Working towards a State-wide Inventory of Estuaries

2010

Advancing the inventory of estuaries in five Natural Resource Management Regions of South Australia

Government of South Australia

Department of Environment and Natural Resources

Adelaide and Mount Lofty Ranges Resources Management Board

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Estuaries Inventory

South Australia

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Natural Heritage Trust

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Project Team

Kym Rumbelow, Amanda Speziali and Elisa Sparrow.

EXECUTIVE SUMMARY

In 2007 the Department for Environment and Heritage (DEH[1]) in South Australia released the Draft Estuaries Policy and Action Plan. The plan contained a recommendation for the development and funding of a project working towards an inventory of estuaries in South Australia. NRM funding was obtained and the project was completed in 2009.

The main outcomes for the projects were:

- GIS Mapping of outer boundaries and internal habitat facies;
- Development of field survey methodology;
- Survey of representative estuaries in SA; and
- Recommendations on monitoring protocols for estuaries.

The project scope included mapping all 102 estuaries in SA, except the Murray Mouth, as identified in the Draft Estuaries Policy and Action Plan (DEH 2007a), with the more intensive survey process restricted to a limited number of representative estuaries.

To support the science underpinning the project, a technical committee was developed consisting of estuaries-based experts in Adelaide and the regions. This was also supported by an internal DEH[1]review and approval processes, to ensure the systems and information produced by the project were sound.

Prior to this project, state estuary mapping in South Australia consisted of a series of points indicating names and locations of estuaries within the state. This project achieved the spatial mapping of all 102 estuary boundaries and their internal habitats identified within them.

Two final products were developed for public release as part of the project, both of which are now available on Deprtament of Environment and Natural Resources (DENR) mapping website “NatureMaps”. The first is an outer boundary layer clearly identifying the inland, lateral and predicted marine boundaries, and the other is a layer indicating the habitats within those boundaries. Habitat mapping was largely based on existing saltmarsh and mangrove maps at 1:10,000. Data obtained from the field survey processes is linked to the boundary layer.

The field inventory process required the development of a rigorous methodology to guarantee its success. The process was designed to ensure that relevant and appropriate data was collected in an efficient and repeatable manner. Therefore, the number of estuaries surveyed was limited to 25. The time limitations placed on the project required the methodology to be based on rapid assessments. Based on advice from the technical committee, it was determined that each survey could be conducted within a two hour time frame.

The Estuaries Rapid Assessment Methodology was based on a set of protocols developed by Claire Harding (DENR) for an inventory of freshwater wetlands on the Fleurieu Peninsula in 2005. The datasheets and process were adapted from this project to ensure relevance to estuaries, but a considerable amount of structure and information was retained in the final estuaries model.

[1] In July 2010 Department for Environment and Heritage (DEH) became Department of Environment and Natural Resources (DENR).

In January 2009, a small pilot study was conducted to determine any field weaknesses or gaps. The full scale survey process was undertaken from February to March in 2009. During this process 25 estuaries from four NRM regions in the state were surveyed.

Some of the results from the mapping and survey work indicated the following trends:

The mapping indicated:

- That KI and AMLR regions contain the highest number of estuaries but N&Y and EP regions have a considerably larger area of estuaries.
- Habitat composition was considerably different in different regions

The survey of 25 sites indicated:

- A low proportion of estuaries are officially protected, with a high percentage of estuaries surrounded by land use that would place pressure on the natural system.
- Water quality varied considerably – particularly between estuaries in different regions.
- A proportion of sites surveyed had issues relating to salinity, temperature, dissolved oxygen and turbidity levels, but none had pH problems
- There are a large number of threats and impacts prevelant at each site due to easy access, their coastal locations and reliance on catchments.

Recommendations for monitoring protocols have also been included in this final report. As the reasons for monitoring a specific site or a selection of estuaries across the state may vary, this set of recommendations tries to cover a set of guidelines or protocols on what to consider when planning to undertake a monitoring program. It also includes what national and state initiatives are currently being undertaken and how these combine to impact on what information should be collected. Ultimately what is to be monitored and the questions involved will dominate how monitoring programs are designed and undertaken, but being conscious of higher level programs and how monitoring can be combined to provide information on a statewide, local or national scale is important. As is the use of available resources and the number of parameters monitored.

Careful consideration of what you are trying to monitor, the number of parameters required to be monitored and the frequency of monitoring, are all questions that need to be posed to maximise the information gathered for the lowest resource investment. As discussed in the protocols, it is often the case that a large number of parameters are monitored, however in many cases they do not provide great detail for the questions being asked, or are too closely related to other parameters tested.

This project has taken a considerable step in the development of a state-wide inventory for estuaries. The production of detailed boundary and habitat mapping as well as the development of a repeatable rapid assessment methodology allows future work to be undertaken more readily. The survey data and mapping is already contributing to planning in the regions before finalisation of the project.

This document contains a series of recommendations based around the conservation, management and monitoring of estuaries in South Australia. These recommendations have been aimed at trying to provide direction for future estuaries work.

TABLE OF CONTENTS

List of Abbreviations

AMLR	Adelaide Mount Lofty Ranges
ANZECC	Australia and New Zealand Environment and Conservation Council
BDBSA	Biological Databases of Biodiversity of South Australia
CAMBA	China – Australia Migratory Bird Agreement
CP	Conservation Park
°C	Degrees Celsius (temperature)
DEH	Department for Environment and Heritage
DENR	Department of Environment and Natural Resources
DIW	Directory of Important Wetlands
DO	Dissolved Oxygen
DWLBC	Department of Water, Land and Biodiversity Conservation
EP	Eyre Peninsula
EPA	Environment Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act (1999)
GIS	Geographical Information Systems
HCVAE	High Conservation Value Aquatic Ecosystem
JAMBA	Japan – Australia Migratory Bird Agreement
KI	Kangaroo Island
NHT	National Heritage Trust
NPW Act	National Parks and Wildlife Act (1972)
NRM	Natural Resource Management
NTU	Nephelometric Turbidity Units
N&Y	Northern and Yorke
pH	Potential of Hydrogen (measure of the acidity or alkalinity of a solution)
ppt	Parts per thousand (salinity)
SA	South Australia
SAWCI	South Australian Wetland Condition Indicators
SE	South East

INTRODUCTION

The Draft Estuaries Policy and Action Plan for South Australia was developed by the Government of South Australia in 2007. The outcomes and actions listed in the Draft Estuaries Policy and Action Plan were designed to guide a whole of government approach to the management and protection of estuaries in this state.

The Estuaries Inventory project stems directly from actions and outcome 1 of the Draft Policy and Action Plan: "Better management of estuaries for environmental, social and economic sustainability" and Actions 1.1.1 and 1.1.2a:

> '*Develop a bioregional understanding of estuaries'* and *'define and describe estuaries and their links to adjacent ecosystems'*.

The project also contributes to Strategy 2.4.4 of the State NRM Plan (Govt. of SA, 2006) '*Use a state-wide inventory of rivers, wetlands and estuaries (to assess conservation values) so as to protect water regimes in those systems'*. Data collected for the project will contribute to the State NRM Inventory for Rivers, Wetlands and Estuaries (State and NRM Plan Strategies 1.3.8 and 1.3.9) and the OzCoasts National 'OzEstuaries database', accessible via the web address: http://www.ozcoasts.org.au/

The inventory project was conducted over a 12 month period and is divided into four main components:

- GIS Mapping of outer boundaries and internal habitat facies;
- Development of field survey methodology and template;
- Survey of representative estuaries in SA; and
- Recommendations on monitoring protocols for estuaries.

The mapping and desktop processes were completed for all 102 estuaries (bar the Murray Mouth) in South Australia as set out in the Draft Estuaries Policy and Action Plan (DEH, 2007a), with 25 estuaries surveyed on ground.

The information contained in this report and the data collected during this project will assist in prioritising, planning and management of estuaries across the state.

Estuary definition

The *Natural Resources Management Act 2004* defines an Estuary as:

'A partially enclosed coastal body of water that is either permanently, periodically, intermittently or occasionally open to the sea within which there is a measurable variation in the salinity due to the mixture of seawater with water derived from on or under the land'.

The Act also notes that an estuary may include any ecosystem processes or biodiversity associated with an estuary or estuarine habitats adjacent to an estuary (NRM Act, 2004).

Also relevant here is the RAMSAR definition of wetlands, as defined by the Ramsar Convention Bureau (2001):

"areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."

Therefore estuaries fit into the wetlands definition and thus mapping produced by this project will contribute to the state wetlands mapping layer.

South Australia's unique estuaries

Due to South Australia's semi-arid to arid climate and the exposure of our coastline to the Southern Ocean and gulf waters, our estuaries are mainly dominated by wave or tidal processes, with only a few dominated by river flow. Consequently, South Australia's estuaries vary greatly and range from coastal lagoons through to tidal creeks and river or creek mouths.

In most parts of the State, the amount of rainfall during each season is variable, meaning that many rivers and creeks flow temporarily and flood occasionally. In the summer months, they often become non-flowing waterholes, with freshwater not reaching the ocean at all. As a result, the estuaries often become salty lagoons with sandbars blocking seawater from entering them. Some estuaries become totally dry, at least on the surface, with only groundwater influences evident in sustaining the surrounding vegetation. However, during periods of high freshwater flow (usually in the winter and spring months), water can break through the sandbars and discharge out to the sea, allowing seawater to re-enter and flush the estuaries.

Project Scope

The Estuaries Inventory Project covers all 102 estuaries, except the Murray Mouth, identified in the Draft Estuaries Policy and Action Plan (DEH 2007a). This includes locations within the Natural Resource Management Board boundaries of Kangaroo Island, Adelaide and Mt Lofty Ranges, Eyre Peninsula, Northern and Yorke and the South East.

The inventory was completed within a 12 month time period from July 2008 to June 2009. This timeline resulted in there only being one survey collection period (February – April 2009) before the winter rains. As a result, the data represent conditions relating to a summer/autumn estuarine system. The timeline did not allow for a second, winter season survey, which would have been the preferred process for an estuarine inventory project.

The project timeline enabled a representative sample of estuaries to be surveyed across the state. Priority reference estuaries were chosen with the support of representatives of the Technical Committee and representatives from each NRM region involved. A desktop process was also employed to identify suitable representative estuaries in each region.

Specific Aims and Objectives of the Estuaries Inventory

The aims and objectives defined for the State Estuaries Inventory include the following:

- Review data and literature relevant to estuaries in South Australia;
- Develop GIS layers indicating estuary outer boundaries and internal habitats;
- Design a rapid assessment methodology and protocol for estuaries (based on advice and previous work carried out by the technical group);
- Undertake surveys using rapid assessment protocols of selected estuaries; and
- Develop recommendations for monitoring protocols (based on national initiatives) for estuaries in SA.

Context and Objectives of this Report

This report is designed to provide an overview of the estuaries inventory project. It provides background on estuarine work carried out in South Australia up to this project. The methodologies used to conduct the inventory are summerised, including the mapping processes and rules, development of surveying methodology and the completion of the survey work.

As there are 102 estuaries spread over five regions to be discussed in this document, it is very difficult to provide an in-depth focus on particular estuaries. Consequently, the results section in this report looks at some of the information provided by the mapping and survey results that give a general overview of the estuaries in South Australia.

Mapping has been completed for each estuary in the state and is now available online through DENR's mapping website NatureMaps (www.naturemaps.com.au). More detailed information on specific sites for management, data, species lists and other information collected during the project are available through links from the spatial information on the NatureMaps website.

EstuariesTechnical Committee

A Technical Committee was formed that consisted of regional, coastal and estuarine experts and state science based personnel from universities and state government departments to ensure a rigorous process was adhered to. It was important to have a team supporting the decision making and the science being used as the basis of the project.

The technical committee were asked to provide input into all important facets of the project including:

- GIS mapping rules –boundary allocation rules and scale;
- Development of the rapid assessment survey protocols; and
- Decisions on what estuaries in each region should be involved in the survey process.

The committee consisted of representatives from three of the five NRM regions studied, as well as centrally-located personnel who have a state and national focus.

The technical committee members were:

Peter Goonan – EPA

Sam Gaylard - EPA

Paul Wainwright – Aquatic Ecosystems, DENR

Mary Alice Ballantine – AMLR NRM Board

Martine Kinloch - KI NRM Board

Kerryn McEwan - EP NRM Board

Meg Goecker – EP NRM Board

Sabine Dittmann - Flinders University

Doug Fotheringham – Coastal Management Branch, DENR

Peri Coleman – Delta Consulting

Faith Cook – Delta Consulting

There was also an internal DENR review and support process for the project. This consisted of regular meetings to discuss mapping, survey protocols and other key decisions for the project both prior to and after the information was assessed by the technical committee. This internal process was supported by the following DENR representatives:

Peter Fairweather – Seconded Marine Advisor - Coast and Marine Conservation, DENR

Alison Wright – Senior Marine Advisor (Science) - Coast and Marine Conservation, DENR

Liz Barnett – Senior Research Officer - Coast and Marine Conservation, DENR

Fab Graziano – Senior GIS Analyst - Coast and Marine Conservation, DENR

Matthew Miles – GIS Team Leader – Information, Science & Technology, DENR

Matthew Royal – GIS Analyst – Information, Science & Technology, DENR

Study Area Boundaries and Characteristics

This project covers estuaries within five NRM regions in South Australia, including the Adelaide and Mt Lofty Ranges, Eyre Peninsula, Northern and Yorke, South East and Kangaroo Island (see Figure 1 and Table 1). These NRM regions are broadly based on landscapes and environments but are essentially management boundaries with considerable variation of environment and landscape within them.

South Australia's coastal geomorphology and climate varies considerably across regions within the state. As a result the estuaries in South Australia vary depending on the region and the actual location of the estuary within the region. For example, Eyre Peninsula is dominated by large open embayments whereas the Northern and Yorke region has numerous low lying tidal mangrove/saltmarsh systems.

This section will summarise the coastal conditions and provide some general background within each individual NRM region. The information in this section has been sourced from the DEH *Estuaries Information Package* publications (DEH, 2007b; DEH, 2007c; DEH, 2007d; DEH, 2007e; DEH, 2007f) pertaining to the five coastal NRM regions in South Australia. These information packages were developed by the Coast and Marine Conservation Branch in 2007.

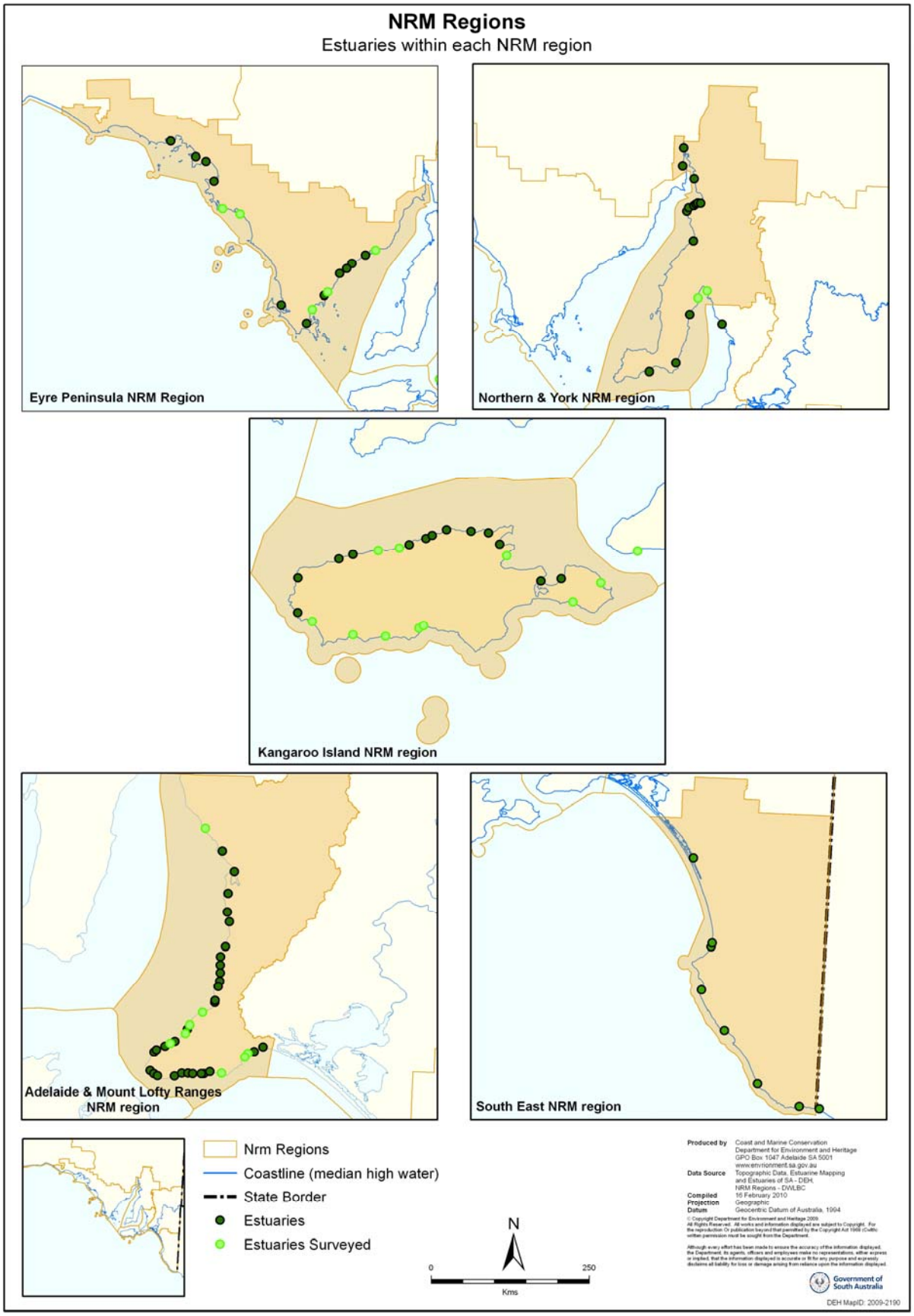


Figure 1. NRM Regions and locations of estuaries mapped and surveyed.

