	1.00	78.8
C – Proof of concept established in Lower Lakes circumstances	50	10				500	112.5	0.75	84.4
Sub Total						1000	225		196.9
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45								
A1 – on a large scale	65			2		130	29.25	0.50	14.6
A2 – on a localised scale	35		5			175	39.375	0.75	29.5
Sub Total						305	68.625		44.2
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**272.3**
8 - Costs to Government (State or Federal)	50								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70								
Capital / Establishment costs are minimal	40	10				400	140.0	1.00	140.0
Operational / Maintenance costs are minimal	40	10				400	140.0	1.00	140.0
Decommissioning costs are minimal	20	10				200	70.0	1.00	70.0
Sub Total						1000	350		350.0
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60		5			300	45	1.00	45.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40	10				400	60	0.75	45.0
Sub Total						700	105		90.0
Sub-Total - Costs and Transparency									**440.0**
					Total		799		712

Adjustments	Preventative Measure or Treatment	Prevention
	Likelihood of negative impacts	Unlikely
	Severity of negative impacts	Moderate
	Risk Multiplier	0.56
	Score	399

Table	008	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Pumping to Lake Albert	**Current Status**	Draft	**Issues Register Reference**	VII
Specific	Taken to be the pumping of saltwater from the Coorong into Lake Albert				
Measurable	• Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic)				
Achievable	• Volume required? • Volume available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	50								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10								
A - Option is theoretically viable	25		5			125	6.3	0.75	4.7
B– Theoretically viable on the scale (spatial) required	75		5			375	18.8	0.75	14.1
Sub Total						500	25.0		18.8
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45								
A - Generic Proof of Concept established	15	10				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35		5			175	39.375	1.00	39.4
C – Proof of concept established in Lower Lakes circumstances	50			2		100	22.5	0.75	16.9
Sub Total						425	95.625		90.0
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45								
A1 – on a large scale	65	10				650	146.25	0.75	109.7
A2 – on a localised scale	35		5			175	39.375	0.50	19.7
Sub Total						825	185.625		129.4
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**238.1**
8 - Costs to Government (State or Federal)	50								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70								
Capital / Establishment costs are minimal	40				0	0	0.0	1.00	0.0
Operational / Maintenance costs are minimal	40			2		80	28.0	1.00	28.0
Decommissioning costs are minimal	20			2		40	14.0	0.75	10.5
Sub Total						120	42		38.5
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60		5			300	45	0.75	33.8
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40			2		80	12	0.75	9.0
Sub Total						380	57		42.8
Sub-Total - Costs and Transparency									**81.3**
					Total		405		319

Adjustments	Preventative Measure or Treatment	Prevention	
	Likelihood of negative impacts	Possible	
	Severity of negative impacts	Critical	
	Risk Multiplier		0.35
	Score		112

Table 009 - Summarised Results

	Technically feasible and achievable		Cost and transpancy				Adjustments				Combined @ 50/50	
Option	Sub-total	Rank	Sub-total	Rank	Preadjustment scores	Rank	PM or T?	Likelihood of Negative	Severity	combined adj	Total	Rank
Do Nothing	79	6	364	4	443	4	0.75	0.6	0.6	0.36	120	6
Salt Water via Barrages	215	5	396	3	610	2	1	0.7	0.5	0.35	214	5
Bioremediation	220	4	214	5	434	5	1	0.7	0.8	0.56	243	3
Revegetation	68	7	453	1	521	3	1	0.8	0.8	0.64	333	2
Neutralisation	247	3	77	7	324	7	0.75	0.7	0.7	0.49	119	7
Provision of fresh water via buybacks	272	1	144	6	416	6	1	0.8	0.7	0.56	233	4
Provision of fresh water via allocations	272	1	440	2	712	1	1	0.8	0.7	0.56	399	1

Appendix G - Local Scale MCA Matrices

Table	001	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Do Nothing	**Current Status**	Draft	**Issues Register Reference**	Table I

