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## MUTTON COVE

### **Statement of context for the report: *Mutton Cove: Levee breach risk assessment***

Mutton Cove is Crown Land under the care and control of the Minister for Sustainability, Environment and Conservation. While often referred to as a Conservation Park, it is not a Conservation Park under the *National Parks and Wildlife Act 1972*.

In the past, the Coastal Protection Board has funded repairs to the levee, in the last few years, they have decided not to fund any further repairs to the levee.

As at March 2015, the Minister is supporting the Department of Environment, Water and Natural Resources position to not repair or replace the levee. This is based on the cost of such repairs and that the environmental changes are acceptable, with the environment expected to shift from a samphire dominated to mangrove dominated system. In the past the area was more mangrove dominated than it is today. Other areas of samphire exist along the northern Adelaide coastline and are to be further protected, under the *National Parks and Wildlife Act 1972* as part of the Adelaide International Bird Sanctuary.

The Adelaide and Mt Lofty Ranges Natural Resources Management Board does not have any responsibility or authority in relation to the levee at Mutton Cove. The Board, in the past, has funded environmental improvement activities at Mutton Cove with the Coast Protection Board and the Friends of Mutton Cove as part of implementing the *Metropolitan and Northern Coastal Action Plan*.

This assessment report was prepared to assist the Board in understanding the potential environmental changes and rate of change to the Mutton Cove environment from the levee breaching to guide future investment in environmental projects at the site and within the region more generally. Future Board investment in this area will need to take into account any local change or impacts on the environment as well as the potentially competing needs of the environment at a regional scale. Local impacts may not be significant at a regional scale and opportunities may exist for co-investment to address regional priorities.

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# Mutton Cove:

## Levee breach risk assessment

**29 January 2015**

**Prepared for:** Natural Resources Adelaide & Mt Lofty Ranges



<b>Consultant:</b>	Peri Coleman  Delta Environmental Consulting  12 Beach Road, St Kilda SA 5110
<b>Telephone:</b>	08 8280 5910
<b>Facsimile:</b>	08 8280 5179
<b>Email:</b>	<a href="mailto:peri@deltaenvironmental.com.au">peri@deltaenvironmental.com.au</a>
<b>Website:</b>	<a href="http://www.deltaenvironmental.com.au">www.deltaenvironmental.com.au</a>

## MUTTON COVE: LEVEE BREACH RISK ASSESSMENT

### **LIMITATIONS STATEMENT**

The sole purpose of this report and the associated services performed by Delta Environmental Consulting is to assess the risk to the habitats of Mutton Cove Coastal Conservation Reserve associated with a breaching of the seawall levee. This risk assessment is conducted in accordance with the scope of services set out in the contract between Delta Environmental Consulting ('Delta') and NR:AMLR ('the Client'). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

Delta derived the data in this report primarily from visual inspections, examination of records in the public domain and interviews with individuals with information about the site. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data, analysis and a re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, Delta has relied upon and presumed accurate certain information (or the absence thereof) relative to the site, provided by government officials and authorities, the Client and others identified herein. Except as otherwise stated in the report, Delta has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by Delta in this report are not, and should not be considered, an opinion concerning environmental or operational liability. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon site conditions and information in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Delta and the Client. Delta accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

### **Document history**

Initial (internal) review: 30/12/2014 (PC)

First draft issued for review: 30/12/2014 (PC)

Second draft: 7/1/2015 (modification of introduction, edits per DM – NR:AMLR)

Third draft: 16/1/2015 (additional risk assessments per TF, ES – NR:AMLR)

Final version released: 29/1/2015 (exec summary - PC)



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## EXECUTIVE SUMMARY

Mutton Cove retains the last vestiges of the back barrier saltmarshes along the Port River edge of the LeFevre Peninsula. The *Metropolitan Adelaide and Northern Coastal Action Plan* identifies Mutton Cove as a significant, partly rehabilitated, remnant mangrove and saltmarsh. Maintenance of the levee is identified as a high priority conservation action (Caton *et al*, 2009).

The building of the seawall levee around this saltmarsh in the 1970s resulted in the site drying out and subsiding after acid sulfate soils developed, with a resultant reduction in the range of habitats present in the Cove. Returning the Cove to the habitat range it supported prior to 1963 was the stated aim of the management plan for the site, developed in response to widespread community consultation (Cook and Coleman 2003). In order for that aim to be realised in this deeply subsided site, the pattern of tidal inundation for the Cove needs to remain restricted, within a fairly narrow tolerance. This is managed by the maintenance of the levee and a series of tidal exchange pipes.

Natural Resources – Adelaide & Mt Lofty Ranges has requested a desktop risk assessment to look at the possible outcomes in the event of the seawall breaching, leading to additional flooding of the site.

A review of site elevations and tidal return intervals highlighted that some types of breaches - those that opened the seawall down to levels of around 1 m AHD (Australian Height Datum) or even lower – would present a high risk of permanent changes in the habitats present on the site, should the breaches not be repaired.

Further high risks were identified, including the potential exacerbation of some of the acid sulfate soil conditions on site, in particular the discharge of mono-sulfidic black ooze (MBO) to the river. The Port River is part of the Adelaide Dolphin Sanctuary and the discharge of MBO could result in anaerobia and fish kills. Other risks identified in this assessment include the possibility of potential on-site or off-site soil contamination being mobilised into groundwater and discharging to the Port River, impacts on recreational users of the site, possible loss of cultural values and potential increases in the difficulty of managing the site for weed and feral animal control, vandalism, dumping and inappropriate uses.

The use of either preventative maintenance (levee inspections and rocking of vulnerable areas) or rapid mitigation after any breaches occurred would reduce all the risks considerably.

A summarised risk table is presented on the next page.

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Risk event	Risk prior to implementation of controls			Possible control or remediation methods	Residual risk if controls implemented		
	Likelihood	Consequence	Risk level		Likelihood	Consequence	Residual level of risk
Vegetation changes from increased inundation where levee is breached down to a level above ≈1.6 mAHd	C	4	Minor	Preventative rocking of seawall	D	5	Low
				Rapid repair of any breaches	C	5	Low
Vegetation changes from increased inundation where levee is breached down to a level ≈1.0 mAHd	C	2	Extreme	Preventative rocking of seawall	D	5	Low
				Rapid repair of any breaches	C	5	Low
Vegetation changes from increased inundation where levee is breached down to a level below 0 mAHd	C	1	Extreme	Preventative rocking of seawall	D	5	Low
				Reconstruction of seawall after a breach	C	5	Low
Increased inundation of Mutton Cove mobilises contaminants from cinders in the southern filled area	D	4	Low	Preventative maintenance and/or rapid repair of breaches	E	4	Low
Increased inundation of Mutton Cove mobilises contaminants from pyrites in nearby areas outside Mutton Cove	D	3	Moderate	Preventative maintenance and/or rapid repair of breaches	E	4	Low
MBO (in benthos of tidal creek) discharge to the river, where levee is breached at a position <b>above</b> the bottom of the tidal pipes	D	4	Low	Preventative maintenance and/or rapid repair of breaches	D	5	Low
MBO (in benthos of tidal creek) discharge to the river, where levee is breached at a position <b>below</b> the bottom of the tidal pipes	A	3	High	Preventative maintenance and/or rapid repair of breaches	D	4	Low
Breached or unsafe seawall (subject to closures) reduces recreational opportunities for bike/hike track users	B	4	High	Preventative maintenance and/or rapid repair of breaches	C	5	Low
Rapid and extensive mangrove growth at Mutton Cove alienates the wreck of the Excelsior from view	C	4	Moderate	Preventative maintenance and/or rapid repair of breaches	D	4	Low
Loss of access along seawall may hamper management actions	B	4	Minor	Preventative maintenance and/or rapid repair of breaches	C	5	Low