Table 1. Estuaries mapped and selected for survey in NRM Regions.

Estuary	Mapped	Survey
Adelaide & Mount Lofty Ranges		
Aldinga Catchment	Yes	No
Balaparudda Creek	Yes	No
Blowhole Creek	Yes	No
Boat Harbor Creek	Yes	No
Bungala River	Yes	Yes
Callawonga Creek	Yes	No
Carrickalinga Creek	Yes	Yes
Christies Creek	Yes	No
Congeratinga - Anacotilla Rivers	Yes	No
Cooalinga Creek	Yes	No
Coolawang Creek	Yes	No
Deep Creek – FP	Yes	No
Field River	Yes	No
First Creek – AMLR	Yes	No
Fishery Creek	Yes	Yes
Gawler River	Yes	No
Hindmarsh River	Yes	Yes
Inman River	Yes	Yes
Maslin Creek / Catchment	Yes	No
Middleton Catchment	Yes	No
Myponga River	Yes	No
Salt Creek	Yes	No
Onkaparinga River	Yes	No
Parananacooka River	Yes	No
Patawalonga Creek	Yes	No
Pedler Creek	Yes	No
Port River Barker Inlet System	Yes	No
Sellicks Creek Catchment	Yes	No
Torrens River	Yes	No
Tunkalilla Creek	Yes	No
Urumbirra Creek	Yes	No
Waitpinga Creek	Yes	Yes
West Lakes	Yes	No
Willunga Creek Catchment	Yes	No
Yankalilla River	Yes	Yes
Yattagolinga River	Yes	No
Yohoe Creek	Yes	No
Eyre Peninsula		
Acraman Creek Streaky Bay	Yes	No
Salt Creek Arno Bay	Yes	No
Baird Bay	Yes	Yes
Blanche Port	Yes	No
Driver River	Yes	No
Duck Ponds Creek	Yes	No
Dutton River	Yes	No
Franklin Harbour	Yes	Yes
Port Douglas/Coffin Bay	Yes	No
Salt Creek – EP	Yes	Yes
Smoky Bay	Yes	No
Tod River	Yes	Yes
Tourville Bay	Yes	No
Tumby Bay	Yes	No
Venus Bay	Yes	Yes
Yabmana Creek	Yes	No

Table 1 (continued). Estuaries mapped and selected for survey in NRM Regions.

Estuary	Mapped	Survey
Kangaroo Island		
American River	Yes	No
Breakneck River	Yes	No
Chapman River	Yes	Yes
Cygnet River	Yes	Yes
De Mole River	Yes	No
Deep Creek - KI	Yes	Yes
Eleanor River	Yes	Yes
Emu Bay Creek	Yes	No
Gum Creek	Yes	No
Harriet River	Yes	Yes
Hummocky Gorge	Yes	No
King George Creek	Yes	No
McDonnell Hill Creek	Yes	No
Middle River	Yes	Yes
Ravine Des Casoars	Yes	No
Rocky River	Yes	Yes
Salt Creek – KI	Yes	No
Smith Creek	Yes	No
Snug Cove Creek	Yes	No
South West River	Yes	Yes
Stunsail Boom River	Yes	Yes
Valley Creek	Yes	No
Waterfall Creek	Yes	No
Western River	Yes	Yes
Willson River	Yes	Yes
Northern and Yorke		
Blanche Port	Yes	No
First Creek - EP	Yes	No
Fisherman Bay/Creek	Yes	No
Mambray Creek	Yes	No
Pavy Creek	Yes	No
Point Davenport	Yes	No
Port Augusta Complex	Yes	No
Port Broughton Estuary	Yes	No
Port Davis Creek/Broughton River Estuary	Yes	No
Port Pirie	Yes	No
Port Wakefield	Yes	Yes
River Light Delta	Yes	No
Salt Creek/Coobowie Inlet	Yes	No
Second Creek	Yes	No
Third Creek	Yes	No
Wills Creek	Yes	Yes
South East		
Blackford Drain	Yes	No
Eight Mile Creek	Yes	No
Glenelg River	Yes	No
Lake Bonney SE	Yes	No
Lake George	Yes	No
Maria Creek Kingston	Yes	No
Robe Lakes Drain L	Yes	No
Salt Creek - SE	Yes	No

Adelaide and Mount Lofty Ranges NRM Region

The region covers over 11,000 km^2 of land and sea, including urban plains, ranges and coast and marine ecosystems. The coastline within the AMLR region is over 385 km, along which 37 estuaries have been identified.

Environment

- The estuaries identified in the National Land and Water Resources Audit (NLWRA, 2001) are either wave or tide dominated, with the exception of the Onkaparinga River estuary that is river dominated.
- Estuaries vary in size from small ephemeral channels such as Boat Harbor Creek to large tide-dominated systems such as the Port River Barker Inlet.
- Groundwater appears to have a significant input into several of the estuaries.
- All of the estuaries and their catchments have been modified to some degree (e.g. through the construction of weirs, dams, or channel modifications) impacting environmental flows.
- The Gawler River, Port River Barker Inlet and the Onkaparinga River estuaries contain extensive saltmarshes.
- The Gawler River estuary and Port River Barker Inlet are the only two estuaries in the region where mangroves are present.

Conservation and protection

- The State and nationally vulnerable bead samphire *Tecticornia flabelliformis* (*National Parks and Wildlife (NPW) Act 1972, Environment Protection and Biodiversity Conservation (EPBC) Act 1999*) has been identified on Garden Island (Port River Barker Inlet) and within the Port Gawler Conservation Park (Gawler River estuary).
- Seventeen of the region's estuaries are within sites listed on the Register of the National Estate.
- The Gawler River, Port River Barker Inlet, Onkaparinga River and Aldinga Catchment estuaries are included in the Directory of Important Wetlands in Australia.
- The Port River Barker Inlet and Onkaparinga River estuaries are within Aquatic Reserves dedicated under the *Fisheries Management Act 2007*.
- The Gawler River, Port River Barker Inlet, Onkaparinga River, Deep Creek, Blowhole Creek and Waitpinga Creek estuaries are all located within conservation parks.
- The Port River Barker Inlet and the Gawler River estuary are within the Adelaide Dolphin Sanctuary.
- The Port River Barker Inlet is an important known breeding and nursery area for many of the State's commercial and recreational fish species.
- Numerous migratory bird species of international and national importance are dependent on estuarine habitats within the AMLR NRM region.
- The golden haired sedge-skipper butterfly *Hesperilla chrysotricha* is associated with coastal saw-sedge *Gahnia trifida*, which is in decline in the area and is the same habitat as for the endangered orange-bellied parrot *Neophema chrysogaster* and southern emu-wren *Stipiturus malachurus* (*EPBC Act 1999*).

Issues

Estuaries are under pressure from a range of activities including land use, recreational pursuits, and agricultural and industrial practices.

Environmental flows

Many of the estuaries within this region have poor flow to the sea, with upstream modifications such as dams and weirs and extensive groundwater extraction decreasing environmental flows and potentially changing channel morphology.

Groundwater influence

Groundwater appears to influence many of the estuaries, with variable groundwater discharges along the coast (e.g. from 120 ML/year at Maslin Sands to 500 ML/year at Northern Adelaide Plains; Lamontagne *et al*. 2005). Unconfined groundwater systems are prevalent in coastal dune systems although accurate estimates of groundwater discharges to Gulf St Vincent have not been possible because of limited groundwater monitoring (Lamontagne *et al*. 2005).

Examples of estuaries in the AMLR Region

Figure 2. Middleton Catchment (DENR).

Figure 3. Myponga River (DENR).

Figure 4. Port River (DENR).

Figure 5. Inman River (DENR).

Eyre Peninsula NRM Region

The region covers over 81,000 km^2 of land and sea and has nearly 3,000 km of coastline. 16 estuaries have been identified within the region.

Environment

- The estuaries identified in the National Land and Water Resources Audit (NLWRA, 2001) were classified as tide dominated, with the exception of the Tod River which is river dominated.
- The Tod River estuary is the only estuary to receive permanent flow throughout the year.
- Smoky Bay and Tourville Bay are two of three estuaries that have been identified as near pristine in South Australia (NLWRA, 2001).

Conservation and protection

- The State and nationally vulnerable bead samphire *Tecticornia flabelliformis* (*National Parks and Wildlife (NPW) Act 1972, Environment Protection and Biodiversity Conservation (EPBC) Act 1999*) is present around Venus Bay, Acraman Creek and Arno Bay.
- The rare cushion samphire *Centrolepis cephaloformis (NPW Act 1972)* is present around Acraman Creek, Tumby Bay, Smoky Bay and Venus Bay.
- There are many important shorebird sites associated with estuaries.
- The region's estuaries are nursery areas for numerous commercially and recreationally important fish, prawn and crab species.
- Five estuaries are within conservation parks, conservation reserves or national parks.
- Seven estuaries are included in the Directory of Important Wetlands in Australia (DIWA) (Environment Australia, 2001).
- Eleven sites listed on the Register of the National Estate are associated with estuaries.

Issues

Land clearance, agricultural and urban run-off, extensive groundwater extraction, and increasing industrial and urban development are all placing pressure on estuarine condition.

Environmental flows

Since surface, fresh water is scarce in the region, most of the creeks have limited or ephemeral river flow and minimal connection to the ocean (EPNRMG 2002). The Tod River estuary is the only surface-water fed system with a permanent connection between the mouth and the ocean. The bays on Eyre Peninsula are also permanently connected to the sea.

Groundwater influence

Within the EP NRM region there is an increasing reliance upon groundwater supplies for human use. Groundwater is considered to contribute to maintaining flow levels and pools within some of the creeks in the region, particularly in those areas where there is no apparent surface water drainage system (EPCWMB 2005). Groundwater is discharged into the marine environment through many of the coastal embayments (e.g. at Tumby Bay and Franklin Harbor) (Environment Australia, 2001).

Examples of estuaries in the EP region

Figure 6. Venus Bay (DENR).

Figure 7. Franklin Harbour (DENR).

Figure 8. Tod River (DENR).

Figure 9. Salt Creek (Eyre) (DENR).

Northern and Yorke NRM Region

The region covers nearly 50,000 km^2 of land and sea and has nearly 1,250 km of coastline. 16 estuaries have been identified across the region.

Environment

- The nine estuaries identified in the National Land and Water Resources Audit (2001) are tide dominated, with the exception of the Light River Delta which is river dominated.
- Many of the estuaries are ephemeral (i.e. flow only for short periods), with poor connectivity between the watercourse and ocean.
- Most of the estuaries in the region and their catchments have been modified to some degree, with all of the estuaries included in the NLWRA (2001) identified as modified or extensively modified.

Conservation and protection

- Extensive saltmarshes, mangroves, mudflats and seagrasses support a variety of internationally and nationally protected bird species and commercially important fish species.
- The State and nationally vulnerable bead samphire *Tecticornia flabelliformis* (*National Parks and Wildlife (NPW) Act 1972, Environment Protection and Biodiversity Conservation (EPBC) Act 1999*) is present around the Light River Delta and Wakefield River estuary.
- All of the estuaries, with the exception of Salt Creek/Coobowie Inlet (Yorke) and Pavy Creek are included in the Directory of Important Wetlands in Australia (Environment Australia, 2001).

Issues

Estuaries are under pressure from a range of activities including recreational pursuits and agricultural and industrial practices that are impacting on estuarine condition.

Environmental flows

Most of the estuaries in the region are either tidal channels or represent the mouth of ephemeral rivers. There is limited water exchange between fresh and marine waters.

Groundwater influence

Groundwater is likely to contribute to stream flow in the Light River Delta, Wakefield River and the Port Davis/Broughton River estuaries, particularly in the winter months due to the shallow water table.

Examples of estuaries in the N&Y region

Figure 10. Wills Creek (DENR).

Figure 11. Wakefield River (DENR).

Kangaroo Island NRM Region

The region covers more than 10,000 km^2 of land and sea and has nearly 600 km of coastline. Within the region, 25 estuaries have been identified.

Environment

- All of the estuaries identified in the National Land and Water Resources Audit (NLWRA, 2001) are wave dominated.
- The Breakneck River estuary is one of three estuaries within South Australia that has been identified in the NLWRA as near pristine.
- Most estuaries in the region receive flow seasonally with intermittent openings to the sea.
- There are no mangroves and only limited saltmarshes within Kangaroo Island's estuaries.

Conservation and protection

- All of Kangaroo Island has been identified as a significant site for fish, shorebirds and seabirds.
- Eight estuaries are protected within national parks, conservation parks, wilderness protection areas or aquatic reserves including Breakneck River, Rocky River, Ravine Des Casoars, Waterfall Creek, American River/Pelican Lagoon, South West River, Salt Creek and De Mole River.
- The American River/Pelican Lagoon estuary is part of the American River (Pelican Lagoon) Aquatic Reserve (*Fisheries Management Act, 2007*).
- Six estuaries are included in the Directory of Important Wetlands in Australia (DIWA) (Environment Australia, 2001).
- Ten sites located within estuaries are listed on the Register of the National Estate.

Issues

Land clearance, agricultural runoff, altered environmental flows and increasing tourism ventures are impacting on the condition of the estuaries in the KI region.

Environmental flows

Many estuaries on the island are subject to seasonal flow or have decreased freshwater flow through water extraction from the catchments, primarily for agricultural activities. This

has a major consequence for water flows in the Harriet, Eleanor, South West, Middle and Chapman Rivers and Deep Creek (KI) estuaries (Bryars, 2003).

Groundwater influence

It is possible that groundwater contributes to stream flow in estuaries in the region, particularly during the summer months, although this is difficult to quantify.

Examples of estuaries in the KI region

Figure 12. American River (DENR).

Figure 13. Chapman River (DENR).

Figure 14. Eleanor River (DENR).

Figure 15. Harriet River (DENR).

South East NRM Region

The region covers nearly 30,000 km^2 of land and sea and has nearly 400 km of coastline. Nine estuaries have been identified within the SE. Unlike other NRM regions in the State, the SE NRM region includes only one catchment area of 28,120 km^2 (SECWMB, 2003). This catchment area extends from the South Australian/Victorian border to the west along the coast and up towards the Murray Mouth. All of the estuaries in the region (apart from the Glenelg River) fall within this catchment boundary. Artificial sub catchments in the region have been created through the development of the drainage system. Estuaries are located within these artificial sub catchments.

Environment

- The estuaries referred to in this document extend from Salt Creek (SE) to the South Australian section of the Glenelg River. The mouth and headwaters of the Glenelg River are within Victorian borders.

- While part of the Coorong lies within the SE NRM region, most of the Lower Lakes, Murray Mouth and Coorong estuary is within the SA Murray Darling Basin NRM region. Details on the Coorong, Lower Lakes and Murray Mouth estuary are not included in this document because information is already available in a number of other reports and documents.
- Lake George is identified as a wave-dominated estuary in the National Land and Water Resources Audit (NLWRA, 2001).
- Groundwater is a key feature of the region, with many estuaries influenced by a shallow watertable.

Conservation and protection

- The South East provides a diversity of habitats for the 275 bird species recorded in the region; Salt Creek (SE), Lake George, Robe Lakes Drain L and Lake Bonney are all identified as important shorebird sites in the region.
- Recreational, commercial and other native fish species including the congolli *Pseudaphritis urvillii*, black bream *Acanthopagrus butcheri* and King George whiting *Sillaginodes punctatus*, are present within the region.
- Salt Creek (SE) is located within the Coorong National Park and Lake Bonney is within the Canunda National Park.
- Salt Creek (SE), Eight Mile Creek, Lake George and the Glenelg River estuaries have been identified as nationally important wetlands in the Directory of Important Wetlands in Australia (DIWA) (Environment Australia, 2001).
- Salt Creek (SE) forms part of the Coorong and Lakes Alexandrina and Albert wetland Ramsar listing (DEH 2000).
- Eight sites around Salt Creek (SE), Blackford Drain, Robe Lakes Drain L, Lake George and Lake Bonney are included in the Register of the National Estate.