Specific	Implement no acidification management option
Measurable	Measure of: • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC)
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability?
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	H=1 / M=0.75 / L=0.5 Value Confidence Score	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	**50**								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	**10**								
A - Option is theoretically viable	25		5			125	6.3	1.00	6.3
B– Theoretically viable on the scale (spatial) required	75			2		150	7.5	1.00	7.5
Sub Total						275	13.8		13.8
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	**45**								
A - Generic Proof of Concept established	15		5			75	16.875	0.75	12.7
B - Proof of Concept established in similar (representative) environments	35			2		70	15.75	0.75	11.8
C – Proof of concept established in Lower Lakes circumstances	50				0	0	0	1.00	0.0
Sub Total						145	32.625		24.5
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	**45**								
A2 – on a localised scale	100			2		200	45	1.00	45.0
Sub Total						200	45		45.0
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**83.2**
8 - Costs to Government (State or Federal)	**50**								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	**70**								
Capital / Establishment costs are minimal	40	10				400	140.0	1.00	140.0
Operational / Maintenance costs are minimal	40	10				400	140.0	1.00	140.0
Decommissioning costs are minimal	20	10				200	70.0	1.00	70.0
Sub Total						1000	350		350.0
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	**30**								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60			2		120	18	0.75	13.5
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40				0	0	0	1.00	0.0
Sub Total						120	18		13.5
Sub-Total - Costs and Transparency									**363.5**
					Total		459		447

Adjustments		
	Preventative Measure or Treatment	**After Event Treatment**
	Likelihood of negative impacts	**Likely**
	Severity of negative impacts	**Dangerous**
	Score	**121**

Table	2	Sponsor / Owner	SA Water	Major Dependencies	See Text
Option Name	Bioremediation	Current Status	Draft	Issues Register	II
Specific	Bioremediation - (Taken to be) addition of organic matter / substrate and Fe to acid generating soils in order to stimulate reduction of sulphate to sulphide (as FeS) and concomitantly consume acidity.				
Measurable	• Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)				
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes (10)	Probable (5)	Unlikely (2)	No/NA (0)	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	50								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10								
A - Option is theoretically viable	25	10				250	12.5	1.00	12.5
B– Theoretically viable on the scale (spatial) required	75		5			375	18.8	0.75	14.1
Sub Total						625	31.3		26.6
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45								
A - Generic Proof of Concept established	15	10				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35		5			175	39.375	0.75	29.5
C – Proof of concept established in Lower Lakes circumstances	50		5			250	56.25	0.75	42.2
Sub Total						575	129.375		105.5
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45								
A2 – on a localised scale	100	10				1000	225	0.75	168.8
Sub Total						1000	225		168.8
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**300.8**
8 - Costs to Government (State or Federal)	50								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70								
Capital / Establishment costs are minimal	40		5			200	70.0	0.75	52.5
Operational / Maintenance costs are minimal	40		5			200	70.0	0.75	52.5
Decommissioning costs are minimal	20		5			100	35.0	1.00	35.0
Sub Total						500	175		140.0
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60		5			300	45	0.75	33.8
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40			2		80	12	0.75	9.0
Sub Total						380	57		42.8
Sub-Total - Costs and Transparency									**182.8**
					Total		618		484

Adjustments		
	Preventative Measure or Treatment	After Event Treatment
	Likelihood of negative impacts	Possible
	Severity of negative impacts	Moderate
	Score	178

Table	3	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Seawater Inundation	**Current Status**	Draft	**Issues Register Reference**	III
Specific	Transfer of seawater into Lake Alexandrina via Barrages to inundate sediments (Prevention).				
Measurable	• Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act) Plus • Sediment salinity				
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	H=1 / M=0.75 / L=0.5 Value Confidence Score	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	**50**								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	**10**								
A - Option is theoretically viable	25		**5**			125	6.3	0.75	4.7
B– Theoretically viable on the scale (spatial) required	75			**2**		150	7.5	0.75	5.6
Sub Total						275	13.8		10.3
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	**45**								
A - Generic Proof of Concept established	15	**10**				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35			**2**		70	15.75	1.00	15.8
C – Proof of concept established in Lower Lakes circumstances	50			**2**		100	22.5	0.75	16.9
Sub Total						320	72		66.4
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	**45**								
A1 – on a large scale	0	**10**				0	0	0.75	0.0
A2 – on a localised scale	100		**5**			500	112.5	0.50	56.3
Sub Total						500	112.5		56.3
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**132.9**
8 - Costs to Government (State or Federal)	**50**								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	**70**								
Capital / Establishment costs are minimal	40		**5**			200	70.0	0.50	35.0
Operational / Maintenance costs are minimal	40		**5**			200	70.0	0.50	35.0
Decommissioning costs are minimal	20			**2**		40	14.0	0.75	10.5
Sub Total						440	154		80.5
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	**30**								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60	**10**				600	90	1.00	90.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40		**5**			200	30	0.50	15.0
Sub Total						800	120		105.0
Sub-Total - Costs and Transparency									**185.5**
					Total		472		318