## INTRODUCTION

Natural Resources – Adelaide & Mt Lofty Ranges manages a tidally restricted remnant saltmarsh on the northern Le Fevre Peninsula. The site was historically impounded with a seawall embankment and several pipes to allow some ingress and egress of waters. Over time these pipes became blocked, acid sulfate soils developed and the site subsided.

When tides were reintroduced to the site in 2003 by the cleaning out of the existing pipes and addition of two more pipes, it was necessary to retain a degree of tidal restriction in order to ensure that the full range of saltmarsh habitats was maintained. Simply breaching the impounding embankment would have resulted in excessive inundation and the saltmarshes of the site would have been lost (Cook and Coleman, 2003). Over the intervening decade continued erosion of the seawall has occurred, as it lies adjacent to a busy port waterway used by large seagoing cargo ships. The wall, where it is not protected by mangroves, is subject to heavy wake wash. The small areas of mangroves are also eroding, for the same reason. Natural Resources – Adelaide & Mt Lofty Ranges has requested a desktop risk assessment to look at the possible outcomes if the seawall barrier degrades further.



Figure 1 - Eroding stand of mangroves

MUTTON COVE:  
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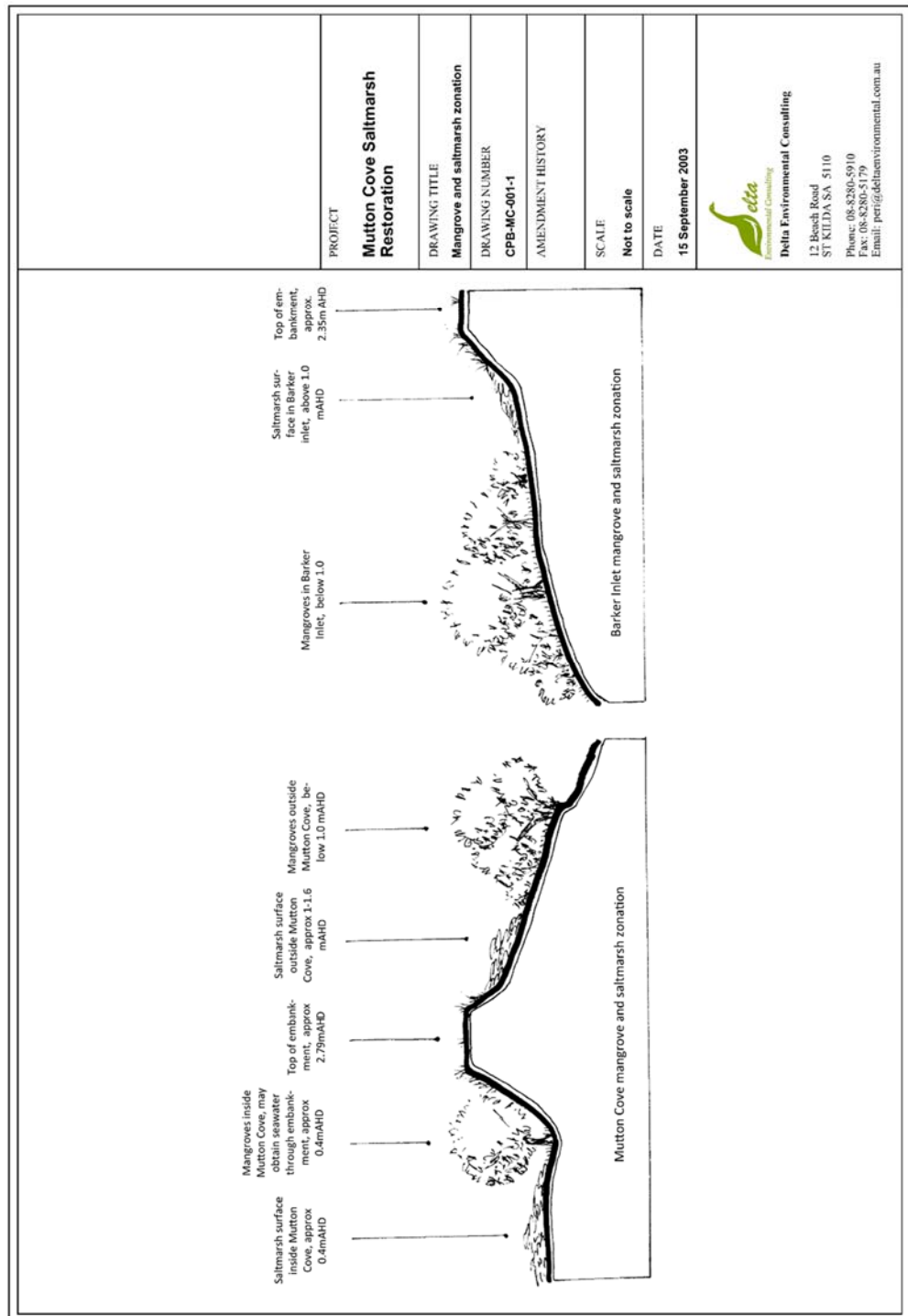


Figure 2 – Typical site cross section compared to tidally unrestricted sites (Cook & Coleman, 2003)



## SITE DESCRIPTION

### TOPOGRAPHY

The management plan for Mutton Cove (Cook and Coleman, 2003) was developed using minimal topographic information – a twenty year old point survey and a few tide pegs placed in the saltmarsh inside and outside the seawall levee using a dumpy level from the local benchmarks. The collected data indicated that the majority of the marsh plane at Mutton Cove had subsided since being isolated from the tides, as a result of oxidation of potential acid sulfate soils.