Issues

Estuaries are under pressure from a range of activities including land use, agricultural and industrial practices and discharges, and recreational pursuits. Drainage discharge in the South East is also affecting the health of dense seagrass beds within several bays.

Environmental flows

Salt Creek (South East), Eight Mile Creek, Maria Creek and Glenelg River estuaries are permanently flowing watercourses (DEH, 2006b; SECWMB, 2003). Lake George and Lake Bonney also have permanent water supplies but have had their flow to the sea limted due to water quality issues (DEH 2006b).

Groundwater influence

Groundwater is an important feature of the region, with a shallow water table occurring throughout much of the South East (SECWMB, 2003). There are two major groundwater basins, the Otway and the Murray. These contain both shallow unconfined aquifers and deeper confined aquifers. The unconfined aquifers are the main source of water for irrigation, industry, stock and domestic supply to the region whilst the deeper confined aquifers are utilised mainly for agriculture and municipal water supplies (SECWMB, 2003). The introduction of the drainage system has altered groundwater discharge to the coast and marine environment. Estuaries such as Eight Mile Creek and Robe Lakes Drain L are predominantly groundwater-fed systems draining used irrigation water (SECWMB, 2003).

Guidance for Developing Monitoring Protocols

National and State Programs

As part of the outcomes for this project, recommendations for monitoring protocols (based on national initiatives) were developed to support conservation, planning and management. This section provides a summary of some relevant programs operating on a national and state basis and how they can be integrated into a monitoring program being undertaklen at a local level.

The Best Practice Framework for the Monitoring and Evaluation of Water Dependant Ecosystems reports 1: Framework and 2: Technical Resource are both comprehensive guides to the development of strong monitoring programs (Wilkinson *et al.,* 2007). The framework outlined in these reports is composed of four groups of tasks that enable an effective monitoring program to be developed. These are summarised very briefly below:

- **Group 1 – Rationale and Priorities**
  - Justification for monitoring.
  - Monitoring objectives.
  - Physical and biological nature of site and the risks and threats.
- **Group 2 – Conceptual Understanding**
  - Development of conceptual models.
- **Group 3 – Monitoring Program**
  - Designed through a process of indicator selection.
  - Determining what to measure.
  - Determining the frequency at which the data are to be collected.
  - Resources required to undertake the program are then calculated.
- **Group 4 – Implement and assess**
  - Steps required to implement monitoring program.
  - Guidelines on data collection and storage.
  - Information on effective data evaluation and assessment (Wilkinson *et al.,* 2007)

These documents are technical in nature and contain the level of detail required for the development of a rigorous monitoring program. It is not the purpose of this estuaries report to compete with the detail contained in these documents. It is instead this document's role to seek key programs and reports such as these and identify the critical components. How these guidelines link into the estuaries work currently being undertaken and that to be conducted in the future will also be discussed.

Deeley and Paling (1999) concluded that a hierarchy of environmental indicators are required for estuaries. These must allow for assessment of the current status, contain a measure of precision and be robust in their capacity to predict impacts (e.g. provide early warnings). It is also important to note these authors also conclude that the ongoing selection, evaluation and refinement of these indicators need to proceed

successfully with close partnerships between land and waterway managers and the scientific community (Deeley & Paling, 1999).

Therefore, development of effective monitoring relies on an improved understanding of the estuarine systems and processes in this state. Fairweather (1999) determined that monitoring and assessment of condition needs to be based on knowledge of the processes in and pressures on estuaries. This project has progressed some of the information required to an extent but further information needs to be obtained on a spatial and temporal basis. New sites need field baseline testing over several years in addition to the continuation of sites surveyed in this project.

Barton (2006) recognised this issue in Victoria, suggesting that there was an immediate need to acknoweledge and utilise the huge variations in estuary types in that state to support future research and management. Barton (2006) also suggested that the lack of available data for a considerable proportion of Victoria's estuaries limits the effectiveness of existing classifications and conceptual models.

Once the baseline level is established across more locations and regions in South Australia, a firmer understanding can be developed of the key processes that influence the condition of estuarine systems. This is supported by the Ramsar guidelines for rapid assessment (Ramsar Secretariate, 2006) which stress that the baseline inventory data provides the basis for guiding the development of appropriate monitoring.

Once this baseline information is collected, a clear classification scheme is required prior to the development of conceptual models. A classification scheme is a procedure that breaks down the estuary systems into subclasses defined by a number of influencing processes, such as landform, tidal and flow influences and salinity.

A project being conducted in South Australia through the DWLBC called the "South Australian Aquatic Ecosystems" is in the process of developing a detailed classification scheme for wetlands in South Australia (Sholz & Fee, 2008). The South Australian Aquatic Ecosystem (SAAE) project classification process is designed to produce conceptual diagrams for all estuary and wetland types specific to South Australia. The project stems from the SAWCI project report that suggests a transparent and repeatable process for the assessment and monitoring of wetland condition was required through: (1) identification of wetland types; (2) creation of wetland type conceptual diagrams and (3) the identification of appropriate wetland condition indicators (Sholz & Fee, 2008).

Conceptual models can be used to identify the ecosystem drivers within each wetland type and response indicators to determine how each type operates (Sholz & Fee, 2008). Therefore they can provide a process to determine the best indication of which parameters can or should be used to monitor the health and condition of the system.

On a national level, the Ozestuaries website (http://www.ozcoasts.org.au/) has a series of conceptual models based on the national classification system for estuaries. Even though this is an excellent start and a great guide, the classifications and the models have been developed from a national viewpoint and tend to be more suited to estuaries in the eastern states. The process is still useful in classifying the estuaries broadly but more work needs to go into programs like the SAAE Project which has a medium-term goal of classifying and developing conceptual diagrams for all wetland types in South Australia.

Currently there is a national project based on developing a nationwide system for classifying and identifying high-value aquatic ecosystems (Mount *et al.,* 2009). This

project is also developing a classification scheme that can be used to model ecosystems first and then determine their value as aquatic ecosystems using input from criteria based on conservation significance and management requirements. It is also designed to work in cooperation with existing state classification systems, rather than adding another level of complexity. The Australian National Aquatic Ecosystem Classification Scheme is in development and will form a key part of the The High Consevation Value Aquatic Ecosystem (HCVAE) framework. The project is being designed to operate and be relevant at a national, state and regional level. (Mount *et al.,* 2009) This process will be useful in identifying representative ecosystems at various levels (i.e. national, state and regional) and will lend support to the HCVAE process by applying conservation criteria such as representativeness, diversity and naturalness. It will be used to describe the current ecosystem and also to identify the conservation potential of the site (Mount *et al.,* 2009).

Monitoring undertaken at a local scale should be conscious of these activities operating at a state or national scale with a view to supporting these processes. Therefore, monitoring needs to occur with both of these considerations in mind. One is to further the inventory process over a greater number of sites within SA and to build on the information available about estuaries in this state. The other is to use this data to inform the national and state classification schemes to further our understanding and ability to effectively manage these sites.

Improving the information being used in the classification schemes will support the conceptual diagram development and improve the accuracy in the modelling process. The conceptual diagrams will help to define the key processes operating within these systems and the impacts that will occur from the disturbances to those drivers. It is designed to allow easier identification of the threats and which parameters are best to monitor to identify any changes in the systems.

A process such as this will enable a monitoring program to be designed that is targeted at fewer but more informative variables and will provide the critical information needed to manage estuaries with limited project resources.

The EPA in South Australia have in recent times reduced the amount of estuary monitoring they are conducting and are considering changing direction on types of questions asked and parameters tested (Peter Goonan, pers. comm. 2009). Although in the early stages, they are developing monitoring systems based on nutrient enrichment as a measure of human disturbance as it fits in well with their pollution-detection focus. The EPA is also looking at the potential of using remote sensing technologies to assess broad condition using spectral images and historical records, focussing on Chlorophyll a and submerged plants (Peter Goonan, pers. comm. 2009).

Current programs often measure a wide range of parameters which is both time and resource consuming. Although it might be beneficial for community groups to monitor a wide range of parameters, serving as a community capacity-building process as well as a data collection tool, it often contains too wide a spectrum. Limited resources at a project or program level require monitoring to become more focused, with clearer questions for the monitoring design to reduce the parameters monitored. Focusing on parameters that detect disturbance in the system on a broad scale allows identification of estuaries that might need further monitoring at finer scales (Peter Fairweather, pers. comm. 2009).

Often monitoring is conducted without clear direction, consuming considerable resources with little relevant information being collected.

Instead, for management purposes, we want to know what the current state of the estuary is for baseline data, then what processes are influencing the state of the estuary to determine the condition.

On the other hand, if the baseline data indicates poor condition, then through the process of conceptual diagrams and models we can determine the key processes influencing the system and which are contributing to the poor condition of the estuary. The monitoring could then be focused on these parameters to identify the processes occuring within the system with managment actions introduced to mitigate these impacts.

Marine Park outer boundaries have been finalized and many estuaries are within them. In fact 72 out of the 102 estuaries mapped (excluding the Murray Mouth) are within marine park outer boundaries and estuaries make up a little over 5% of marine parks by area. However, the internal zoning of these marine parks are yet to be finalized. Monitoring of estuaries should be part of marine park management in the future and should feed into programs like the SAAE Project.

As this project only visited 25 sites once during the summer period, it is very difficult to provide any parameters that would be suitable for certain monitoring circumstances. It is important that this work is continued and expanded so scientific knowledge on the systems can be strengthened. Critical work will be to create firmer linkages with research institutions and other government departments as well as other bodies conducting water testing. Statewide minimum standards for training and data collection need to be determined so information can confidently feed into central databases and support the statewide and national mechanisms being developed. Currently monitoring is directly related to the individual institutions' specific questions of the system and is rarely collected in a central location and available to contribute to something like the SAAE project. There needs to be greater communication and cooperation between groups conducting data collection and management in estuaries in South Australia.

Recommendations for Protocols

- That resources and consideration continues to be given to programmes like the SAAE project which are trying to improve our classification of these systems and develop conceptual models.
- Resources are often a key issue when developing a monitoring program. A decision needs to be made whether to monitor many parameters at a few sites infrequently or a few key parameters frequently at more sites.
- A process of collecting baseline information followed by classification of the system which then leads to conceptual models should be promoted and adopted to support monitoring programs
- Questions need to be clearly articulated at the beginning of monitoring.
- Parameters monitored need to be relevant to the questions set out.
- Responsive monitoring – a process focussing on straightforward monitoring to test if there are any broad impacts. If any issues are found, this triggers more intense monitoring to seek specific answers.
- Responsive monitoring is an optimising process, so focus is on identifying parameters that vary and tell a story rather than monitor those that do not.
- Identify parameters and then determine necessary timing of monitoring for each parameter – some may be seasonal, some annual, some every few years – results and their interpretation will vary based on season.
- Focus on the correct parameters depending on the season and conditions. There are parameters to investigate in wet times and others to investigate in dry times. To provide the full picture, the above process must be conducted for both seasons to obtain information on what processes are dominant during different parts of the year.
- The national processes are a guide to designing the process. However, local conditions may warrant the inclusion or deletion of some monitoring elements, and definitely will alter their exact interpretation.

OVERVIEW OF INVENTORY DATA AND ESTUARINE RESEARCH IN SOUTH AUSTRALIA

National Data

The Australian Wetlands Database (AG DEH 2004) and the Directory of Important Wetlands (Environment Australia 2001) identify nationally important wetlands across Australia. They provide information on each wetland, including their classification and the dependent flora and fauna. The Directory is a cooperative project between the Commonwealth, State and Territory Governments of Australia. 15 estuaries in South Australia have been identified in this process.

In 2001 the National Land and Water Resources Audit (NLWRA 2001) included 38 South Australian estuaries. The audit included the collection of exiting desktop data and the mapping of boundaries and habitats within the 38 estuaries in the study. This study was undertaken in cooperation with technical expertise in each state but no actual field work or surveys for the project were conducted. All information collected and mapping completed were done using existing state data, expertise and aerial photography. The mapping of estuaries as part of the NLWRA in 2001 provided a coarse scale of boundary and habitat mapping sourced from desktop developed information.

South Australian Data

Prior to this project, there was little overall knowledge regarding estuaries in South Australia. Estuarine monitoring in this state historically has been piecemeal. Often monitoring of different parameters in estuaries has been undertaken independently by a range of agencies based on different priorities or questions. It has and still is the case today with the EPA, DWLBC, regional NRM Boards, universities and DENR all working within estuarine sites focusing on a range of projects or independent issues.

In 2001, DEH produced the report “The status of South Australia’s Estuaries: A proposal for a state estuary program” (DEH 2001). This document provided an overview of estuarine issues in this state and detailed some recommendations. However, it is primarily a planning and policy type document that holds little value as a scientific, data-containing report.

In 2007, DEH produced the “Draft Estuaries Policy and Action Plan”. This is still in draft form, yet is being utilised as an internal policy and planning document. The document is focussed on planning and policy in regards to estuarine data collection, management and protection rather than being a document containing specific estuarine data or mapping. During the development of the policy and action plan a statewide estuaries map was produced. This consisted of point data indicating locations of 102 estuaries in South Australia identified under the policy.

Following this document a series of “Regional Estuaries Information Packs” were published by DEH in 2007 (DEH, 2007b; DEH, 2007c; DEH, 2007d; DEH, 2007e; DEH, 2007f). These documents were developed purely on a desktop basis using existing information stored in a number of state agency databases and reports. They contain information regarding threats, hydrology and habitats but much of the information was at a coarse scale and sourced from the NLWRA (2001).

Over the last few years some estuaries around the state have been included in statewide mapping and inventory work but these projects have been specifically wetland focussed and the data collected not necessarily relevant to estuary monitoring. The questions asked and the focuses of the studies were not comprehensive enough to supply the baseline data required for an inventory of estuaries.

A considerable number of studies have been completed in the Coorong and Lower Lakes region and due to this the Coorong, Lower Lakes and Murray Mouth system was not included in this inventory process.

The EPA has focussed monitoring and data collection on pollution at a number of key sites around the state, to feed information into the pollution control aspects of their business.

There is an urgent need to provide these data in a common format or central location that is widely accessible and provides a useful format for querying and extracting data.

Regional Estuarine Works Within South Australia.

A number of biological surveys have involved floral assessments of locations within the designated estuarine boundaries at a number of sites. These were identified using mapping programs linked to the BDBSA.

Depending on the NRM region and its priorities, estuarine works are mixed and vary across the state. The regions are often more implementation focussed with the development of site management plans and actions undertaken at priority sites. The foci of the NRM Boards are mainly site specific with a few priority sites in their region receiving resources and active management.

Existing GIS Databases Relating to Estuaries in South Australia

Estuary layer

There is an existing estuaries statewide point layer indicating the approximate location of estuaries within South Australia. This layer was created as part of the development of the Draft Estuaries Policy and Action Plan in 2007 (DEH, 2007a). In total 102 estuaries are identified in this layer and named in accordance with their names in the official list of South Australian Estuaries.

NLWRA

This mapping included lateral, marine and inland boundaries and the major habitat types within these outer boundaries. From this areas of different habitat types were calculated and summarised and the estuaries were classified under the national classification scheme.

Coastal saltmarsh and mangrove layer

Covering the whole state, this mapping layer has been developed and continually updated with increased accuracy over the last 15 years. It shows with good accuracy the presence of a number of habitats related to saltmarsh and mangroves in South Australia. As these habitats are common within several types of estuarine systems, this layer was used extensively to support the location of boundaries and coding of internal habitats for the mapping carried out in this project. Refer to Appendix 3 for full details.

ESTUARY INVENTORY METHOD

The inventory process had a mapping phase and a data collection phase. The mapping is discussed; as this was a critical step in the process of identifying estuary boundaries and determining where surveying and data collection limits applied on the ground.

Mapping rules had to be developed to guide the mapping process and provide consistency across the state. These rules are set out below.

Estuary Mapping Rules, Protocols and Classifications

These protocols were designed to allow consistent boundary mapping of estuaries across the state. As most initial mapping was conducted in a desktop fashion, a clear set of rules to delineate boundaries were required.

The desktop mapping of estuaries utilised the existing DENR Mangroves and Saltmarsh GIS Layer as a base, due to it already containing a considerable amount of estuarine habitat information (DEH, 2007g). Current habitat descriptions within the mangroves and saltmarsh layer were retained with the addition of habitat codes to cover gaps specific to estuaries.

The additions to the habitat descriptions in the Saltmarsh and Mangroves layer are listed below:

- Floodplain - an area that does not fit the strict mould of supratidal areas but would be inundated during floods and extreme tidal events. Often covered in grasses and sedges rather than saltmarsh communities.

- Reeds (covers *Typha* sp. and *Phragmites* sp.)