Adjustments	**Preventative Measure or Treatment**	**Prevention**
	Likelihood of negative impacts	**Likely**
	Severity of negative impacts	**Moderate**
	Score	**134**

Table	004	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Revegetation	**Current Status**	Draft	**Issues Register**	IV

Specific	Re-vegetation – (Taken to be) plant based strategies for remediation of acid sulphate soil (Phytoremediation)
Measurable	• Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	**50**								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	**10**								
A - Option is theoretically viable	25			**2**		50	2.5	0.75	1.9
B– Theoretically viable on the scale (spatial) required	75			**2**		150	7.5	1.00	7.5
Sub Total						200	10.0		9.4
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	**45**								
A - Generic Proof of Concept established	15				**0**	0	0	1.00	0.0
B - Proof of Concept established in similar (representative) environments	35				**0**	0	0	1.00	0.0
C – Proof of concept established in Lower Lakes circumstances	50				**0**	0	0	0.75	0.0
Sub Total						0	0		0.0
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	**45**								
A1 – on a large scale	0			**2**		0	0	1.00	0.0
A2 – on a localised scale	100		**5**			500	112.5	0.75	84.4
Sub Total						500	112.5		84.4
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**93.8**
8 - Costs to Government (State or Federal)	**50**								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	**70**								
Capital / Establishment costs are minimal	40	**10**				400	140.0	0.75	105.0
Operational / Maintenance costs are minimal	40	**10**				400	140.0	0.75	105.0
Decommissioning costs are minimal	20	**10**				200	70.0	0.75	52.5
Sub Total						1000	350		262.5
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	**30**								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60	**10**				600	90	1.00	90.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40		**5**			200	30	1.00	30.0
Sub Total						800	120		120.0
Sub-Total - Costs and Transparency									**382.5**
					Total		593		476

Adjustments	**Preventative Measure or Treatment**	**Prevention**
	Likelihood of negative impacts	**Possible**
	Severity of negative impacts	**Moderate**
	Score	**233**

Table	5	**Sponsor / Owner** SA Water	**Major Dependencies** See Text
Option Name	Neutralisation	**Current Status** Draft	**Issues Register Reference** V
Specific	Treatment Option – acidity control / treatment within the lake sediments and/or water body via addition of alkaline amendment (e.g. limestone, hydrated lime or caustic magnesia).		
Measurable	• Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)		
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc		
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)		
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?		

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	50								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10								
A - Option is theoretically viable	25	10				250	12.5	1.00	12.5
B– Theoretically viable on the scale (spatial) required	75	10				750	37.5	0.75	28.1
Sub Total						1000	50.0		40.6
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45								
A - Generic Proof of Concept established	15	10				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35	10				350	78.75	1.00	78.8
C – Proof of concept established in Lower Lakes circumstances	50		5			250	56.25	0.75	42.2
Sub Total						750	168.75		154.7
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45								
A1 – on a large scale	0			2		0	0	0.75	0.0
A2 – on a localised scale	100		5			500	112.5	0.75	84.4
Sub Total						500	112.5		84.4
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**279.7**
8 - Costs to Government (State or Federal)	50								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70								
Capital / Establishment costs are minimal	40			2		80	28.0	1.00	28.0
Operational / Maintenance costs are minimal	40			2		80	28.0	0.50	14.0
Decommissioning costs are minimal	20		5			100	35.0	0.75	26.3
Sub Total						260	91		68.3
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60				0	0	0	0.75	0.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40			2		80	12	0.75	9.0
Sub Total						80	12		9.0
Sub-Total - Costs and Transparency									**77.3**
					Total		434		357

Adjustments		
	Preventative Measure or Treatment	After Event Treatment
	Likelihood of negative impacts	Possible
	Severity of negative impacts	Moderate
	Score	131