The resultant subsided marsh plane lay between 0.3 mAHD and 0.55 mAHD elevation. This was considerably lower than similar habitats that were not tidally restricted around Barker Inlet. Unrestricted tidal habitats tend to support mangroves below 0.95 mAHD and the lowest marsh plane grows on land above 0.95 mAHD. Figure 2, on the previous page, represents transects taken at unrestricted mangrove and saltmarsh sites in Barker Inlet, compared to a transect through Mutton Cove, from the mangroves and saltmarshes seaward of the impounding embankment and then across the impounded saltmarsh.

To undertake a reasonably thorough risk assessment, more recent site topography was required than that provided in the management plan, which relied on a Department of Marine and Harbours survey (1982). Recent LIDAR data, provided by Natural Resources – Adelaide & Mt Lofty Ranges, were extracted by EcoProTem and a contour map was produced.

This new contour map was compared to the old point survey drawing derived from aerial photography (Department of Marine and Harbours, 1982). The survey points generally fell inside the appropriate contour bands of the new LIDAR image. Agreement between the two surveys was excellent where site elevations were higher than 1m AHD. In low elevation areas there are some small (10 to 20 cm) discrepancies between the older data and the new data, particularly adjacent to the creeks. The differences may be a result of inaccuracies in either survey, or a result of further subsidence that may have occurred after 1982 and before tidal inundation was reinstated in 2003. Survey staff from the Conservation and Land Management Branch of DEWNR are hoping to undertake a surveyed elevation and vegetation transect during 2015 and the data from such a survey would also be helpful in calibrating the LIDAR data.

The LIDAR mapping confirms just how flat, and how subsided, the site is. The majority of the marsh plain is lower than 1.0 mAHD in elevation. In fact, most of the plain lies between 0.13 mAHD and 0.53 mAHD. The remnant areas of chenier and other small rises in the marsh plain do not exceed 1.3 mAHD. These account for less than 5% of the marsh plain area. Only the filled southern portion of the site and the bounding embankments exceed that height.



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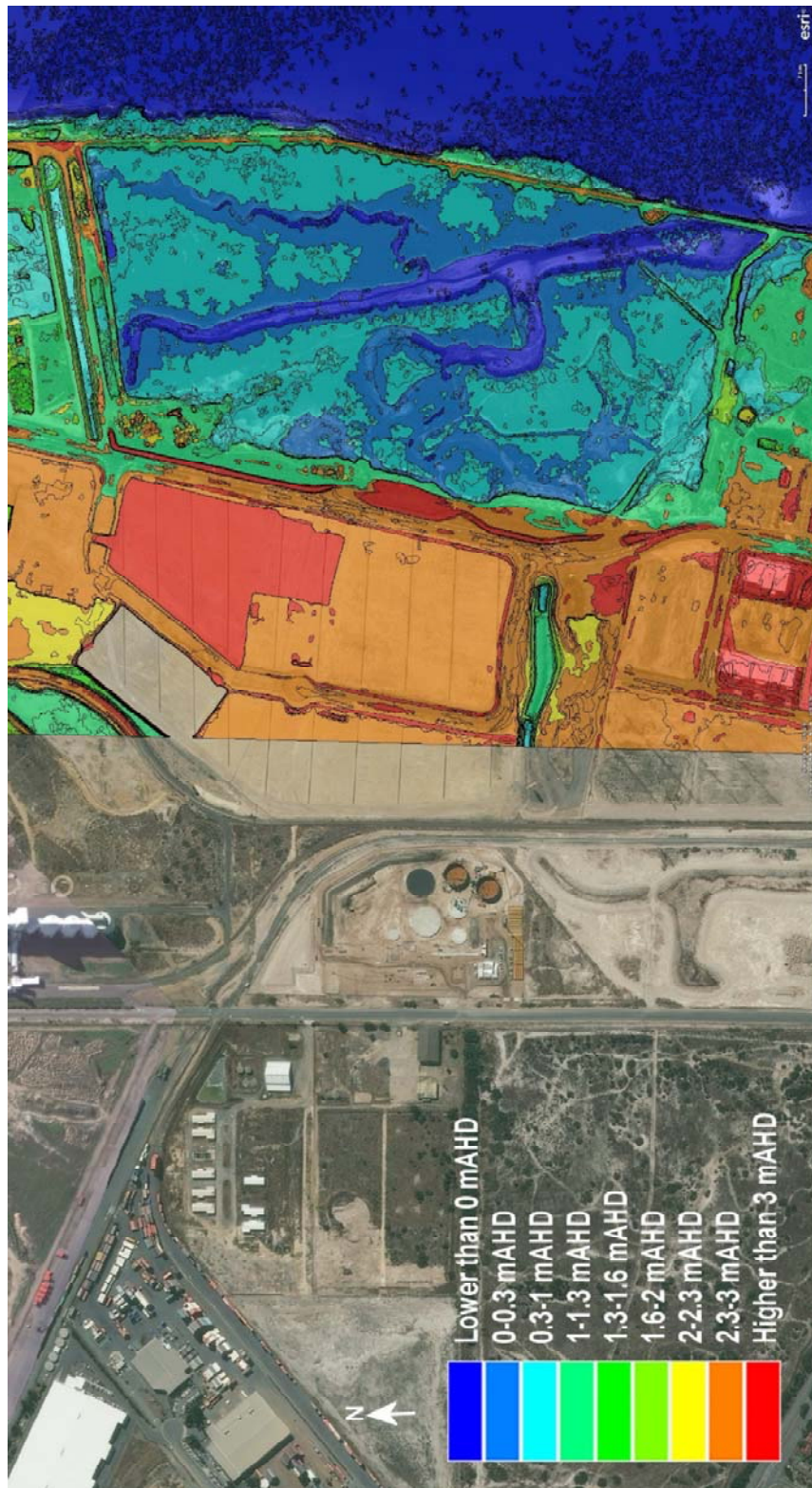


Figure 3 - Site topography, derived from LIDAR 2012



### SURROUNDING FILL

The back barrier swamps forming the tip of the LeFevre Peninsula were encircled with embankments progressively after 1909 up until the late 1970s. The bunded area was used as a repository for fluvial fill dredged from the shipping channel in the river, and for waste materials from other local industries. As the creek at Mutton Cove served to discharge the supernatant water from the dredge spoil settlement ponds, the Cove was the last remaining area of natural surface by the time most filling ceased in the mid-1980s. When filling ceased, soil surveys were conducted by Marine & Harbours and these surveys were used as part of the development studies undertaken for the Multi Function Polis project (Kinhill Delfin 1991, Maunsell 1995).