- Lignum (*Muehlenbeckia* sp.*)*

Scale

The scale of the mapping was influenced by the following rules or limitations:

- Estuaries containing existing Saltmarsh and Mangrove mapping data – scale determined by existing mapping data, ranging from 1:10,000; to 1:40,000; to 1:80,000.

- Estuaries containing no Mangroves or Saltmarsh information (65 estuaries in this project had no mangrove or saltmarsh information) were mapped at a scale according to:
    - The quality of the aerial photography (ability to accurately distinguish between habitat boundaries; smallest scale was 1:5,000).
    - The size (area) of the estuary and its associated habitats; smallest scale 1:5,000.

Minimum Habitat Mapping Size

Based on the existing saltmarsh and mangrove layer, and the scale of the aerial photography, a minimum polygon or habitat size was allocated. As a result, habitats had to be larger in area than 100m² to be mapped as a polygon. Anything smaller was not mapped or differentiated from larger habitat areas.

Boundaries

The following set of rules were assessed and passed through the technical committee process. The second methodology indicating the use of an ellipsoid was chosen as the preferred option by the committee.

Seaward (Downstream) Boundary

- *Without a river mouth and not an embayment*
    - The highest astronomical tide (HAT) line (Qld EPA mapping methodology) (EPA, 2005). The South Australia mean high tide coastal overlay was used.
    - A line drawn where the river meets the sea but includes saltmarsh, mangroves, intertidal flats and other associated habitats where present (Simon Bryars, pers. comm. 2008.)

- *With a river mouth and not in an embayment*
    - Furthermost point of the headlands either side of the river mouth (EPA, 2005; NSW DNR, 2004)
      Or
    - Indicative ellipsoid surrounding mouth that indicates estuarine influence within the marine environment (D. Fotheringham & L. Barnett, pers. comm. 2008) – issue here was scale – but ellipsoid is indicative only. Include saltmarsh and mangroves and intertidal flats where present (Simon Bryars, pers. comm. 2008).

- *With or without a river mouth, within an embayment*
    - Where water reaches 34 ppt, but without field work residence times and depth (to 6 metres in wetlands definition) can be used (Qld EPA mapping methodology; EPA, 2005).
    - The definition of the outer boundary of the estuarine zone is that area which is impacted by a single tidal excursion on an average tide (Qld EPA mapping methodology; EPA, 2005).
    - Draw a line across the whole bay e.g., Venus Bay, Coffin Bay, Baird Bay up to highest water mark (Simon Bryars, pers. comm. 2008.)

Landward (Upstream) Boundary

The Draft Estuaries Policy and Action Plan (DEH, 2007a) defines the landward boundary of an estuary to be where there is no further mixing between sea and fresh water.

- Water sampling is the best method to determine where no further mixing occurs – the boundary should be to mean high water springs (MNWS).

- However, this was a remote-based mapping project that was designed to use existing data. Therefore the following possibilities were looked for:

    - Salinity level of 0.5ppt (these data rarely exist).

    - A barrier such as a barrage or weir (Note, this may be a natural barrier such as sand on a beach or a cliff if permanent).

    - Pre-clearance vegetation coverage based on the line between estuarine and non estuarine vegetation (Queensland EPA Mapping Methods; EPA, 2005).

(This may be difficult in areas where primary salinity is high or the effects of secondary salinisation have become acute).

- If the above processes could not produce a boundary, the 5 metre contour line was used as a guide for the landward boundary (D. Fotheringham & L. Barnett, pers. comm. 2008).
- If the data was not available to support the use of the above rules, local knowledge and ground truthing was used to determine the boundary.

Lateral Boundaries

- All intertidal habitats and all wetlands – salt, brackish and fresh – that interact with the tidal and flood flow, and marshes that are inundated only during extreme tides or flood events were included in lateral boundaries (NSW DNR, 2004)

- In some cases the lateral habitat is extensive and it was difficult to decide where the estuarine influence dissipates (coastal homogenous communities). In this case where new drainage lines were evident that did not flow into the designated estuary system (as set out in the Draft Estuaries Policy and Action Plan), the lateral boundary was located bordering the new drainage lines.

- Boundary between estuarine and other vegetation/water (Queensland EPA Mapping Methods; EPA, 2005).

Where there was no clear mapping method set out in the above rules to determine the seaward, landward and lateral boundaries, local knowledge was utilised and reinforced with ground truthing as much as resources allowed.

Aerial Photos and Mouths

Where two aerial photos were available displaying the estuary in two different seasons (for example one in summer with the mouth closed and one in winter with the mouth open to the sea), the one showing the open mouth was used for mapping the channel to the high tide mark.

Human-Constructed Channels

Human-constructed channels that now form part of the estuarine system were included in the mapping and designated (or grouped in) as Tidal Stream Bare or Vegetated.

Estuary Mapping

The estuaries habitat mapping was established using the ESRI program ArcGIS 9.1 undertaken in the DENR SDE edit environment. The layer shows the lateral boundary, head and mouth of each estuary and identifies habitats within those boundaries. The outer boundary of each estuary was digitised first, followed by internal vegetation and landforms (Figs 16 & 17). Habitats were then identified and created by utilising the DENR Saltmarsh & Mangrove Habitat Mapping layer. This layer was adjusted with the addition of several vegetation and landform types that specifically relate to estuarine habitats (Figure 18, Table 2). The mouth of the estuary was then mapped, finalising the extent of flow coming from the land (Figure 19).

The mapping was based on digital orthophotography at a scale of 1:2,500, 1:10,000, 1:15,000, 1:40,000 and 1:80,000. Interpreting the imagery can lead to inaccuracy in classifying areas of habitats. Therefore, ground-truthing was undertaken in some areas using a PDA (Personal Digital Assistant) with Arc Pad 7.1 installed to verify accuracy.

The minimum mapping unit for the habitats within the estuarine boundaries were set at 100m^2 due to the small size of some estuarine systems. Therefore the scales when digitising were set at 1:2,500 to 1:5,000. Further information can be obtained from the Department of Environment and Natural Resources website www.environment.sa.gov.au under Information Resources, GIS Mapping, Metadata, EGIS SDE, Coastal, Estuarine Habitats of South Australia.

Outer Estuarine Boundaries

The outer boundaries were derived by using existing DENR spatial mapping including: Topography Contours 10,000; Pre-European Settlement Vegetation; and Saltmarsh Mangrove Habitats. A stereo scope was also used in the Adelaide Mount Lofty Region. This device was used as a guideline for the head of the boundaries and land formation because the photographs were taken before the year 2000. Field capture provided further details and confidence in the accuracy of the outer boundary.

Habitat Boundaries

The boundaries of each habitat were digitised based on varying patterns, tones and textures visible in true colour orthorectified aerial photography imagery as seen in Figures 16 and 17 below.

Figure 16. Imagery.

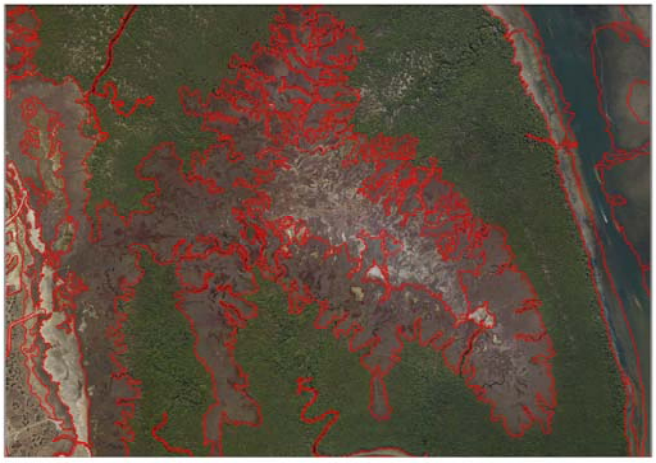


Figure 17. Imagery with digitized boundaries shown as red lines.

The imagery in Figures 16 and 17 are examples of what was used to classify the habitats. Identification of habitats was supported by DENR 2008 coastal oblique photographs, Coastal Saltmarsh and Mangrove Mapping, Marine Benthic Habitats, ground-truthing and Google Earth. Each habitat within each boundary is given a classification code to identify the type of habitat (see Table 2 for a list of habitat types). A table is present for each habitat showing the name of the estuary, type of habitat, tidal class, cover as well as the percent and condition of the cover (see Metadata – Appendix 4).

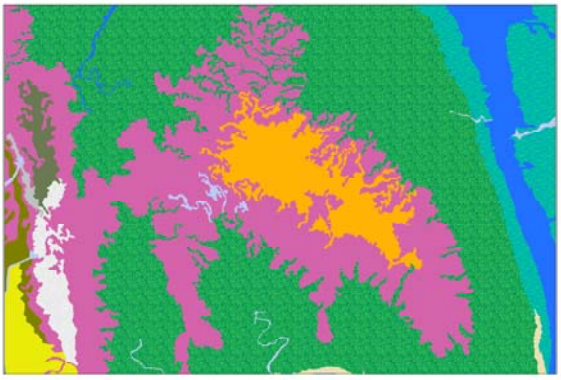


Figure 18. Habitats Classified.

Table 2. Habitat classifications and descriptions.

Beach	Intertidal Rotten Spot	Subtidal Channel Bare
Calcarenite Ridge Bare	Intertidal Saline Patch Bare	Subtidal Channel Seagrass
Clacarenite Ridge Vegetated	Intertidal Samphire	Subtidal Marine
Central Basin	Intertidal Sandflat Marine Bare	Supratidal/Estuarine *Casuarina glauca*
Channel	Intertidal Seagrass	Supratidal/Estuarine Flat
Chenier/Beach Ridge Bare	Land Outside Study area	Supratidal/Estuarine Grassland
Chenier/Beach Ridge Vegetated	Lunette Bare	Supratidal/Estuarine Mangrove +/- Samphire
Coastal Dune Bare	Lunette Vegetated	Supratidal/Estuarine Melaleuca +/- Sedges
Coastal Dune Vegetated	Non Marine Dune Bare	Supratidal/Estuarine Samphire +/- Atriplex +/- Grassland
Floodplain	Non Marine Dune Vegetated	Supratidal/Estuarine Sedges
Intermittent Estuarine	Point Bar Deposit Vegetated	Supratidal Cyanobacterial Mat
Intermittent Estuarine Samphire	Riparian	Supratidal Flat
Intertidal/Estuarine Sedges	Shingle Ridge Bare	Supratidal Flat Grassland
Intertidal Cyanobacterial Mat	Shore Platform Algal	Supratdial Melaleuca
Intertidal Flat	Shore Platform Bare	Supratidal Rotten Spot
Intertidal Flat Algal	Shore Platform Samphire	Supratidal Saline Patch Bare
Intertidal Flat Vegetated	Stranded Tidal Flat	Supratidal Samphire
Intertidal Hardpan	Strandard Tidal Flat Samphire	Supratidal Samphire +/- Atriplex +/- Grassland
Intertidal Mangrove	Stranded Tidal Rotten Spot	Tidal Stream
Intertidal Melaleuca	Stranded Tidal Saline Patch Bare	Mouth of Estuary (Ellipsoid)

Marine Boundary

The marine extent of each estuary is an arbitrary ellipsoid, which indicates the possible distance of influence of fresh water flow entering the marine environment (Figure 19). The ellipsoids were based on size of estuaries, coastal land formation and bays and should only be taken as an arbitrary line to complete the estuary boundary.

Figure 19. Ellipsoid indicating marine boundary.

Wetland Numbering System

A State-wide numbering system was developed for identifying wetlands which follows the system established for the Murray River wetlands (Jensen *et al*., 1996). The system numbers wetlands with the letter S (indicating South Australia) followed by a four-digit number where the first number indicates the region the wetlands occur within.

As a result of this project, estuaries within this state have been assigned numbers using the methodology detailed above.

Ground-Truthing

The mapping of the outer boundaries and inner habitats was supported with field ground-truthing excursions. A number of representative sites in each region (except the SE) were visited and assessed. Comparisons with the draft maps were made with many adjustments, additions and deletions. A considerable amount of information, such as habitat type, was recorded in the field using a Hewlett-Packard PDA with ArcPad and fitted GPS unit. Draft maps with line work were loaded onto the unit which enabled edits to the maps to be made on site at the time of ground truthing.

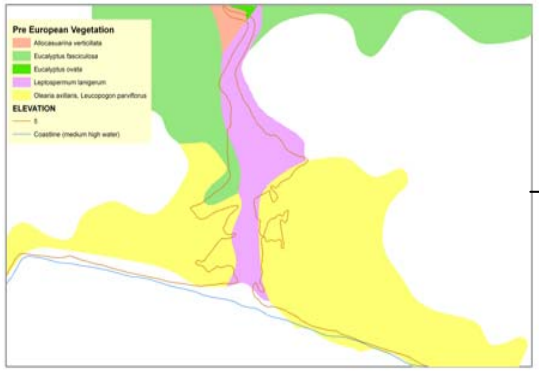
Community Consultation

In addition to the ground-truthing, the AMLR and KI regions also undertook small workshops involving regional NRM workers and community members involved in estuarine works. At these workshops, draft line work indicating external boundaries and internal habitat boundaries were assessed by the group with experience and local knowledge used to increase the accuracy of the mapping process.

The EP and the NY regions had considerable existing ‘Saltmarsh and Mangrove’ GIS layers that had been ground-truthed previously. This layer gave an excellent indication

of estuarine boundaries within these regions in many cases. The EP also contained a considerable proportion of embayments which were easily mapped.

Figure 20 identifies the overall mapping process undertaken during this project. Examples of estuary maps produced for each region are shown in Figures 21 to 25. These figures contain aerial photography overlayed with habitat line work, ellipsoid and final polygons with habitat types coded.



Existing spatial data

Overlay spatial data on aerial photography

Outer boundary digitized

Field	Value
OBJECTID	164
TYPECODE	Floodplain
LOCNAME	Waitpinga Creek
LANDFORM	Floodplain
ESTUARINE	Estuarine
TIDALCLASS	Non Tidal
COVER	Vegetated
DENSITY	30-50%
STRUCTURE	Continuous
INTEGRITY	Patchy
MEDDESC	Floodplain
SHORTDESC	Other Coastal Features
ASSCLASS	5
ASSLEGEND	PASS(s)
ASSDESC	Potential acid sulfate soils in subsoil below 50 cm (up to 1 metre thick) - supratidal. Moderate to low risk.
GROUNDTRUTH	Ground Truth Site
CAPTUREPROJECT	Estuaries Mapping
CaptureSource	Marine: Estuary Mapping
CaptureMethod	ArcMap Digitisation
FeatureSource	True Colour - Ortho Rectified - Aerial Photography
FEATURERELDATE	25/01/2005
ATTRIBUTERELDATE	16/03/2009
HORIZONTALACCURACY	15
MINSCALE	2500
MAXSCALE	50000
EDITDATE	24/06/2009 2:06:34 PM
USERID	ASPEZIALI
Shape	Polygon
SHAPE.AREA	8786.290020
SHAPE.LEN	796.239959

Attribute information recorded for each polygon

Habitat boundaries classified

Habitat boundaries digitized

Figure 20. Overall Estuary Mapping Method.