Reference	6	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Freshwater	**Current Status**	Draft	**Issues Register**	VI

Specific	Taken to be: • Buy-back allocations And also • Use of freshwater resources to mitigate acid generation in sediments (Prevention)
Measurable	Buy back: • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) Resource use on sediments • Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	Value Confidence Score (H=1 / M=0.75 / L=0.5)	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	50								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	10								
A - Option is theoretically viable	25	10				250	12.5	1.00	12.5
B– Theoretically viable on the scale (spatial) required	75	10				750	37.5	0.50	18.8
Sub Total						1000	50.0		31.3
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	45								
A - Generic Proof of Concept established	15	10				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35	10				350	78.75	1.00	78.8
C – Proof of concept established in Lower Lakes circumstances	50	10				500	112.5	0.75	84.4
Sub Total						1000	225		196.9
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	45								
A1 – on a large scale	0			2		0	0	0.50	0.0
A2 – on a localised scale	100	10				1000	225	0.75	168.8
Sub Total						1000	225		168.8
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**396.9**
8 - Costs to Government (State or Federal)	50								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	70								
Capital / Establishment costs are minimal	40			2		80	28.0	0.75	21.0
Operational / Maintenance costs are minimal	40		5			200	70.0	0.75	52.5
Decommissioning costs are minimal	20	10				200	70.0	0.75	52.5
Sub Total						480	168		126.0
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	30								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60		5			300	45	1.00	45.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40			2		80	12	1.00	12.0
Sub Total						380	57		57.0
Sub-Total - Costs and Transparency									**183.0**
					Total		725		580

Adjustments	Preventative Measure or Treatment	Prevention
	Likelihood of negative impacts	Likely
	Severity of negative impacts	Moderate
	Score	244

Reference	7	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Freshwater - allocations	**Current Status**	Draft	**Issues Register Reference**	VII
Specific	Taken to be: • Reallocation of water within the River Murray And also • Use of freshwater resources to mitigate acid generation in sediments (Prevention)				
Measurable	Buy back: • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) Resource use on sediments • Porewater geochemistry • Groundwater quality And • Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic) • Ecological component – impact on NES matters (Part 3 EPBC Act)				
Achievable	• Volume FW resource required? • Volume FW available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results? • What is the effective lifespan of the treatment? • How long are we measuring for?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	H=1 / M=0.75 / L=0.5 Value Confidence Score	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	**50**								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	**10**								
A - Option is theoretically viable	25	**10**				250	12.5	1.00	12.5
B– Theoretically viable on the scale (spatial) required	75	**10**				750	37.5	0.50	18.8
Sub Total						1000	50.0		31.3
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	**45**								
A - Generic Proof of Concept established	15	**10**				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35	**10**				350	78.75	1.00	78.8
C – Proof of concept established in Lower Lakes circumstances	50	**10**				500	112.5	0.75	84.4
Sub Total						1000	225		196.9
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	**45**								
A1 – on a large scale	0			**2**		0	0	0.50	0.0
A2 – on a localised scale	100		**5**			500	112.5	0.75	84.4
Sub Total						500	112.5		84.4
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**312.5**
8 - Costs to Government (State or Federal)	**50**								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	**70**								
Capital / Establishment costs are minimal	40		**5**			200	70.0	0.75	52.5
Operational / Maintenance costs are minimal	40		**5**			200	70.0	0.75	52.5
Decommissioning costs are minimal	20	**10**				200	70.0	1.00	70.0
Sub Total						600	210		175.0
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	**30**								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60		**5**			300	45	1.00	45.0
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40	**10**				400	60	0.75	45.0
Sub Total						700	105		90.0
Sub-Total - Costs and Transparency									**265.0**
					Total		703		578

Adjustments		
Preventative Measure or Treatment	**Prevention**	
Likelihood of negative impacts	Likely	
Severity of negative impacts	Moderate	
Score		**243**

Reference	8	**Sponsor / Owner**	SA Water	**Major Dependencies**	See Text
Option Name	Pumping to Lake Albert	**Current Status**	Draft	**Issues Register Reference**	VII
Specific	Taken to be the pumping of saltwater from the Coorong into Lake Albert				
Measurable	• Lake water alkalinity (>25 mg/L) • Lake water elevation (>1.5m AHD) • Lake water salinity (EC< 1500 EC) • Trophic state (oligotrophic)				
Achievable	• Volume required? • Volume available? • Long term availability? • Theoretically possible? • Is there proof of concept, trials etc				
Relevant	Is the option relevant to the Lower Lakes environment? (can the option be practicably implemented?)				
Timebound	• When do we expect to see results?				