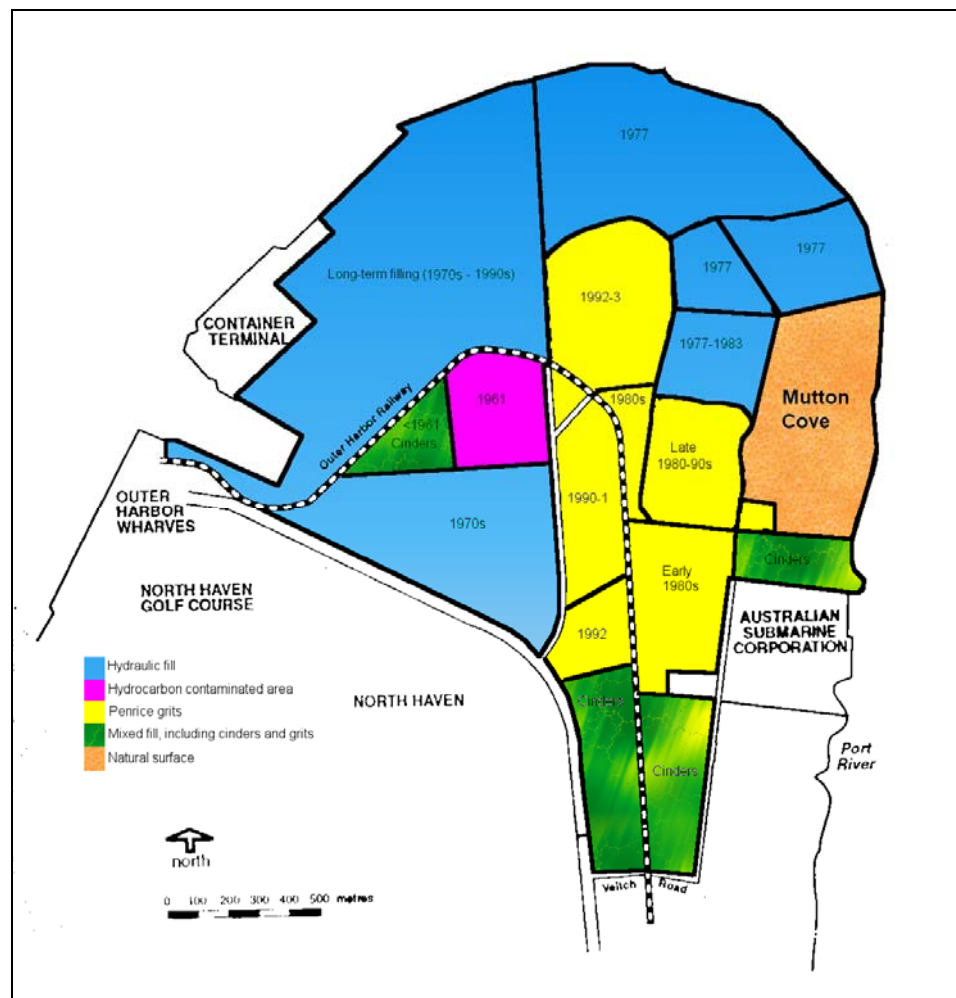


Figure 4 - Map of fill, derived from Maunsell (1995)

## MUTTON COVE: LEVEE BREACH RISK ASSESSMENT

Maunsell's report (1995) found that the southern filled area of sandy soil at Mutton Cove was underlain by cinders and ash in a narrow strip inland of the seawall between the Mutton Cove Creek and the Australian Submarine Corporation.

Between Mutton Cove and Biodiversity Park both consultant reports recorded pyritic wastes from the Acid Plant at Taperoo, overlain with Penrice grits, an alkali waste. The most usual ions associated with sulfides as pyrites are iron and copper, however a blend of minerals such as silver, lead, zinc and arsenic may also form sulfides. These are known to occur in the southern Mt Lofty Ranges, for example silver-lead-arsenopyrites are found at Talisker and deposits of other metal sulfides are found at Brukunga in the Adelaide Hills. However, a soil sample taken by Kinhill Delfin (1991) close to this vicinity revealed no metals with concentrations above the Interim Urban Ecological Investigation limits or above the Health Investigation Limits for Recreational Areas (NEPC, 1999)

North and north-west of Mutton Cove the fill material was apparently hydraulic fill which was considered relatively benign.

Other sites on the western side of the peninsula (the old Steelmains site and the Amoco storage terminal) were found by the same studies to be contaminated with petroleum derivatives and heavy metals. Bores determined that the groundwater elevation was between mean sea level and 1 mAHD, unsurprising considering that the peninsula is a very recent sand spit. Groundwater flows locally are towards the north, with micro flows along the original sand dune formations. This means that any petroleum spills from these contaminated sites are unlikely to drain towards Mutton Cove (Maunsell 1995, Kinhill Delfin 1991).

Since the reports undertaken in the 1990s there have been further changes in the nearby topography. When the Common User Facility (ship-lift) was being built after 2006, land between Mutton Cove and the railway was used as a disposal site (Figure 5) for the materials retrieved from the river during the dredging of the ship-lift pocket and the fitting-out berth pocket. These filled areas were then levelled and stabilized with grasses before being offered for sale for maritime industrial and supply uses.

Finally, a connecting link between Mutton Cove and Biodiversity Park was redeveloped, according to *Detailed Master Planning and Open Space on the Northern LeFevre Draft Master Plan* (Aurecon, 2010). Irrigated and landscaped open space, cycling and pedestrian paths and stormwater detention basins servicing the Osborne Maritime Precinct were developed. Pyritic and other wastes directly underlying the proposed stormwater detention basins were to be excavated and replaced with "engineered fill" during this development (Aurecon 2010).



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Figure 5 - Dredge disposal site for CUF (designated MEC6a)

### MUTTON COVE'S TIDES

Seawater enters Mutton Cove through pipes, and these restrict the tidal range within the site. When the seawall was built in the 1970's the pipes initially allowed sufficient tidal water ingress and egress to maintain the saltmarsh and mangroves inside the site. Over time the pipes blocked, leading to further restriction in tidal movement, as well as the death of mangroves in the Cove and significant subsidence as a result of the oxidation of acid sulfate soils.

In 2003 there was about a 2 hour lag time for the tides inside the Cove when compared to those in the river, and the tides were truncated at the top and bottom of their range by about 0.75m (see Figure 6). The truncation of the top of the tide is entirely to do with the length of time of the lag – the rising tide inside the Cove intersects with the falling tide outside. It was considered that a reduction of lag time (by increasing flows into the Cove) would result in higher high tides. The truncation at the bottom of the tide was considered more recalcitrant, as the Cove can only drain out to an elevation that matches the bottom of the lowest pipe (approximately -0.4 mAHD). As the Cove drained to that level even with the restricted pipes it seemed unlikely that pipe rejuvenation would have any impact on the truncation of the low tide.