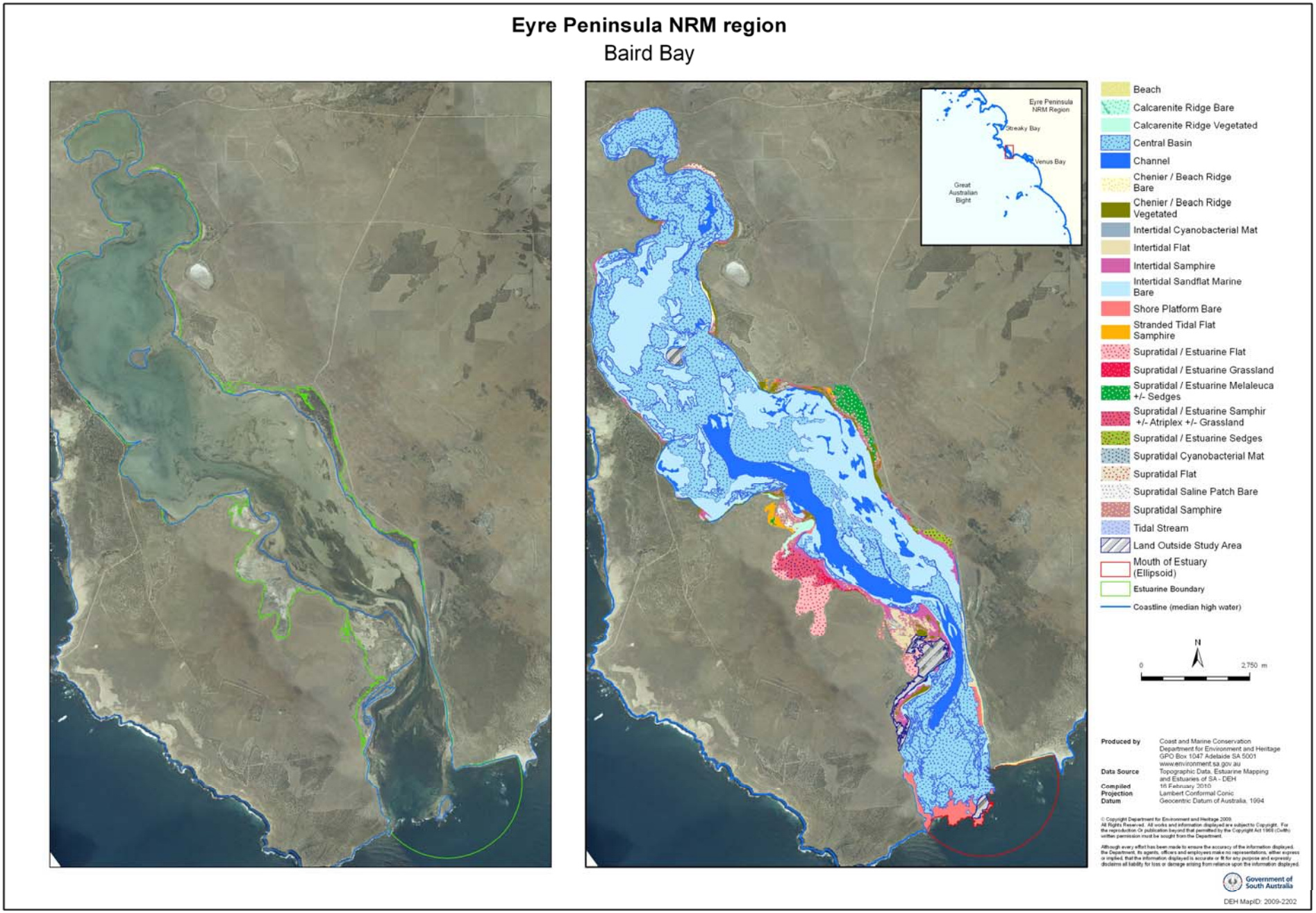


Figure 21. Example map of an estuary in EP Region.

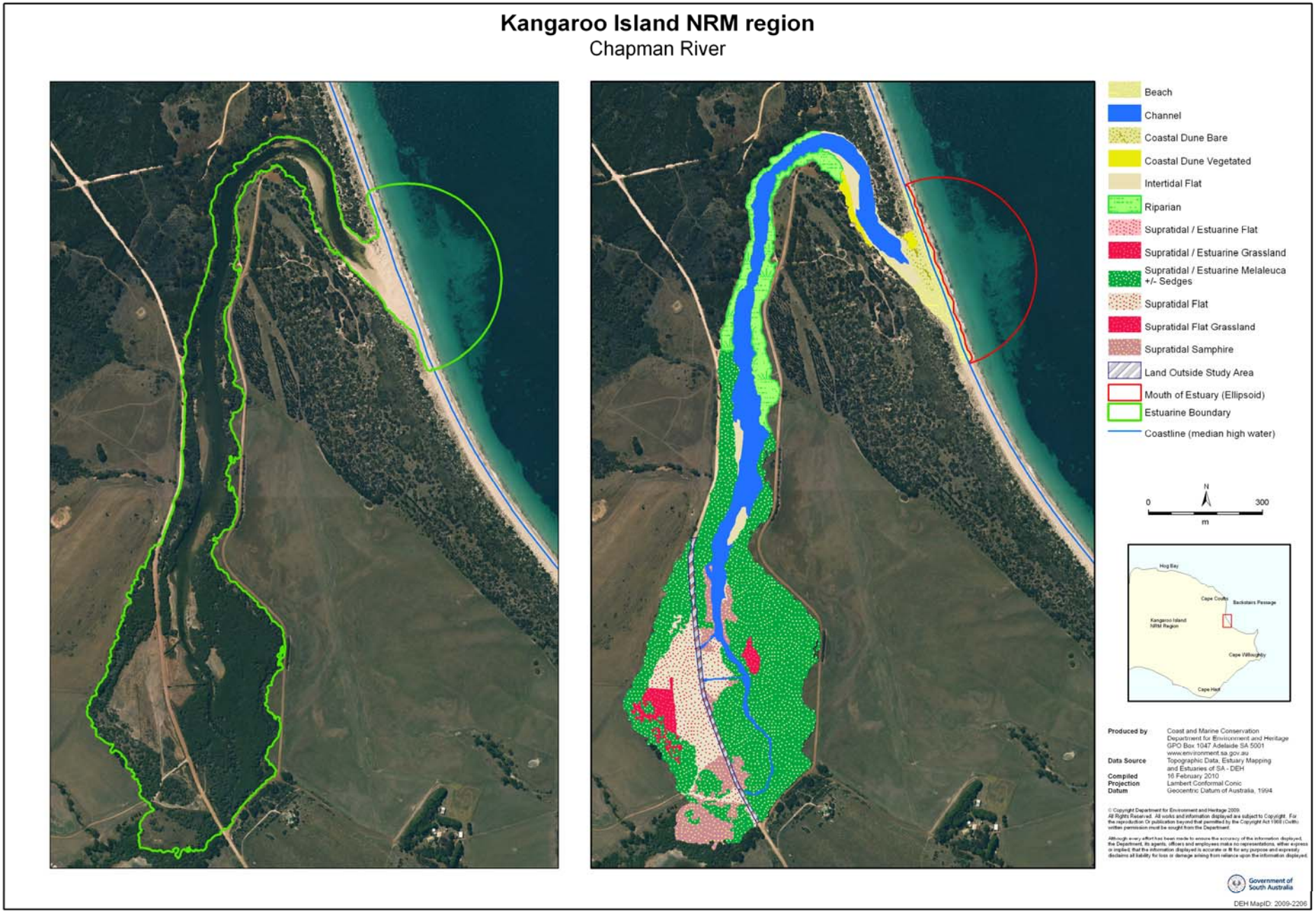


Figure 22. Example map of an estuary in KI Region.

Figure 23. Example map of an estuary in the SE Region.

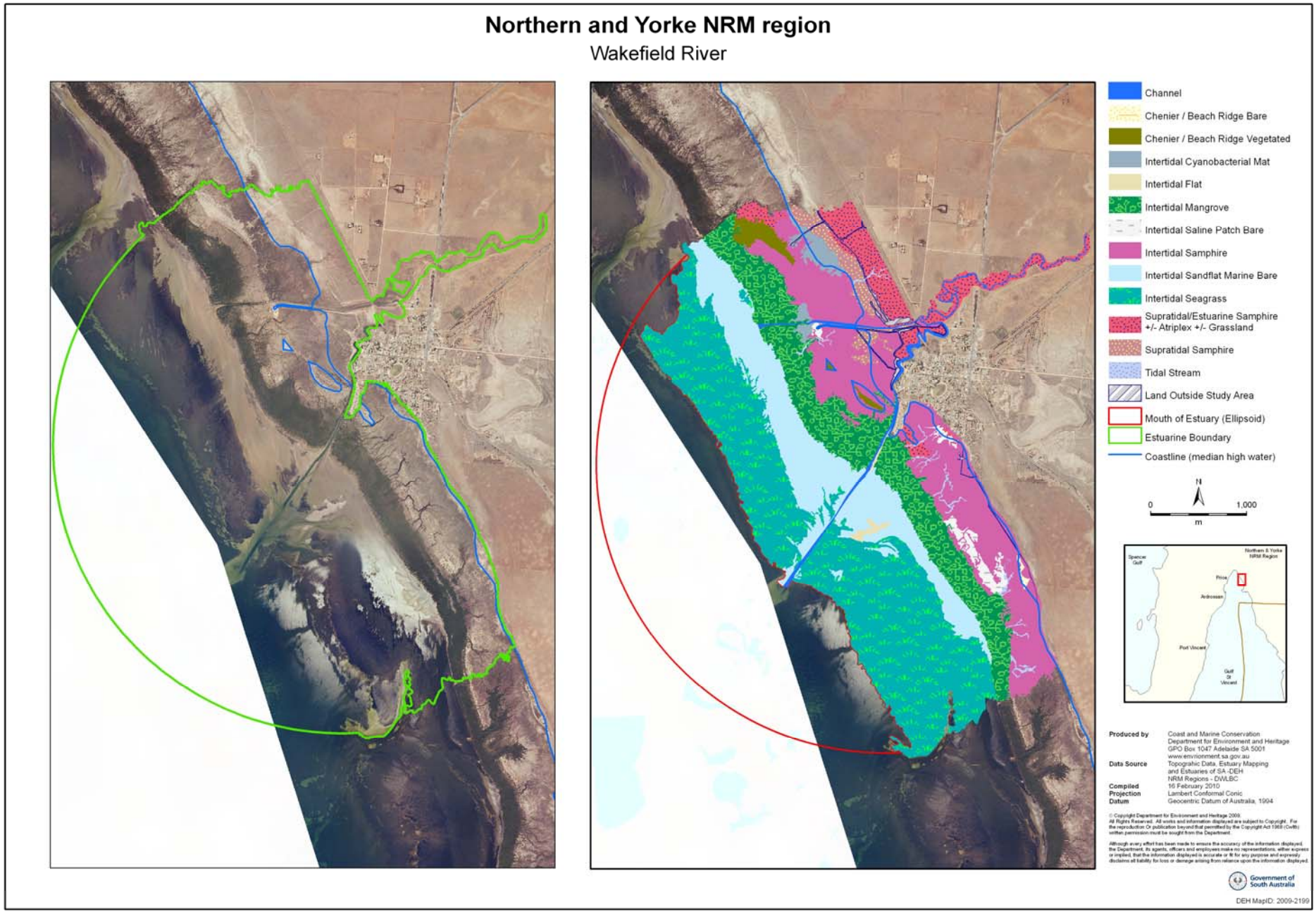


Figure 24. Example map of an estuary in N&Y Region.

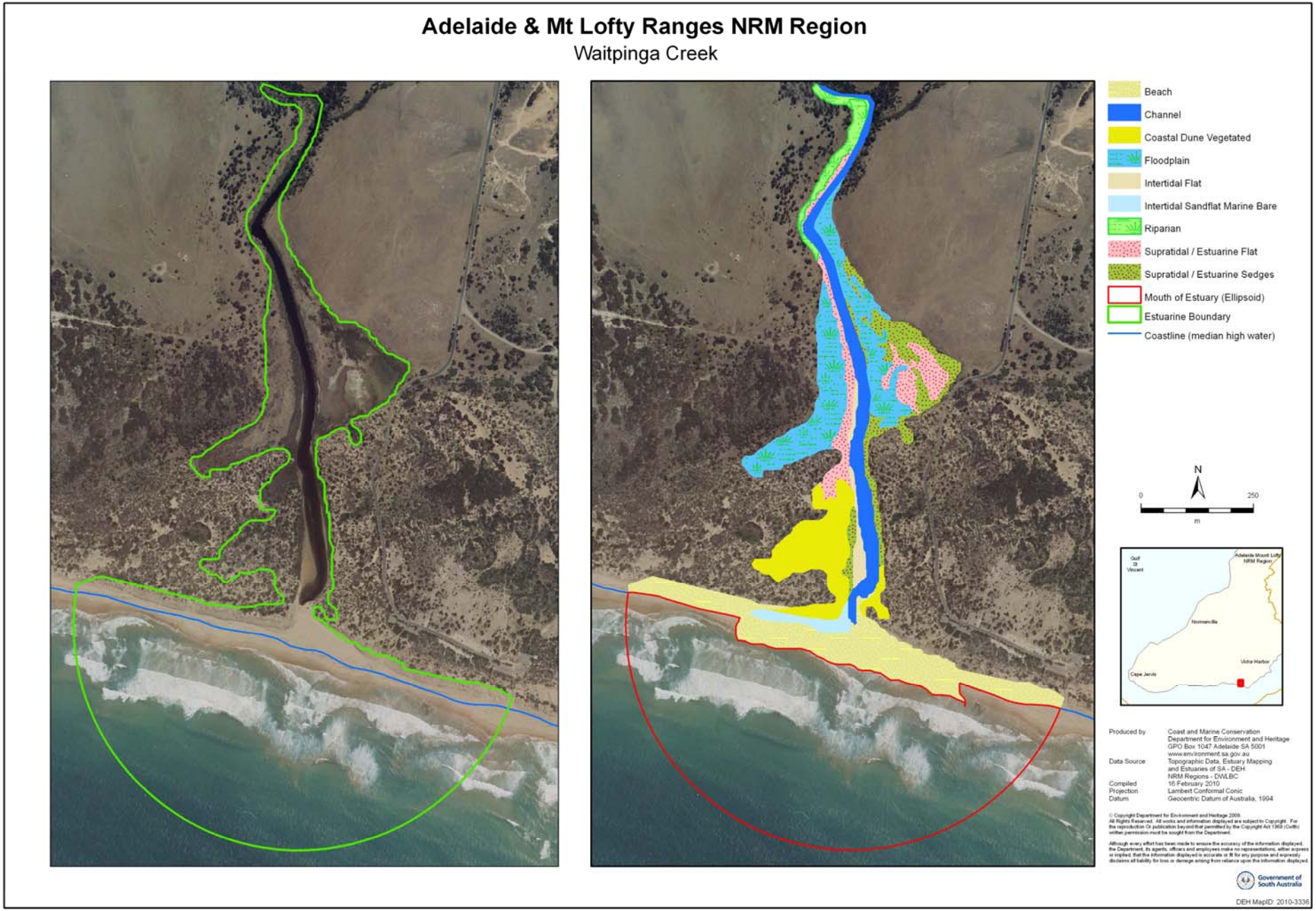


Figure 25. Example map of an estuary in the AMLR Region.

Estuary Inventory Protocol Development

Wetland inventory is the process for determining and recording the location, number and specific characteristics of estuaries within a given area (Costa *et al.,* 1996). Ramsar COP8 (8th Conference of Parties) has adopteded the following definitions of wetlands inventory:

- The collection and/or collation of core information for inland water management, including the provision of an information base for specific assessment and monitoring activities (Ramsar Secretariet 2006).

The data sheet and methodology used in the field for the survey work was based heavily on the work and processes developed in the Fleurieu Wetlands Inventory in 2005 (Harding, 2005). The estuary inventory project developed a process that was adapted from the wetlands protocols to suit the estuarine environments.

Essentially, the Fleurieu Peninsula Wetland Inventory process consisted of a set of field templates that contained data collection information requirements such as location and size, physical and biological features, human activities and impacts, wetland function and values for the wetlands in the Fleurieu Peninsula region (Harding, 2005).

As the protocols for the estuaries inventory project were so heavily influenced by the Fleurieu protocols, it is important to briefly detail their development and the science behind them before detailing the final estuaries methodologies.

The following information outlining the wetland methodology is taken from the Fleurieu Peninsula Wetland Inventory (Harding, 2005)

> *"A survey protocol was developed specifically to allow the rapid collection of essential biological and physical quantitative data including subjective assessments of selected wetlands. The rapid nature of the assessments required approximately 1 – 1.5 hours at each site.*
>
> *Numerous existing wetland inventory methods were researched and elements of all were adapted to suit the specific requirements of the Fleurieu Peninsula Wetland Inventory. The protocol is required to meet the criteria of several State and National inventory procedures and must also meet minimum dataset requirements for the collection of biological data in South Australia (DEH 2003a).*
>
> *Table 3 lists particular wetland inventories adapted for the Fleurieu Peninsula Wetland Inventory. A draft protocol was formulated and edited by several wetland ecologists and members of the field survey team before the final protocol were set."*

Table 3. Existing wetland inventory methods used in the development of the Fleurieu Peninsula Wetland Inventory.

Title	Reference
Simplified method for wetland habitat assessment.	Cable *et al*. 1989
Techniques for survey, inventory and classification. In: *Manual of Wetlands Management*.	Beilharz 1992
Mediterranean Wetland Inventory (MedWet): Volumes 1 – 4.	Costa *et al.* 1996
Development and testing of a rapid appraisal wetland condition index.	Spencer *et al.* 1998
Wetland Inventory and Habitat Requirements – Wetlands Waterlink	Wilson 1999
A Manual for an Inventory of Asian Wetlands: Version 1.0.	Finlayson *et al.* 2002
A Ramsar framework for wetland inventory. In: *Wetlands: water, life, and culture*.	Ramsar Convention Bureau 2002
Wetland Inventory for the Mount Lofty Ranges. Wetland Inventory for Kangaroo Island Wetland Inventory for Eyre Peninsula Wetland Inventory for Northern Agricultural Districts	Seaman 2002a Seaman 2002b Seaman 2002c Seaman 2002d
Coorong & Lower Lakes Ramsar Habitat Mapping	Seaman 2003
Wetland Inventory: Corangamite Region, Victoria.	Harding 2004

Estuary Protocols

Methodologies from the South Australian Wetlands Database were adapted specifically for estuaries. The latest field data sheets used for data collection for the database were developed for the Fleurieu Peninsula Wetlands Inventory Program. The templates from the Fleurieu Peninsula program were adapted to suit the specifics of estuarine environments in South Australia. A number of reference materials were used to identify and add estuarine-specific indicators to the inventory assessment sheets.