Assessment Criteria	Weight (Out of 100)	Alignment with Criteria: Yes 10	Probable 5	Unlikely 2	No/NA 0	Raw Value Score	Weighted Value Score	H=1 / M=0.75 / L=0.5 Value Confidence Score	Confidence Weighted Score
4 - Technically feasible and achievable in practice on the scale required	**50**								
4.1 TECHNICALLY FEASIBLE (theoretically, will it work?)	**10**								
A - Option is theoretically viable	25		**5**			125	6.3	0.75	4.7
B– Theoretically viable on the scale (spatial) required	75		**5**			375	18.8	0.75	14.1
Sub Total						500	25.0		18.8
4.2 ACHIEVABLE IN PRACTICE (Has it been proven to work?)	**45**								
A - Generic Proof of Concept established	15	**10**				150	33.75	1.00	33.8
B - Proof of Concept established in similar (representative) environments	35		**5**			175	39.375	1.00	39.4
C – Proof of concept established in Lower Lakes circumstances	50			**2**		100	22.5	0.75	16.9
Sub Total						425	95.625		90.0
4.3 - Implemented successfully before acidification of the Lakes occurs – Dec 2010	**45**								
A1 – on a large scale	0	**10**				0	0	0.75	0.0
A2 – on a localised scale	100		**5**			500	112.5	0.50	56.3
Sub Total						500	112.5		56.3
B – The Lakes can be returned to their pre-action trophic state	*To be assessed qualitatively*								
C – A salinity of <1500EC is achievable in the long term									
D - An alkalinity concentration >25mg/l is maintained in the Lower Lakes									
Sub-Total - Technically feasible and achievable in practice on the scale required									**165.0**
8 - Costs to Government (State or Federal)	**50**								
8.1 DIRECT LIFECYCLE COSTS (Dollar costs directly apportioned to the entire lifecycle of the option.)	**70**								
Capital / Establishment costs are minimal	40				**0**	0	0.0	1.00	0.0
Operational / Maintenance costs are minimal	40			**2**		80	28.0	1.00	28.0
Decommissioning costs are minimal	20			**2**		40	14.0	0.75	10.5
Sub Total						120	42		38.5
8.2 INDIRECT OR ENVIRONMENTAL COSTS & BENEFITS (Limited to impacts that Government may be liable for through the application of the option)	**30**								
Minimises the extent of indirect costs in other environments (geographically distinct from Lower Lakes Region)	60		**5**			300	45	0.75	33.8
Maximises the indirect benefits experienced in the wider Lower Lakes Region (eg/ tourism, agriculture, wine, lifestyle)	40			**2**		80	12	0.75	9.0
Sub Total						380	57		42.8
Sub-Total - Costs and Transparency									**81.3**
					Total		332		246

Adjustments		
	Preventative Measure or Treatment	Prevention
	Likelihood of negative impacts	Possible
	Severity of negative impacts	Critical
	Score	86

Table 009 - Summarised Results

	Technically feasible and achievable		Cost and transpancy		Adjustments						Combined @ 50/50	
Option	Sub-total	Rank	Sub-total	Rank	Preadjustment scores	Rank	PM or T?	Likelihood of Negative	Severity	combined adj	Total	Rank
Do Nothing	83	7	364	2	447	5	0.75	0.6	0.6	0.36	121	7
Salt Water via Barrages	133	5	186	4	318	7	1	0.6	0.7	0.42	134	5
Bioremediation	301	3	183	6	484	3	0.75	0.7	0.7	0.49	178	4
Revegetation	94	6	383	1	476	4	1	0.7	0.7	0.49	233	3
Neutralisation	280	4	77	7	357	6	0.75	0.7	0.7	0.49	131	6
Provision of fresh water via buybacks	397	1	183	5	580	1	1	0.6	0.7	0.42	244	1
Provision of fresh water via allocations	313	2	265	3	578	2	1	0.6	0.7	0.42	243	2