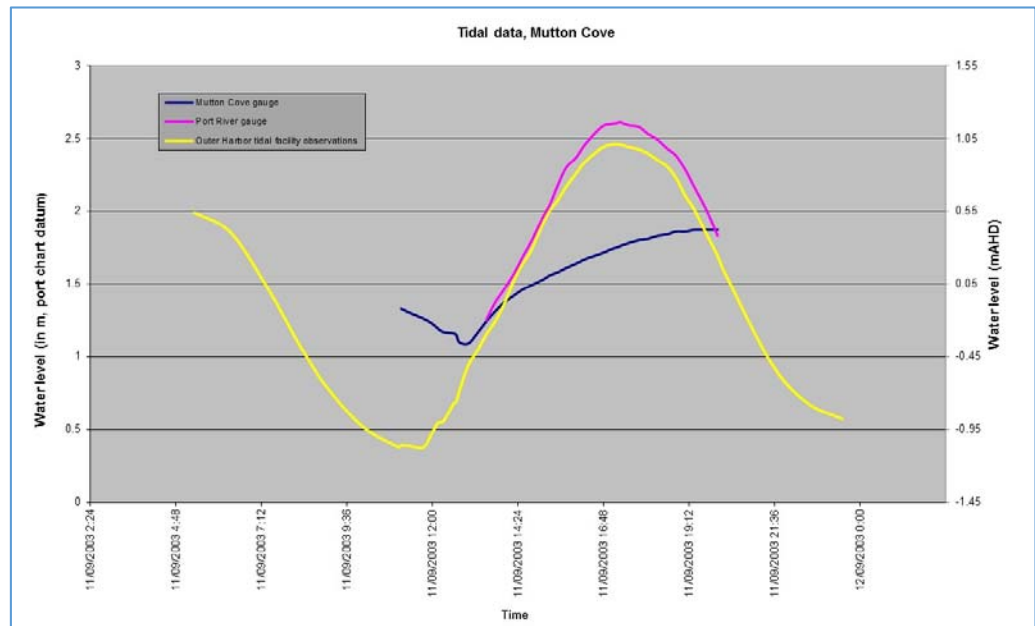


Figure 6 – Tidal restriction at Mutton Cove, 2003, prior to pipe restoration.

Pegs were placed into the *Sarcocornia* marsh at Mutton Cove (elevation 0.4 mAHD) and Barker Inlet (elevation 0.95 mAHD). The tidal restriction resulted in the *Sarcocornia* zone at Mutton Cove flooding on about 25 occasions of the year. The *Sarcocornia* zone at the measured Barker Inlet site floods on more than 145 occasions a year. Around Barker Inlet more widely, the *Sarcocornia* zone is documented as flooding between 100 and 350 times annually (Fotheringham 1994).

Once the pipes into the Cove were cleaned out in 2003 and a new basin was built to prevent them from blocking again, the pattern of tidal flooding improved, with a much shorter lag time and the “top” truncation of the tides being reduced to 0.28m. This improvement resulted in tidal waters entering the *Sarcocornia* low marsh plain at Mutton Cove on about 250 occasions per year.

#### VEGETATION AND INUNDATION

Because the patterns of vegetation in saltmarshes are banded according to elevation, it is tempting to assume that elevation is the important factor – but it is only the driver for the factor that counts – frequency of inundation.

Mutton Cove initially (prior to 1963) supported a mixed mangrove and saltmarsh habitat, with the marsh plain supporting approximately 50% mangroves (Cook and Coleman 2003) and a mixture of wetter (*Sarcocornia quinqueflora*) and drier (*Tecticornia arbuscula* and *T halocnemoides*) saltmarsh. Once the site became tidally restricted the mangrove population died, except for a small rim of trees along the seawall embankment, the land subsided and most of the marsh plain could only support aging saltmarsh shrublands.

Based on the flooding regime established after the pipe restoration, the tidal data collected for that year (2003), and records of vegetation elevation and flooding frequency for Barker Inlet developed by Fotheringham (1994), it was estimated that the marsh at Mutton Cove would receive the types of inundation frequencies for the specified elevation ranges detailed in Table 1, on the following page.

A decade after the restoration of tidal flows, the site vegetation (except the filled areas and the embankments) is currently a mixture of low and mid marsh species, with an expanding rim of mangroves along each creek line in addition to the mangroves that existed prior to the restoration along the seawall embankment. The mangroves have gradually re-established themselves and now there are a range of age cohorts, with the oldest trees being sufficiently mature that they are carrying reproductive propagules. It is likely, if the inundation regime stays as it is, that mangroves will slowly continue to expand until they occupy much of the area that has an elevation lower than 0.6m AHD. This would return the site to the state it was in prior to 1963, with about 50% mangrove and most of the remainder being low-mid saltmarsh. The tiny areas of chenier would likely support high marsh species. The highest site landforms (the filled

## MUTTON COVE: LEVEE BREACH RISK ASSESSMENT

areas and the embankments) are being revegetated and would support dunal vegetation and a lower rim of *Melalucua halmaturorum*.

This gradual evolution, ensuring the widest range of back barrier wetland habitats in the Cove, was the stated aim of the management plan for the site (Cook and Coleman 2003). It was considered that this target would take some decades to be realised, and that some reduction in tidal exchange may be required eventually in response to future sea level rise. Considerable investment in rehabilitation to a managed tidal inundation regime and revegetation of this area has been undertaken by the community, Coast Protection Board and NR:AMLR to retain this significant saltmarsh remnant on LeFevre Peninsula.

Vegetation association	Inundation frequency	Elevation range (mAHD) in unrestricted marsh (Barker Inlet)	Elevation range (mAHD) in tidally restricted marsh (Mutton Cove)
<i>Avicennia marina</i> (mangrove woodland)	Twice daily (350-700 pa)	0.4m to 0.7m	Lower than 0.4m
<i>Sarcocornia</i> and <i>Tecticornia arbuscula</i> with scattered <i>Avicennia</i> (submergent low marsh transitioning to mangrove woodland)	Daily (350 pa)	0.7m to 0.92m	0.4m to 0.6m
<i>Sarcocornia quinqueflora</i> and <i>Tecticornia arbuscula</i> (submergent low marsh)	Daily to twice weekly (100-350 pa)	0.7m to 1.0m	0.4m to 0.75m
<i>Tecticornia halocnemoides</i> shrubland (emergent mid marsh)	Twice weekly to monthly (25-100 pa)	0.85m to 1.25m	0.65m to 0.85m
<i>Maireana oppositifolia</i> shrubland (emergent mid-high marsh)	Monthly to 6-monthly (5-25 pa)	1.13m to 1.7m	0.85m to 0.92m
<i>Atriplex paludosa</i> shrubland (emergent high marsh)	Less than twice a year (<5 pa)	Higher than 1.7m	Higher than 0.92m

Table 1 - Estimated vegetation flooding frequency preferences and elevation ranges

### RISK ASSESSMENT

Levee breaches could allow an unrestricted tidal prism to develop across the site, to a greater or lesser extent, depending on the size and location of any breaches. Breaches of the seawall could occur in areas where the seawall is fronted or backed by marsh plain, and such breaches would have a different effect to breaches that could occur at



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creek lines. These two types of breaches are described in this report as “high elevation” and “low elevation” breaches.