Arundel and Mount (2007) outlined the nationally-agreed Estuarine, Coastal and Marine (ECM) Indicators. These are essentially broken into three indicator types, extent and distribution of key habitat types (covered by the mapping in this project), biological condition and physical/chemical condition. As this project involved a rapid assessment scheme, collecting first-pass information, only indicators deemed relevant for the scope of the project were considered from this document.

The Guidelines for the Rapid Ecological Assessment of Biodiversity in Inland Water, Coastal and Marine Areas (Ramsar Secretariat 2006) also set out a clear model for when rapid assessment is appropriate; what information should be collected during a rapid assessment; a conceptual framework for the assessment; and the outputs required. These guidelines contributed significant knowledge and support in the development of the estuary rapid assessment methodology for this project.

As part of the process of adapting the data sheets and the survey methodology, a number of other sources were used to provide input into the final template. These are listed below:

- Guidelines for the Rapid Ecological Assessment of Biodiversity in Inland Water, Coastal and Marine Areas. This was a Technical Report developed by the Ramsar Convention Secretariat (2006).
- Parameters and information contained within the Ozestuaries website, http://www.ozcoasts.org.au/
- Parameters used within current AMLR NRM Estuary Monitoring indicated on the Board's website: www.amlrnrm.sa.gov.au/
- WATERWATCH South Australia Estuarine Monitoring Guidelines (Coleman, 2003)
- Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers (Barbour *et al*, 1999).
- Parameters suggested in a DEH report regarding the Trialling of Resource Condition Indicators for the South Australian Coast (von Baumgarten, 2007)
- Estuarine, Coastal and Marine National Condition Assessment; Scoping Report (Mount, 2008)
- Guide to native vegetation survey (DENR, 1997)

An internal review process was applied to each incarnation of the datasheets with technical meetings attended by science, design and planning members of the Coast and Marine Conservation Branch and Coast Protection Branch, DENR.

In addition to the internal process, the datasheet development process gained critical input from the Estuaries Inventory Project Technical Committee.

It was considered that the information contained on the wetland sheet was too much for a two-hour rapid assessment and that a proportion of the information to be collected could be done in the office before the field survey. As a result the single datasheet was divided into desktop and field applications and proved successful.

Once the datasheets had gained feedback and approval internally and through the technical committee, a pilot study was undertaken in the company of Delta Environmental Consulting at two sites on the Fleurieu Peninsula to determine its field effectiveness. The sites visited were Myponga Estuary and Onkaparinga Estuary. The pilot study highlighted minor template-usability issues but confirmed that the process was sound and could be completed in the set time to gain the required information.

Due to the multiple site nature of estuarine surveys, the length of time required at each site for an estuary rapid assessment was lengthened to 2 hours from the 1.5 hour goal of the wetland survey process. This allowed for a standardised survey effort for each site, however time was largely dependant on the size of the estuary being surveyed.

Aims and Objectives

The guidelines for rapid ecological assessment of biodiversity in inland water, coastal and marine areas developed by the Ramsar Secretariat (2006) stress the importance to clearly establish the purpose of the survey as a basis for the design and implementation. As a result, a clear set of aims and objectives were developed for the rapid assessment process:

- To develop a repeatable and robust methodology;
- Collect first-pass (baseline) information;
- Rapid assessment – 1.5 - 2 hours per estuary (or subsection of a large estuary);
- Defining and describing estuaries at the estuary and habitat scale; and
- To provide a general overview of the physical, biological and chemical properties within the estuary.

Estuary Survey

The wetland protocols were designed to focus on defining and describing wetlands at both the “wetland” and “habitat” scale and the estuaries protocol is no different. Different estuarine habitats can occur in the same estuary system and have variable characteristics, as can wetland habitats (Finlayson *et al*., 2002). As estuaries primarily have different characteristics near their mouths than they do near their head, particularly for large scale sites, it was important to split the site into sectors where habitats and management issues varied. This was determined by the distance or size of the estuary, with estuaries of 0 – 1 km length having one sector or one datasheet completed and 1 - 2 km in length had two datasheets or sectors. There were no sites visited that were longer than 3 km. Due to their more uniform nature, embayments were completed on one form as a single sector. Splitting estuaries into sectors is in keeping with the Fleurieu Peninsula Wetlands Inventory.

For each estuary (or estuary sector) surveyed, the data attributes presented in Table 4 were collected via a desktop study and the attributes in Table 5 were collected in the field. The estuary survey data sheets used for this inventory and the accompanying instruction manual are given in Appendicies 1 & 2.

Desktop inventory information was collected in the form of a species list from DENR’s Biological Database of South Australia (DEH, 2006a). This information consisted of flora and fauna lists and only included historical surveys conducted within the newly developed estuarine boundaries. Other information was sourced from regional management plans and research papers from university institutions developed from research at estuary sites in South Australia.

Table 4. Desktop data collected during Estuary Inventory for each estuary.

Subject area	Attributes
Reference Data	▪ Date and time ▪ Compiler details ▪ Organisation / project ▪ Location description ▪ Wetland ID (reference number) ▪ Wetland name ▪ GPS location ▪ Site photos
Land tenure and Landuse	▪ Tenure – on-site and surrounding ▪ Landuse – on-site and surrounding ▪ Management authority ▪ Social / Cultural values and recreational facilities
General Hydrology & Landform within Estuarine Boundaries only	▪ Mouth - open/closed ▪ Estuary classification ▪ Water regime ▪ Flow control structures ▪ Water source – type
Biological Characteristics	▪ Fauna survey info available on databases ▪ Flora survey info available on databases ▪ Riparian vegetation width
Conservation Measures	▪ Management plan ▪ Environmental burning/slashing/grazing ▪ Listed Nationally Important ▪ Privately managed for conservation ▪ Within formal reserve system

Table 5. Data attributes collected for each estuary survey site in the field.

Subject area	Attributes
Reference Data	▪ Date and time ▪ Compiler details ▪ Organisation / project ▪ Location description ▪ Wetland ID (reference number) ▪ Wetland name ▪ GPS location ▪ Site photos
General Hydrology & Landform within Estuarine Boundaries only	▪ Mouth - open/closed ▪ Tide status ▪ Water flow ▪ Water course channel - natural, physically altered, combination
Weather Conditions	▪ At time of survey ▪ Past 24 hours ▪ Rainfall in the last 7 days ▪ Cloud cover ▪ Air Temperature
General Description Section	▪ Any comments ▪ Mud map if required
Water Chemistry and Substrate Type	▪ At least 3 sites - head/middle/mouth ▪ Multiple depths if possible - depth of testing ▪ Maximum water depth ▪ pH ▪ Conductivity ▪ Temperature ▪ Dissolved Oxygen ▪ Secchi depth ▪ GPS of water testing location
Sediment (% makeup)	▪ 0 - 2 cm depth ▪ Greater than 2 cm depth
Threatening Processes	▪ Disturbances / Management issues ▪ Current extent of disturbance ▪ Conservation measures taken (current or suggested)
Surface Water Chemistry	▪ Conductivity ▪ pH ▪ Dissolved Oxygen ▪ Temperature ▪ Turbidity ▪ Water depth and flow at reading sites
Biological Characteristics	▪ Estuary fauna noted during survey process ▪ Micro habitats present ▪ Estuary vegetation summary ▪ Portion of reach with aquatic vegetation ▪ Riparian vegetation - dominant types ▪ Flora diversity – within each vegetation zone ▪ Weed species present
Water Colour	▪ Colour of water assessed against colour charts
Subjective Assessment	▪ Subjective assessment of flora and fauna values ▪ Subjective assessment of entire wetland condition

Due to time and resource constraints it was not practical to visit and survey all 102 estuaries in South Australia. As a result, a number of reference estuaries in four NRM regions around the state were chosen to be surveyed using the rapid assessment process. No estuaries in the SE were visited due to funding restrictions. 25 estuaries were visited and surveyed during the period from February 2009 to April 2009 (see Table 6).

Estuaries were chosen using the following criteria:

- Regional representatives on the technical committee had identified them as priorities in the region to be assessed;
- Estuaries that were an estuary type that represent of a number of estuaries in the region; and
- Estuaries where significant data already existed were not considered in the survey process.

Many estuaries occur on private land and visiting these locations relied on the approval of the landowner. In several cases, permission was not granted to enable estuaries identified to be surveyed.

Flora lists were generated using two methods. Newly developed estuary boundary maps were used in conjunction with the BDBSA during the desktop process to identify survey sites that existed within the estuary boundaries. Threatened flora and fauna locations were also identified via existing DENR records.

During the field survey work the main species in the each habitat were recorded on the data sheet. These lists are critical for sites with no formal surveys within them and will complement the desktop lists. It is clearly indicated in the completed lists the sources of the species identified for any specific location.

MAPPING AND SURVEY FINDINGS

The mapping process produced visual information to identify estuary boundaries and habitats. Once these boundaries were determined the GIS program was used to produce a range of statistics. Information such as sizes of each habitat in each region and the percentage of each habitat type for each region gave an indication of the major estuary characteristics in each NRM region. This data represents all 102 estuaries mapped during this project.

The raw data gained from the field survey results of the 25 estuaries is utilised in two different ways to provide useful information. In the most basic form the data is used to identify trends and highlight components of the estuaries surveyed. For example, indications of the main surrounding land uses and the main types of threats present. A more complicated analysis of water quality data sets is also discussed.

The findings discussed in this document are an overview of information on estuaries found in this state and as a result not one estuary is singled out for special attention. Trends, similarities, differences and any significant findings are highlighted in this section.

Individual data for each estuary are stored in a database that is accessible online through the mapping site “NatureMaps”. Any estuary site specific information should be sourced through the NatureMaps Website at the following website: http://www.naturemaps.sa.gov.au/

Estuaries Surveyed

Representative estuaries from four of the five NRM regions were chosen to be included in the field survey process. These are shown in Figure 1 and listed in Table 6 with information regarding the estuary mouth status at the time of survey. Due to private property access, water quality data was not collected at Waitpinga Creek and Yankalilla Estuary and there was no water in the Fishery Creek Estuary during the survey period. Therefore these estuaries have no water quality data, although subjective assessment of threats was done.

Table 6. Estuaries visited during the survey process and status of estuary mouth at time of survey. *No water quality data.

Estuary Name	NRM Region	Mouth Status
Baird Bay	EP	Open
Franklin Harbour	EP	Open
Salt Creek	EP	Open
Tod River	EP	Open
Venus Bay	EP	Open
Bungala	AMLR	Closed
Carrickalinga	AMLR	Closed
Fishery Creek*	AMLR	Closed
Hindmarsh River	AMLR	Closed
Inman River	AMLR	Closed
Waitpinga Creek*	AMLR	Closed
Yankalilla*	AMLR	Closed
Chapman River	KI	Closed
Cygnet River	KI	Open
Deep Creek	KI	Open
Eleanor River	KI	Closed
Harriet River	KI	Closed
Middle River	KI	Closed
Rocky River	KI	Closed
South West River	KI	Closed
Stunsail Boom River	KI	Closed
Western River	KI	Closed
Willson River	KI	Closed
Wakefield River	N&Y	Open
Wills Creek	N&Y	Open

Estuaries Mapping Results and Discussion

Total Estuary Numbers and Area

As mentioned earlier in the report, 102 estuaries in the state have been mapped as part of this project. The numbers in each region can be seen in Figure 26.

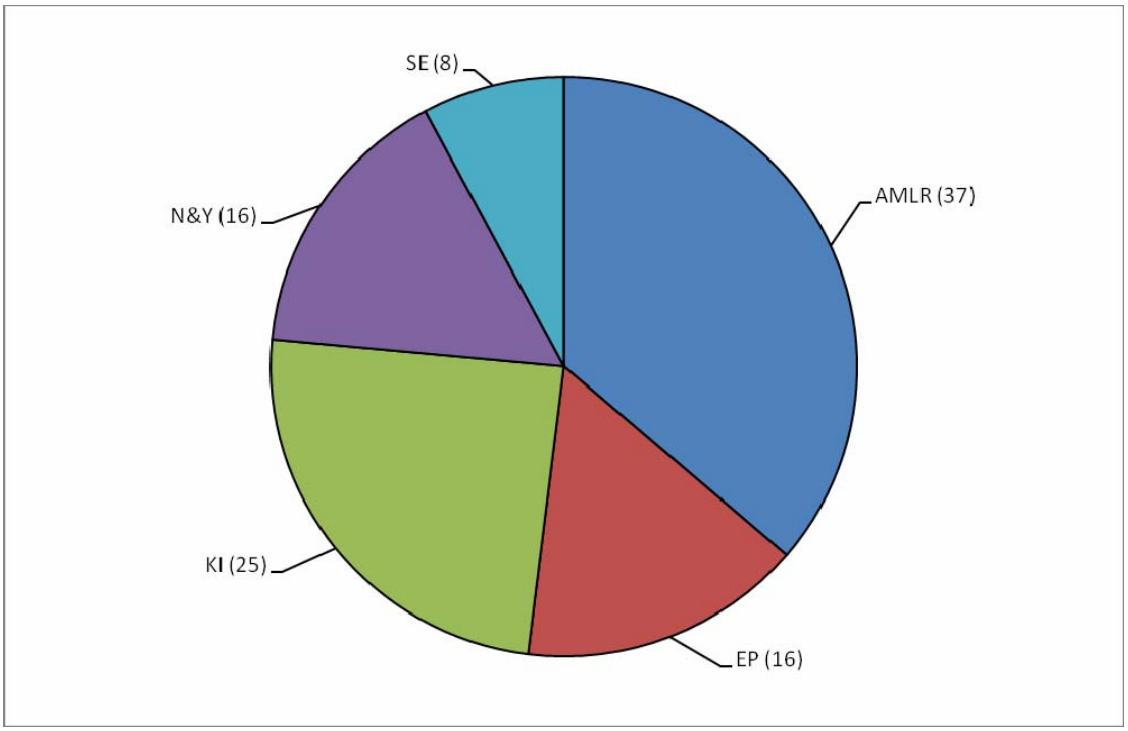


Figure 26. The number of estuaries in each of the five NRM regions mapped.

Figure 27 shows the percentage of total area of estuaries in the state by region covered by this project. Figures 26 and 27 together show that the two regions containing the highest number of estuaries in the state, AMLR and KI, cover a considerably smaller area than the EP and N&Y regions. This suggests that there are different types of estuaries found in these regions.

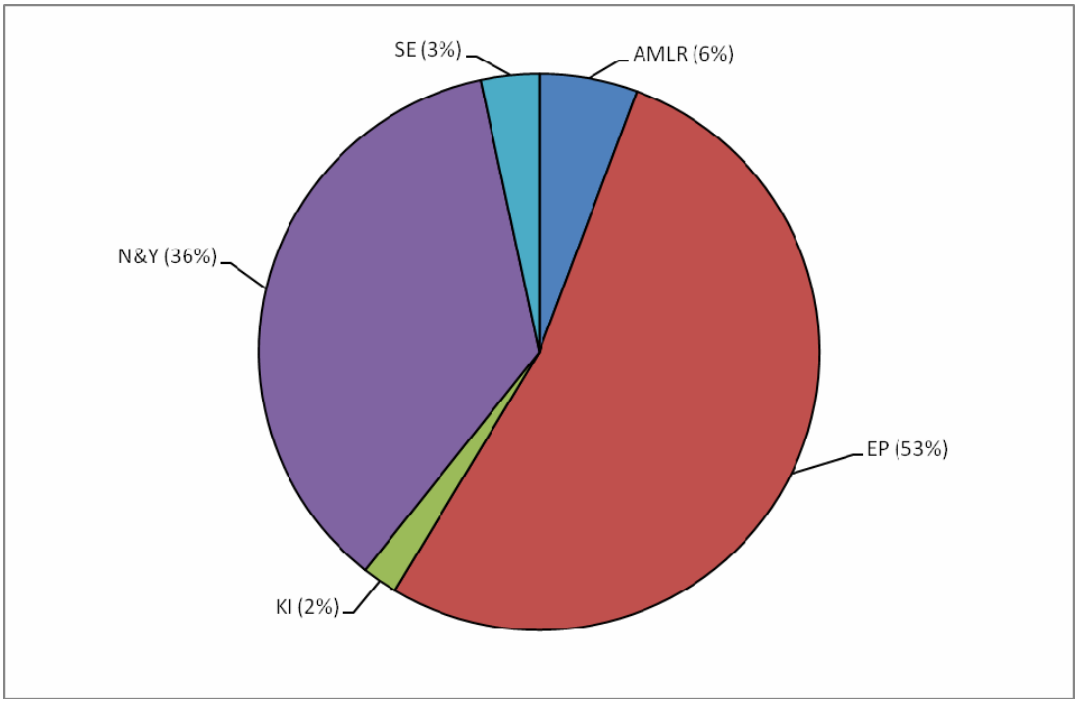


Figure 27. Area of estuaries in each region as a percentage of the mapped estuarine area.

Eyre Peninsula (EP) NRM region has a high proportion of large embayments containing considerable open areas of water with narrow surrounding supratidal associated habitats. Northern & Yorke (N&Y) NRM region also has a large area in proportion to other parts of the state but this is not due to large embayments like EP. The large percentage area in N&Y is due to considerable amounts of low lying intertidal and supratidal associated habitats, extending some distance inland. The N&Y NRM region contains the highest proportion of mangrove and saltmarsh communities in the state (see Figs 28 and 29) and this is due to the sparse low-lying nature of the country allowing estuarine conditions to spread over larger areas than in other parts of the state. The conditions in the gulfs are conducive to mangrove and saltmarsh communities and N&Y NRM region covers parts of both gulfs.

In contrast to the EP and N&Y NRM regions, the majority of estuaries in the AMLR and KI NRM regions have more defined channels that create quite confined linear boundaries that do not spread far from the actual channel, thus reducing the overall area of the estuaries. Therefore the pie charts highlight the differences within each region and hint at the need for different planning and management in different regions.

Vegetation is a good proxy for the types of estuaries found in the region, because of their indication of estuarine types, geomorphology and influence by tidal action or freshwater flows. Figure 28 shows the area of mangroves found in each region, with the largest area found in the N&Y region followed by the EP and AMLR regions. This supports the findings that the estuaries in the N&Y are heavily reliant on tidal flows and are low lying, spreading over large areas. The embayments on EP clearly have similar conditions in many areas supporting over 3,000 hectares of mangroves. The mangrove areas in the AMLR are limited to the northern extremes of the region and are contained within a few large estuaries around the Barker Inlet Port Gawler region. KI and the SE have no mangrove populations within them indicating the estuaries are different from the ones in the N&Y and EP.

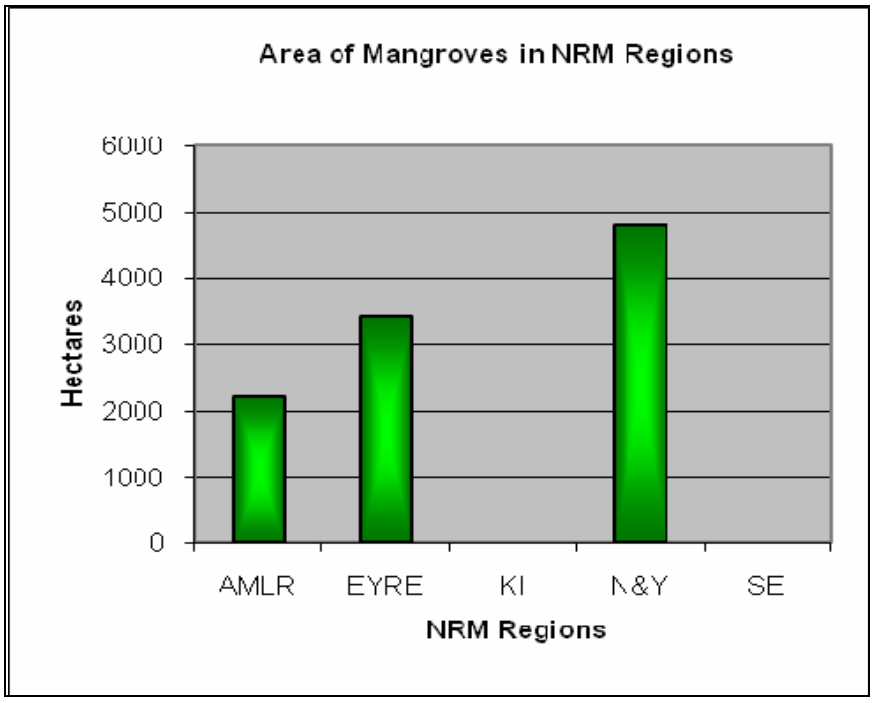


Figure 28. Total area of mangroves in each NRM region in SA.

Figure 29 shows the area of samphire in each region. Similar to mangroves, the area of samphire is very low in KI and the SE, but marginally higher in the AMLR. The nature of the estuaries in the N&Y (low lying, spread over large areas and reliant on tidal movement) are perfect for samphire growth, as shown by the vast area of samphire found in this region, followed by the embayment dominated EP.

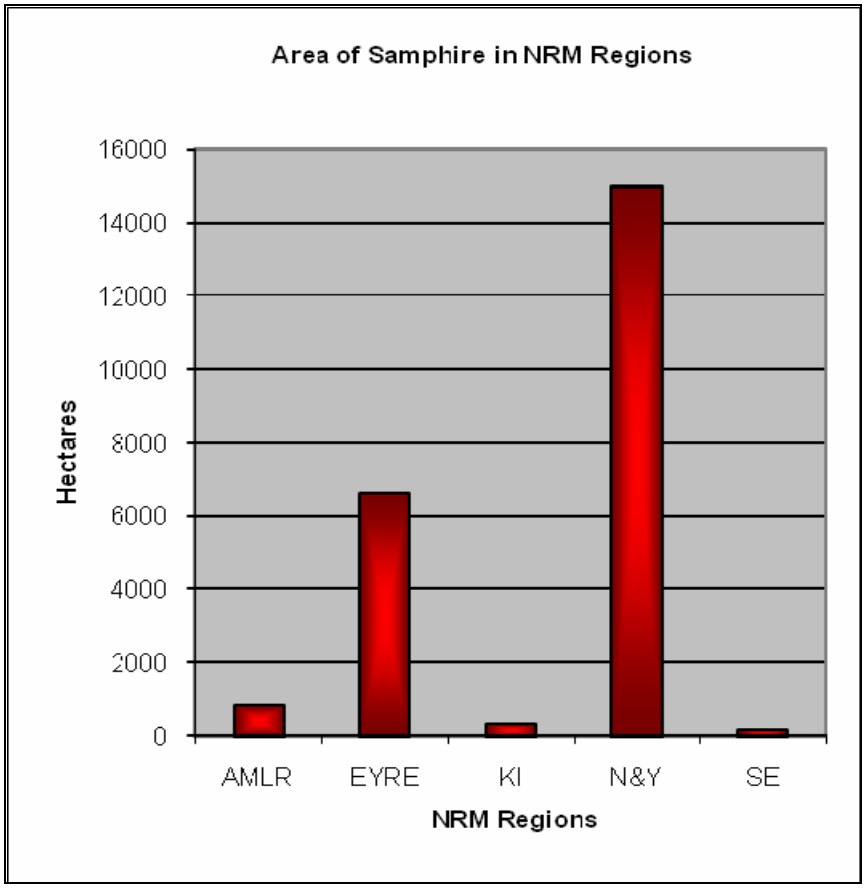


Figure 29. Total area of samphire in hectares within estuarine boundaries in each NRM region in SA.

Central basins are are uniform, lower energy environments in the deeper and quieter parts of estuaries, and are often formed landward of barrier bar deposits in wave-dominated estuaries (OzCoasts). Figure 30 shows the area occupied by central basins in regions, once again giving an indication of the type, geomorphology and processes operating in many of the estuary systems in those regions. It can be seen that the EP has by far the largest area of central basins, an indication of the dominance of embayment estuaries in the region. AMLR and N&Y have no estuaries containing central basins and the areas in the SE and KI are represented by one or only a few sites in those regions.

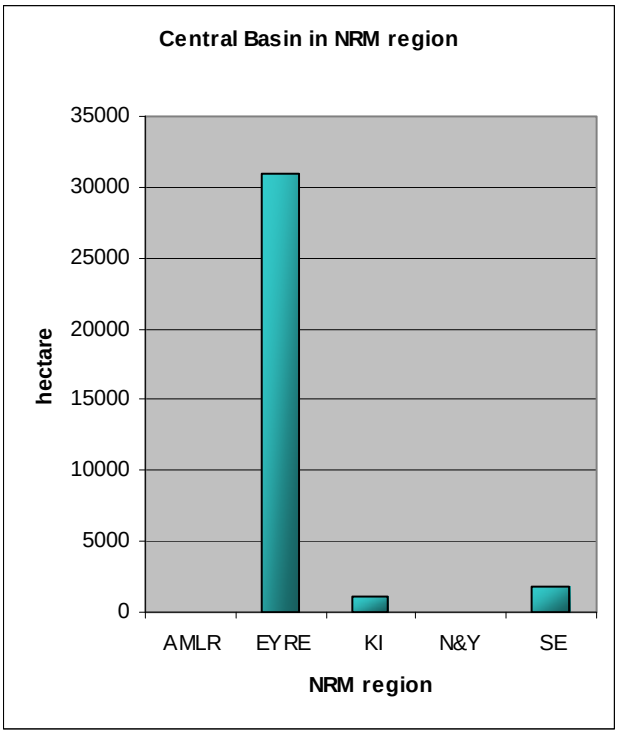


Figure 30. Total central basin area within estuarine boundaries in each NRM region in SA.

Estuary Surveys Results and Discussion

Only one survey event occurred during this project and this took place during the summer/autumn period before the breaking of any significant winter rain. As a result, the data presented here represents summer characteristics. Many of the estuary mouths were closed when surveyed, with only nine of the 25 estuaries surveyed being open to the sea (see Table 6 above). However of these nine, four are embayments that are permanently open to the sea, leaving five estuaries that were open to the sea that could potentially close over.

Due to the climate and catchment size in South Australia, it is not uncommon for estuaries to have closed mouths during the dry summer period. Issues arise when altered water flows, physical barriers and water interception in the catchment reduces flows to the point that mouths stay blocked for multiple years, extending these conditions past their natural timeline. When this information is matched with the threats to estuaries graph (Figure 41), which indicates a high level of altered water flows and barriers to flows, it becomes an important issue facing our estuaries. More existing historical information is required to assess historical flows and associated mouth opening events to compare with more recent trends so to identify any alterations to this natural process. The duration of mouth closure can impact a number of other important processes operating within the system and these changes can significantly alter the state of the estuary.

This data also needs to be combined with winter testing over a number of years as well as regional collection of historical data to try and determine historical character.

Adjacent land use

Land use adjacent to estuaries is important to consider for overall potential status of the estuary and potential impacts. The inventory project was strictly investigating the area within or directly adjacent to the estuarine boundaries and the adjacent land use is

summarised in Figure 31. Of the estuaries visited for the rapid assessment inventory, only eight were located next to a Conservation Park, one was within to a National Park (Rocky River) and seven had Heritage Agreements adjoining the estuary boundary. However, almost all estuaries had grazing or some primary production or industry adjacent to them and many (15) had residential zones next to them.

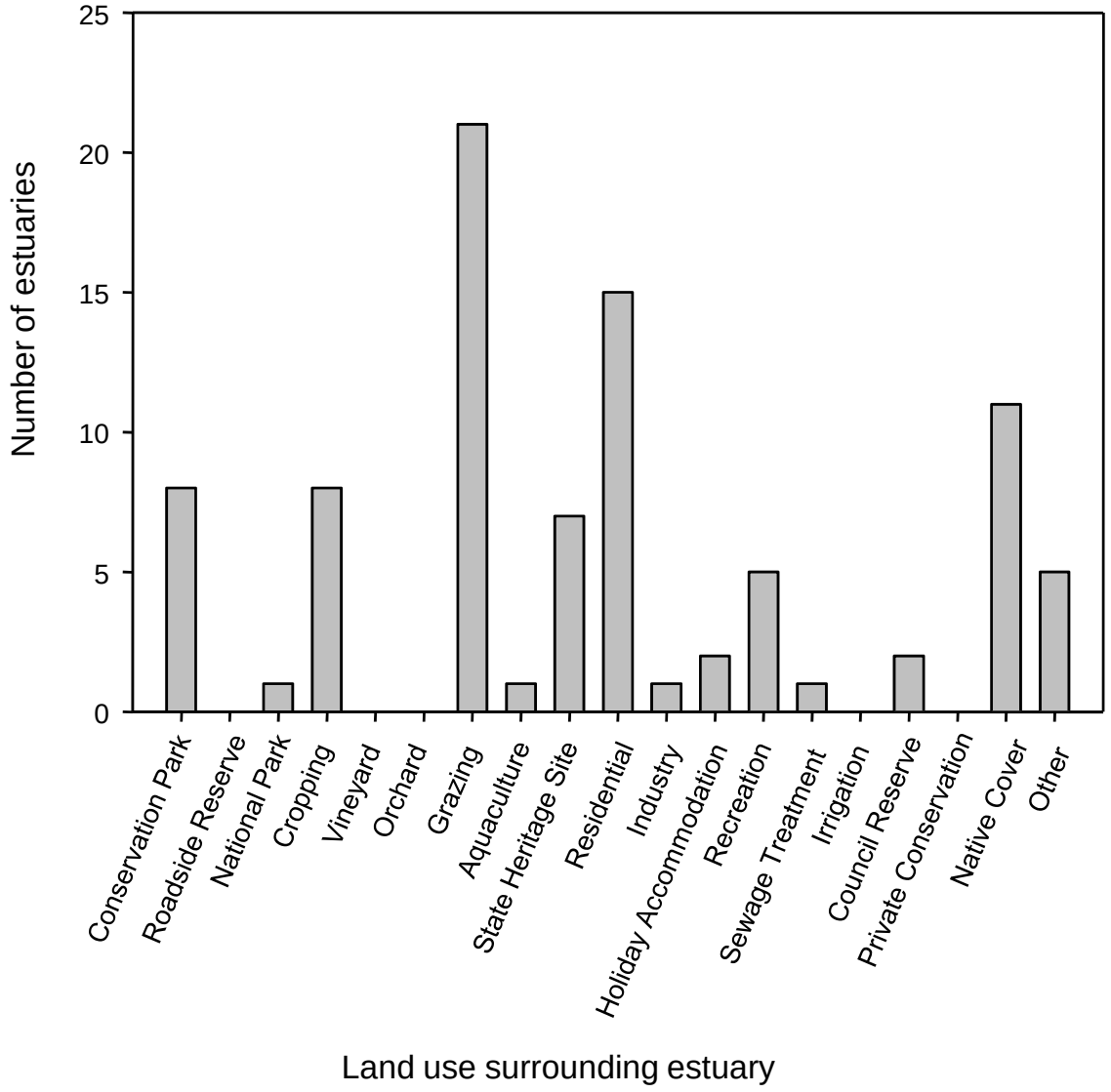


Figure 31. The number of estuaries with particular landuse directly adjacent to estuary boundaries observed during surveys.

Water Quality Results

Water quality data was collected during the survey period at 22 estuaries (excluding those that could not be sampled; see Table 6) around the state. A number of water quality measurements were taken with some of these results highlighted in this section.

It should be noted that the majority of sites had water quality measured at the mouth and the head of the estuary (as designated by mapping) and many had measurements taken at the middle and the upper-most headwaters as well, when they were particularly large. It was endeavoured to take measurements at two depths at each site but in a few cases there was not enough water to perform two measurements. In this case only one measurement was taken.

The graphs are labelled with the location within the estuary (mouth, middle, head and upper-most) and the depth (shallow or deep) at which the water quality measurements were taken. Bottom depths varied depending on the site, with a maximum depth of 2.4m for one reading. For information on depth readings please see the raw data linked to the mapping layer on Naturemaps (http://www.naturemaps.sa.gov.au/).

Water chemistry

Conductivity, salinity, pH, temperature, turbidity and dissolved oxygen were recorded as part of the estuary inventory process. Methods for recording water chemistry are explained within the field survey instructions located in Appendix 2 of this document and were undertaken with a HORIBA U52 Mulitparameter Water Quality Checker (see Figures 32 and 33).

Water quality indicators are highly variable in estuarine systems and require extensive spatial and temporal sampling (Deeley & Paling, 1999). They provide a snapshot of condition and can support efforts to determine the ecological status by acting as triggers for monitoring purposes (ANZECC & ARMCANZ, 2000). It is important to understand the natural variation in these parameters and to be wary of making rapid assumptions based on them (Barton, 2006).

Surface-water nutrient indicators and pollutants were not collected as part of this inventory due to time and resource constraints. However, excessive nutrients from agricultural production are expected to affect many estuaries in South Australia (Harding, 2005). Point sources such as sewage treatment plants can be significant contributors to surface-water nutrient loads (e.g. Victor Harbor Waste Water Treatment Plant) (Liddicoat *et al.,* 2004). However most other studies have generally found a larger contribution of pollutants comes from sources such as soil erosion and domestic animal wastes (NLWRA, 2003), and fertiliser applications (Liddicoat *et al.,* 2004) that accumulate over large areas of each catchment (Harding, 2005). Threats to wetlands regarding nutrient enrichment and pollutants was identified during the inventory process and included agricultural (animal wastes and fertilisers), dairy effluent, stormwater discharge and urban runoff (Harding, 2005).