The resulting increased inundation could present a number of risks to both on-site habitats and off-site environments.

As a result of the development of acid sulfate soil conditions in the past, site elevations are significantly lower than “normal” for the habitats that are present on the site, so the increased inundation would be likely to cause rapid changes in the vegetation of the site, reducing habitat diversity.

The increased inundation may also mobilise contaminants in nearby areas of fill, or may exacerbate some aspects of the acid sulfate soils present on the site.

As the levees support the access tracks for the site, breaches may impact on recreational values and may make other maintenance activities on the site more difficult.

Qualitative assessment of the risk of high elevation breaches and low elevation breaches is presented in the next few pages, following the process outlined in AS/NZS 4360. In a qualitative risk assessment the risk associated with any particular event can be classified for comparative purposes using the following matrix:

			Likelihood of consequence				
			E	D	C	B	A
			Rare	Unlikely	Possible	Likely	Almost Certain
Severity of consequence	5	Insignificant	Low	Low	Low	Moderate	High
	4	Minor	Low	Low	Moderate	High	High
	3	Moderate	Moderate	Moderate	High	High	Extreme
	2	Major	High	High	Extreme	Extreme	Extreme
	1	Catastrophic	High	Extreme	Extreme	Extreme	Extreme

**Table 2 - Risk matrix**

Risks are not absolute. The full range of risks is present for small local events and areas, and the same range of risks is present for large global events. Needless to say, the risks between such extremes are not comparable. For this particular analysis, **Likelihood of consequence** is defined as:

- Almost certain - will occur, or is of a continuous nature, or the likelihood is unknown
- Likely - will probably occur every year or so
- Possible - could occur over a decade or two
- Unlikely - is not likely to occur in the average lifetime
- Rare - has never occurred but conceivably could



**Severity of Consequence** for this assessment revolves around the risk of permanent habitat change on-site, or the extent of any off-site impacts, and is defined as:

- Insignificant - possible impacts but not easily noticed
- Minor – very **temporary** consequence
- Moderate – **significant temporary** changes on-site or localised impacts off-site, but can be rehabilitated, remediated or mitigated with difficulty at significant cost
- Major - **permanent** changes on-site, or widespread off-site impacts, only partially able to be rehabilitated or alleviated
- Catastrophic – **substantial permanent** changes to the natural environment (not able to be practically or significantly rehabilitated or alleviated)

It may be possible to reduce the likelihood of risks occurring, and any risks that eventuate may be able to be mitigated. If it is possible to take action to further reduce the likelihood of a risk eventuating or the severity of the consequences, it can be considered that the residual risk may be reduced, and this “residual risk”, after all risk reduction and amelioration strategies are implemented, is reflected in the risk tables.

#### CHANGES TO HABITAT AND VEGETATION

High elevation breaches may be the result of undercutting the top part of the levee from wave action during storms, or as a result of the wash from regular passage of large ships at high tide. Breaches are most likely to occur where there is no protection on the seaward side of the levee – where there are mangroves and saltmarsh outside the levee there has rarely been damage to the levee structure to date. Such breaches are likely to occur along the northern part of the seawall where it is backed inside the Cove with marsh plain, rather than a creek line.

This type of breach is possible, as several partial collapses of the upper seawall in the northern area have occurred over the past ten years, although it is believed there has not been complete breaching to date.

A very high elevation breach would increase tidal flooding hardly at all, with only storm surges penetrating a breach that was only down to 1.6 mAHd, resulting in only insignificant changes to habitat beyond those foreseen in the management plan for the Cove.

A more substantial breach, down to 1 mAHd would rapidly widen. Tidal data suggest that a substantial breach to this elevation could result in water across the site reaching the same elevation as the outside tides on average 100 times in most years, including areas that currently flood only twice a year.

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In this case, if the breach were left unrepaired, mangroves would more rapidly colonise across the site and only very small areas of low marsh (*Sarcocornia*) would eventually remain on the areas currently occupied by cheniers and as a very narrow rim along the encircling embankments. The mid and high marsh types and chenier dune habitats on the marsh plain would be permanently lost.

Breaches that could occur where the main creek line of Mutton Cove meets the seawall have the potential to be substantive. Breaches here are possible as there is no protection on the seaward side of the seawall at this location, there is open water landward of the seawall for some distance to the marsh plain inside the Cove, and it is not known how well the wall is founded. A large breach to a low level would result in a totally unrestricted high tide pattern developing across the site, combined with the potential for ponding at low tide, in the event that the breach not reach below the base of the tidal pipes.

The resultant site conditions on the marsh plain would be as wet as possible, and the mangroves currently lining the creeks would start to move rapidly landward. Fotheringham (1994) has recorded mangrove fronts advancing at up to 18m per annum in parts of Barker inlet near the Little Para. With many of the mangroves in Mutton Cove now being mature enough to carry propagules there is no reason to suspect they would not advance at a similar rate should conditions suit them.

The maximum distance from any point on the marsh plain at Mutton Cove to a creek line is less than 100m and over 95% of the marsh plain lies under 1 mAHD. Even making allowance for the fact that some of the smaller creeks have only recently been colonised by immature mangroves, it would seem reasonable to expect that in the saturated conditions of full tidal inundation, Mangrove Cove's marsh plain would be completely converted to mangroves within one or two decades.

Preventative maintenance to minimise the risk along the seawall would involve regular inspections to identify vulnerable locations, followed by rock armouring those locations as they became evident. An alternative to preventative maintenance is to mitigate by repairing the wall whenever breaches or partial collapses occur. The latter has been the process to date.

Mitigation by repairing the wall in the event of a breach to a low elevation is likely to be a much more expensive option than repairing high level breaches, as the seawall would need to be completely rebuilt. This is likely to take some time and there may be a period where increased inundation causes an acceleration of mangrove migration in the Cove. Providing the seawall is completed fairly rapidly, the site would then redry and mangrove movement should slow again.

The identified risk of vegetation change reducing habitat diversity may be either prevented, or may be rapidly mitigated after a breach occurs. Either approach reduces the residual risk to low.



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Risk event	Risk prior to implementation of controls			Possible control or remediation methods	Residual risk if controls implemented		
	Likelihood	Consequence	Risk level		Likelihood	Consequence	Residual level of risk
Vegetation changes from increased inundation where levee is breached down to a level above $\approx 1.6$ mAHd	C	4	Minor	Preventative rocking of seawall	D	5	Low
				Rapid repair of any breaches	C	5	Low
Vegetation changes from increased inundation where levee is breached down to a level $\approx 1.0$ mAHd	C	2	Extreme	Preventative rocking of seawall	D	5	Low
				Rapid repair of any breaches	C	5	Low
Vegetation changes from increased inundation where levee is breached down to a level below 0 mAHd	C	1	Extreme	Preventative rocking of seawall	D	5	Low
				Reconstruction of seawall after a breach	C	5	Low

Table 3 - Risk table for loss of habitat diversity

## MOBILISATION OF ON-SITE & OFF-SITE CONTAMINATION

There are areas of contaminated soils on the site. Cinders and ash are found in the southern part of the site. Much of this area is quite high, being between 2.3 mAHd and 3 mAHd. The Maunsell report (1995) shows cinders and ash were dumped in a layer about 0.75m thick at the top of the soil profile, with about 2m of brown sand or clayey sand below the cinders, and seaweed detritus below that. Should this accurately reflect the distribution of the cinders and ash, then it is probable the elevation of the cinders may be above that the tides would regularly reach, even in the event that the Cove seawall was breached completely resulting in unrestricted tides.

The low lying marsh plain appears to be the subsided natural surface and so site contamination from wastes or dumped materials in this area is unlikely.

The EPA has previously advised that it is important to reduce water movement through off-site areas where pyrites was dumped historically, to ensure that heavy metals or other chemicals remain in-situ. That said, the area identified as potentially containing pyrites has more recently been used to contain hydraulic dredge spoil during the construction of the Common User Facility in the 2 years following 2006. Presumably



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this activity did not result in mobilisation of significant quantities of heavy metals, as the activity was approved by and under the oversight of the EPA.

More recently pyritic materials were listed as being potentially present in the area proposed for the construction of stormwater detention facilities between Mutton Cove and Biodiversity Park. While Aurecon (2010) stated the materials would be removed and engineered fill used to reform the land, it is not known whether adjacent filled areas also contain pyritic material. If any pyrites remains in the profile adjacent to the detention ponds, the stormwater ponds themselves may provide sufficient head to mobilise contaminants towards Mutton Cove.

Risk event	Risk prior to implementation of controls			Possible control or remediation methods	Residual risk if controls implemented		
	Likelihood	Consequence	Risk level		Likelihood	Consequence	Residual level of risk
Increased inundation of Mutton Cove mobilises contaminants from cinders in the southern filled area	D	4	Low	Preventative maintenance and/or rapid repair of breaches	E	4	Low
Increased inundation of Mutton Cove mobilises contaminants from pyrites in nearby areas outside Mutton Cove	D	3	Moderate	Preventative maintenance and/or rapid repair of breaches	E	4	Low

Table 4 - Risk table for contaminant mobilisation

The location suggested for the pyrites is somewhat closer to the centre of the peninsula than Mutton Cove and may have been above mean sea level prior to dumping commencing. The speed at which groundwater moves towards the sea is dependent on the head differential between the groundwater and mean sea level. Adding water to the groundwater lens from above (in the case of the stormwater detention basins) may increase the head differential and lead to the mobilisation of contaminants.

Increased inundation frequency at Mutton Cove is unlikely to increase the rate of discharge of groundwater, for two reasons. Firstly, while Mutton Cove's tides are truncated at the top and bottom of their range, they still appear (based on what little data is available) to cycle around mean sea level. Increasing the frequency of flooding should therefore not increase the head differential. Even if tidal flooding increased at



the top end of the tidal cycle while the tidal pipes remained to restrict drainage at the lower part of the tidal cycle and the mean tidal elevation in the Cove changed, it would change upward, thus reducing the head differential and slowing the discharge of groundwater into the Cove, even while increasing saturation of the neighbouring area.

While this is reassuring, the increased area that is saturated does slightly increase the risk that potential contaminants in that area may be dissolved into the groundwater in the first place. Avoidance of saturation minimises the quantity of materials that may be mobilised. Therefore, managing the Cove to ensure the frequency of inundation remains stable would add a further layer of surety, by not saturating nearby soils that could possibly contain contaminants. Maintenance of the levee, or rapid repair of any breaches, would therefore reduce this risk.

#### EXACERBATION OF ACID SULFATE CONDITIONS

CSIRO's Acid Sulfate Soils map classes for South Australia were accessed online via DEWNR's Naturemaps application. Mutton Cove contains three classes of ASS – the mangroves outside the Cove are Class 2 (Potential ASS – mangrove), the marsh plain inside the site is Class 4 (Potential ASS – intertidal) and creek lines within the Cove are Class 3 (Potential ASS – tidal stream). The area of sandy fill in the south is not classified as containing ASS.

It is very likely that in the past, during the period that the Cove was cut off from the tides, the site developed Actual ASS, and that this was the cause of the subsidence of the marsh plain. Reconnection to the tidal prism is likely to have gradually mitigated this through daily fresh inundation with carbonate rich seawater.

The mangroves (Class 2) pose a high risk for developing actual ASS, if they are drained, but breaches of the seawall would not lead to such an impact so are not discussed further here.

Increased inundation of the marsh plain and tidal creeks (which are mapped as Classes 3 & 4 PASS) would not lead to the development of actual ASS. Re-inundation is, in fact, a method widely used to prevent PASS from converting to ASS.

The one aspect that may be negatively impacted by increased inundation is the mobilisation of monosulfidic black ooze (MBO) and its potential discharge to the river. The reduced scouring in the tidal creeks of the Cove, a function of the pipes that control water flow in and out of the Cove, will have allowed any MBO present to accumulate in the benthos of the creek, rather than dispersing as it forms daily, as occurs in unrestricted tidal creeks.

In the event of a high elevation breach of the seawall, there should be little or no increased risk, as the tidal pipes would still form a sill that prevented the egress of

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MBO to the river. Some small quantity of MBO may be disturbed if there is a rapid initial ingress of water, but would settle quickly.

In the event that a low elevation breach occurred that removed the tidal pipes, there is very likely to be a discharge of MBO to the river. The impacts would not be permanent, as the accumulated MBO would flush out over a period of time and then stabilise (similar to tidally unrestricted tidal creeks). During the period the MBO was discharging at above background concentrations to the river, it is likely to have an impact on marine life in the river. MBO is an oxygen scavenging material and its immediate impact is to deoxygenate the water body it is suspended in, leading to fish kills. The oxidation of MBO can also generate acid (EPHC 2011), leading to red spot in fish and having deleterious effects on infrastructure such as bridges and wharves.

The magnitude of any impact depends on the quantity of material available for discharge (unknown for Mutton Cove), the rate at which it discharges (a function of the width and elevation of the seawall breach) and the volume of tidal exchange water it is diluted within (a function of the neap-spring stage of the tidal cycle). For the purpose of this risk assessment, an assumption of significant quantities of MBO, large breach and neap tides forms the worst case scenario.

Levee maintenance and rapid repair of breaches reduces the risk to low.

Risk event	Risk prior to implementation of controls			Possible control or remediation methods	Residual risk if controls implemented		
	Likelihood	Consequence	Risk level		Likelihood	Consequence	Residual level of risk
MBO (in benthos of tidal creek) discharge to the river, where levee is breached at a position <b>above</b> the bottom of the tidal pipes	D	4	Low	Preventative maintenance and/or rapid repair of breaches	D	5	Low
MBO (in benthos of tidal creek) discharge to the river, where levee is breached at a position <b>below</b> the bottom of the tidal pipes	A	3	High	Preventative maintenance and/or rapid repair of breaches	D	4	Low

Table 5 - Risk table for exacerbation of acid sulfate conditions



## REDUCTION IN RECREATIONAL VALUES

Breaches may have a social impact as well as an impact on the habitats of the Cove. The encircling path network at Mutton Cove is heavily used. In addition to opportunistic recreation (occasional visitors, birdwatchers, dog walkers, cyclists) the Mutton Cove seawall and embankment tracks are used daily by numbers of staff working at Defence-related industries nearby, as part of their daily exercise routines. These workers have invested in park bench infrastructure at the Cove, as a mark of their appreciation of the trail. Temporary closure of collapsed parts of the seawall has an impact on their regular circuit and forces them out onto nearby roadways.

Permanent breaching of the levee would result in a loss of opportunities for visitor access and cycle and pedestrian recreational opportunities, including those related to future expansions or linking with the Port Loop cycle and pedestrian pathways, the Outer Harbor greenway and the shared use pedestrian and bikeways of the Northern LeFevre open space master plan (Aurecon, 2010).

While temporary closures for repair of the seawall interrupt visitor use of the site, the interruptions have, until recently, rarely been for extensive periods. Permanent breaching of the seawall would interrupt the track loop significantly, as there are not alternative routes to bypass any breaches. The impact of temporary closures and potential complete breaches of the Mutton Cove seawall and tracks, for this type of recreational use, has been somewhat ameliorated over the last few years by the increased number of tracks being installed into neighbouring parklands (Biodiversity Park and The Link).

Risk event	Risk prior to implementation of controls			Possible control or remediation methods	Residual risk if controls implemented		
	Likelihood	Consequence	Risk level		Likelihood	Consequence	Residual level of risk
Breached or unsafe seawall (subject to closures) reduces recreational opportunities for bike/hike track users	B	4	High	Preventative maintenance and/or rapid repair of breaches	C	5	Low
Rapid and extensive mangrove growth at Mutton Cove alienates the wreck of the Excelsior from view	C	4	Moderate	Preventative maintenance and/or rapid repair of breaches	D	4	Low

Table 6 - Risk table for reduction in recreational values



## MUTTON COVE: LEVEE BREACH RISK ASSESSMENT

The Cove contains two historic shipwrecks. Increased mangrove coverage could reduce the visibility of the Excelsior wreck, which is currently viewable from much of the site. In South Australia the Heritage Branch is responsible for wrecks around the entire coast of the State. Many of these wrecks are subject to wave action, increased sea level impacts and other wear and tear. While the Branch is eager to prevent human mediated destruction of historic wrecks and provides interpretive material, they do not engage in active management of wrecks to prevent their ultimate subjection to the rigors of time.

Regular maintenance of the levee would ensure that the loop track at Mutton Cove remains available for recreational purposes. Controlling inundation frequency with an intact levee and pipe system ensures mangrove growth in the Cove occurs slowly and with a specific end-point in view. This would enable the wreck of the Excelsior to remain visible for the longest time.

### IMPACTS ON MANAGEMENT ACCESS

Loss of pedestrian and light vehicular access along the levee, because of damage or complete breaching, may lead to an increase the occurrence of undesirable activities, including illegal trail bike use, vandalism and dumping. These were major issues at Mutton Cove and across the entire northern section of LeFevre Peninsula a decade ago when the management plan for Mutton Cove was being developed. The regular presence of visitors and site managers has done much to reduce undesirable activities on the site.

Weed and feral animal control along the levee is also dependant on access along the levee. Because of its elevation, the marsh plain backing the levee is saturated and not suitable for the construction of alternative tracks.

Risk event	Risk prior to implementation of controls			Possible control or remediation methods	Residual risk if controls implemented		
	Likelihood	Consequence	Risk level		Likelihood	Consequence	Residual level of risk
Loss of access along seawall may hamper management actions	B	4	Minor	Preventative maintenance and/or rapid repair of breaches	C	5	Low

Table 7 - Risk table for impacts on management



## MOVING FORWARD

### DECISION

Mutton Cove retains the last vestiges of the back barrier saltmarshes along the Port River edge of the LeFevre Peninsula. Returning the Cove to the habitat range it supported prior to 1963 was the stated aim of the management plan for the site, developed in response to widespread community consultation (Cook and Coleman 2003). In order for that aim to eventuate in this subsided site the pattern of tidal inundation for the Cove must remain restricted, within a fairly narrow tolerance.

If that aim is to remain, the maintenance of the seawall is essential. Should the aim be changed and the loss of all saltmarsh and intertidal habitats except mangroves be countenanced, then the seawall may no longer be required.

The following sections are only applicable in the event that the seawall is to be retained.

### PREVENTION

Regular seawall maintenance minimises the need for large repairs. A regular levee inspection regime allows potentially vulnerable locations to be identified so that smaller maintenance actions are required. Rocking vulnerable parts of the seawall with larger rock and topping the surface to ensure water drains away rapidly are required.

In the past there has been some discussion of using “sand sausages” with a top elevation of about 1 mAHD, located a little offshore from the seawall to encourage the development of mangroves in the intervening space. Sand sausages require a considerable depth in order to be filled and placed, and so this suggestion has never been trialled. However the use of artificial reef structures, for example interlocking blocks, located just sub-tidally may be worth exploring. Such structures may be colonised by cementing organisms such as the native mud oyster (*Ostrea angasi*) and may provide habitat for nearshore mangrove development, protecting the seawall.

### EMERGENCY RESPONSE & MITIGATION

In the event of a breach, any response should be determined depending on the severity of the breach.

In a high elevation breach, when tides and storm surges are not envisaged immediately following the breach, no immediate action may be required. Simply flag the site off to prevent access and move to immediately organise the repair of the breach.



## MUTTON COVE: LEVEE BREACH RISK ASSESSMENT

In low elevation breaches or when further storm surges and high tides are predicted that will result in water entering the site through the breach and enlarging it, sandbagging may be the best immediate action, minimising further damage to the seawall. Once the flow of seawater is controlled, flagging the site off and arranging to repair the seawall can commence.

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