Salinity

As was to be expected for a late summer/early autumn survey period, the estuaries all displayed what was considered to be brackish to saline water qualities. Estuary salinity ranged from close to 5 ppt for the Wilson River and Deep Creek on KI to locations containing considerable salt, such as Wakefield and Wills Rivers on N&Y and the embayments on EP which had salinities above 40 ppt.

The type of estuarine system largely influences salinity levels. For example, embayments would have salinities near sea water consistently year round whereas

estuaries receiving high surface flows during winter rains would fluctuate depending on the season and conditions at the time of measurement.

For the purposes of determining when a system was stratified, a definition was established in discussions with DENR staff. It was decided that if there was a difference of 4 ppt or greater between measurements of salinity in the surface test and the bottom test then it was considered to be a stratified system. If the results were below 4 ppt then it was a mixed system. Figure 34 indicates a trend of greater mixing near the mouth and less mixing (i.e. more instances of stratification) near the head of the system. Many locations with this trend also have closed mouths, indicating mixing is not a result of tidal influx but may be due to wind mixing.

Figure 32. Water clarity testing with a Secchi Disc (DENR).

Figure 33. Water quality testing with the HORIBA U52 (DENR).

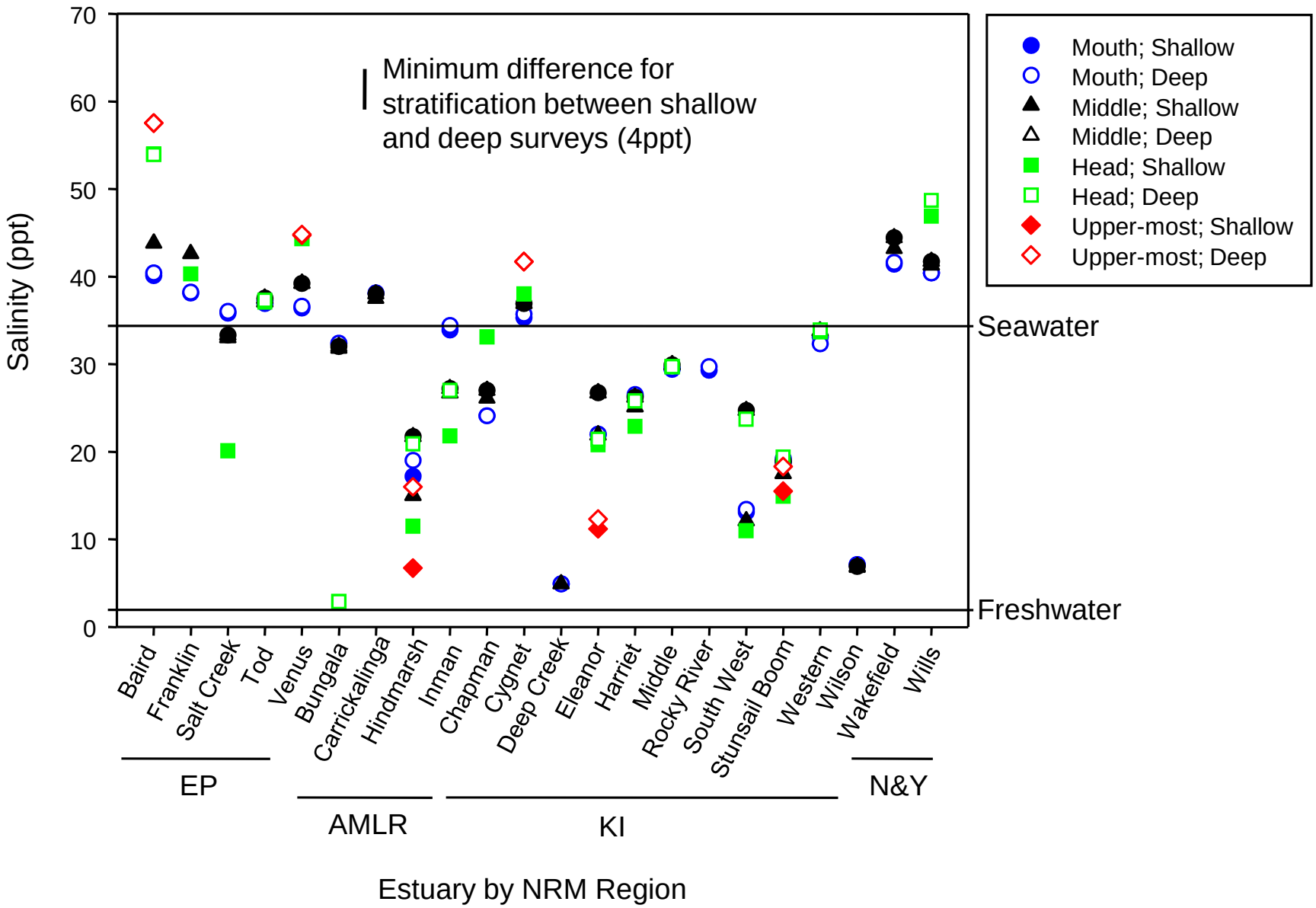


Figure 34. Salinity measurements taken during field surveys.

pH

The pH of water influences many biological and chemical processes. Lower pH in particular can increase the toxicity of some pollutants and it can increase the solubility of heavy metals (Harding, 2005). At extremely high or low pH values the water becomes unsuitable for most organisms (Cugley *et al.,* 2002).

Figure 35 indicates the pH values measured at each water-testing site during the survey. The pH value of water indicates the acidity or alkalinity of water on a sliding scale ranging from 1.0 – 14.0. A low pH of around 2.0 – 4.0 indicates acidity with 2.0 being a strong acid such as sulphuric acid and 4.0 being a weak acid such as lactic acid. Alkaline substances have a high pH of around 12.0 such as for sodium hydroxide. A value of 6.0 – 8.0 would indicate a neutral pH value. The natural range of freshwater in South Australia is between 6.0 and 8.5, with most having a pH value of 7.0 – 8.0 (Seaman, 2002a,b,c,d) whereas estuarine waters usually have a pH of between 6.5 and 9.2 (EPA, 2003). pH can rise with salinity due to many of the salts found in the water being alkaline, this can also be an indication of algal blooms. Low pH readings may be an indication of large amounts of organic matter or peat in the system (Coleman, 2003).

The results in Figure 35 indicate that all sites tested fell within the EPA figure of between pH 6.5 and 9.2 (EPA, 2003). Some estuaries show variations between and within sites, but still fall within these limits indicating that there are no sites that require further investigation due to extreme pH levels.

Temperature

Temperature plays an important role in the ecology of an estuary and along with salinity is one of the main determining factors of stratification (Coleman, 2003). Temperature affects the solubility of oxygen in water, with cooler water being able to hold more dissolved oxygen (DO) than warmer water. As water becomes warmer the rate of photosynthesis by algae and other water plants increases, thereby increasing the occurrence of algal blooms. Higher water temperatures can also lead to organisms becoming stressed and less resilient to other stresses such as toxic waste, parasites and diseases. An increase in water temperature also leads to increases in other biological activity (Harding, 2005). However, should temperatures increase too far beyond the optimal range of organisms, numbers within species may decrease (Munson *et al.,* 2004).

It should be noted that seasonal and even daily changes in temperature can occur in estuaries, depending on a number of parameters. It is reinforced here that these records are a “snapshot” of the sites at the specific times we visited. To gain trends or an indication on seasonal ranges it is recommended that regular long term data is collected.

Figure 36 indicates that temperatures from the sites surveyed ranged from approximately 12°C in the Wilson River on KI, up to nearly 28°C in the Inman River on the Fleurieu Peninsula. However, these estuaries were surveyed at different times of the day. The Wilson River temperature was measured at 9am on a cool day of 12°C air temperature, whereas the Inman River temperature was measured at 1pm on an overcast day of 24°C air temperature.

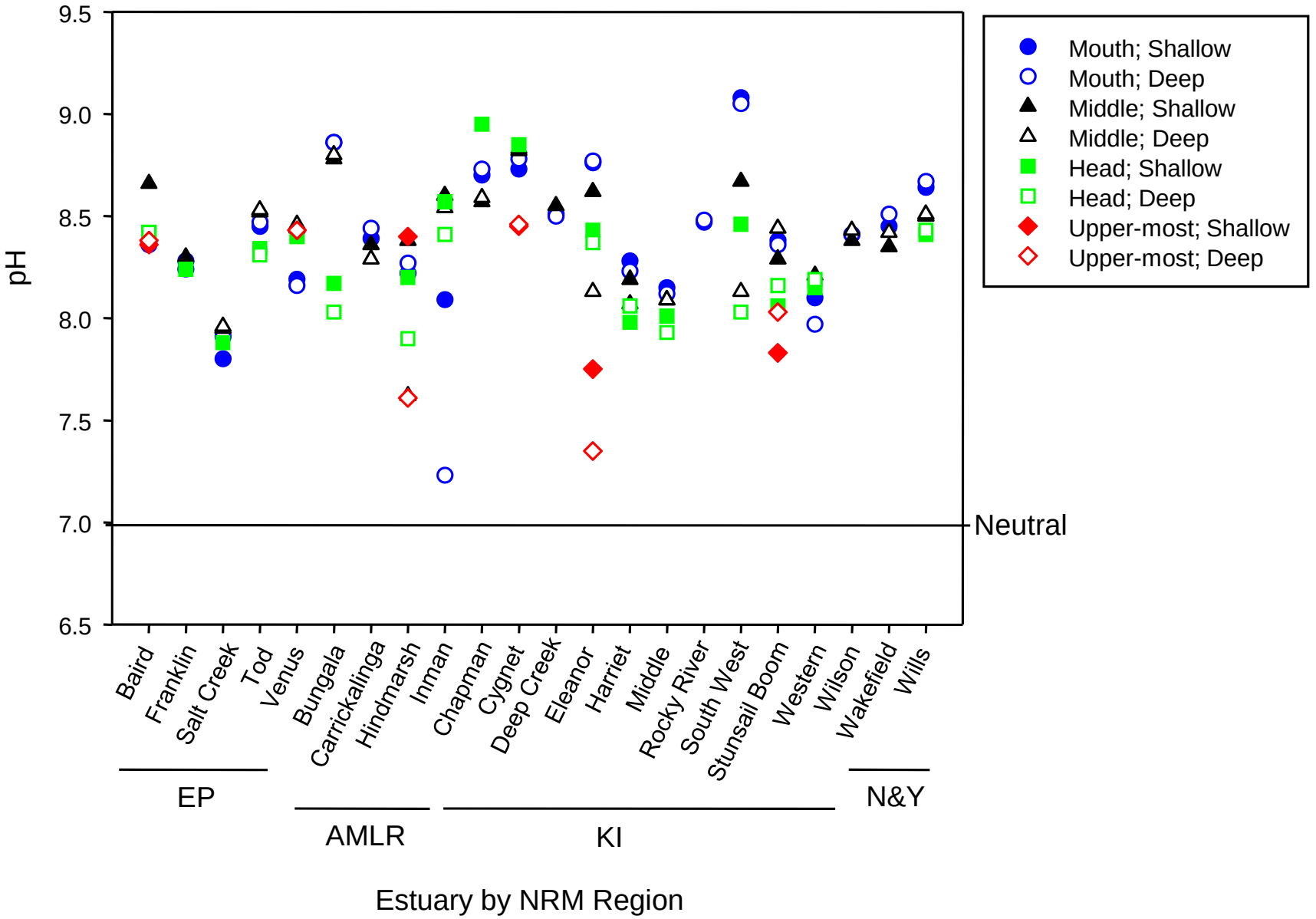


Figure 35. pH measurements taken during field surveys.

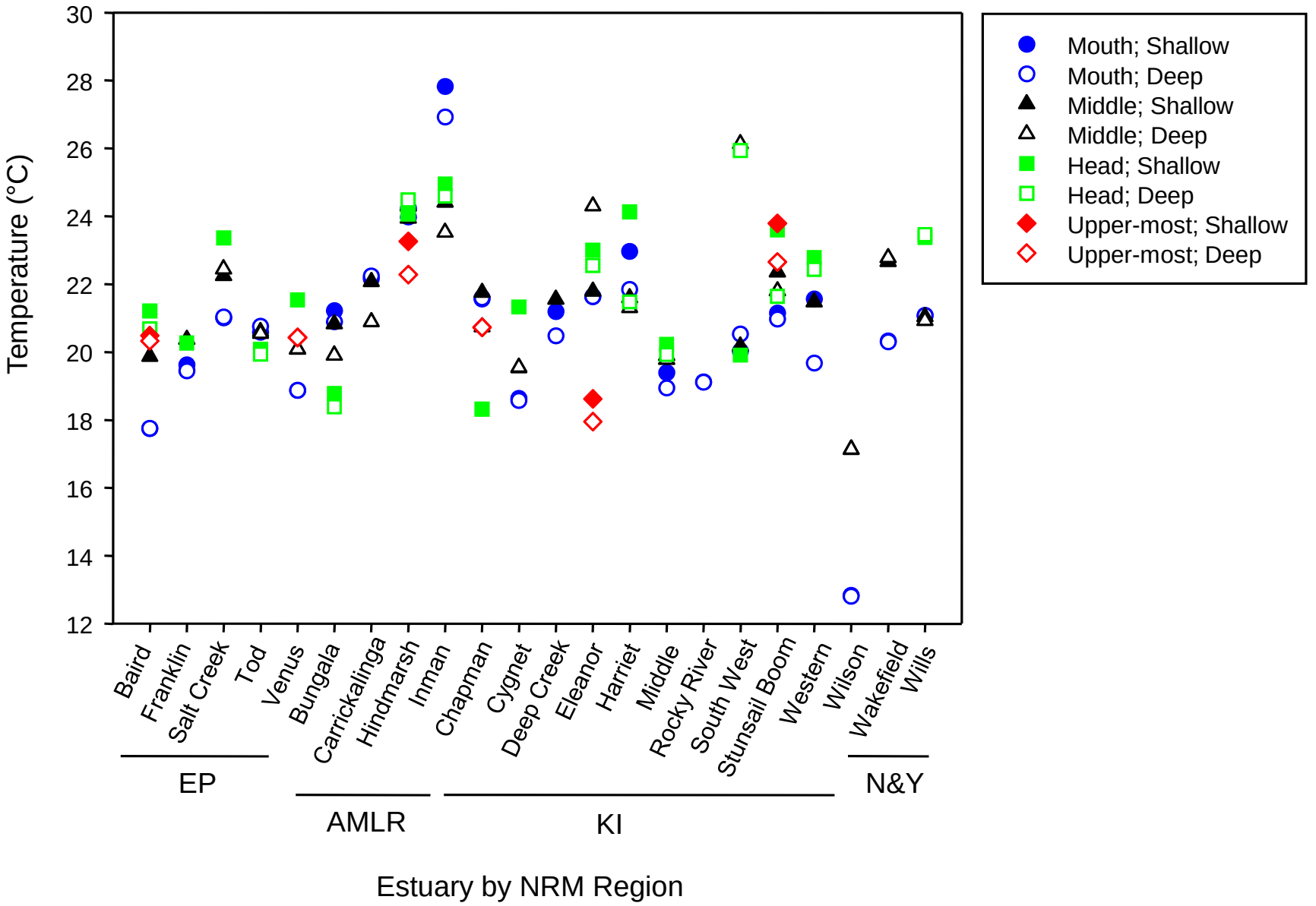


Figure 36. Temperature measurements taken during field surveys.

Dissolved Oxygen (DO)

Dissolved oxygen levels indicate the amount of oxygen dissolved in the water that is available for use by aquatic animals for respiration (Coleman, 2003). A number of natural and human factors can influence the concentration of DO in water. Natural factors include temperature, salinity, time of day and light intensity. Human influences include pollution and increased nutrient loads (Coleman, 2003). As previously mentioned, there is some correlation between temperature and DO levels but it is still important to look at DO in isolation.

Most aquatic animals require at least 3 – 5 mg/L of DO to survive. Water becomes hypoxic below 3 mg/L and anoxic below 0.5 mg/L (Coleman, 2003). Fish tend to move away from waters when the DO drops to less than 5 mg/L.

As can be seen in Figure 37 there were some very interesting results spread out within and between sites tested. Most estuaries displayed changes in DO levels to varying degrees between sites and depths. Three sites measured 0 mg/L at the deep measurement (Inman mouth, Hindmarsh middle and Eleanor head) indicating that these sites were severely anoxic at depth. In addition, five other sites recorded at least one reading of DO levels at or below 3 mg/L indicating hypoxic conditions (Bungala head, Cygnet head, South West head and Eleanor middle all at the deep recording, plus Inman mouth at the shallow recording). These results highlight the poor condition of the Inman River, in particular, with the mouth being hypoxic to anoxic at depth.

The Inman and Hindmarsh Rivers recorded some extreme values within them and between them indicating quite different conditions for two sites so close together. This is an example of how variable individual estuaries of the same classification can be and how hard it is to find mechanisms to group them.

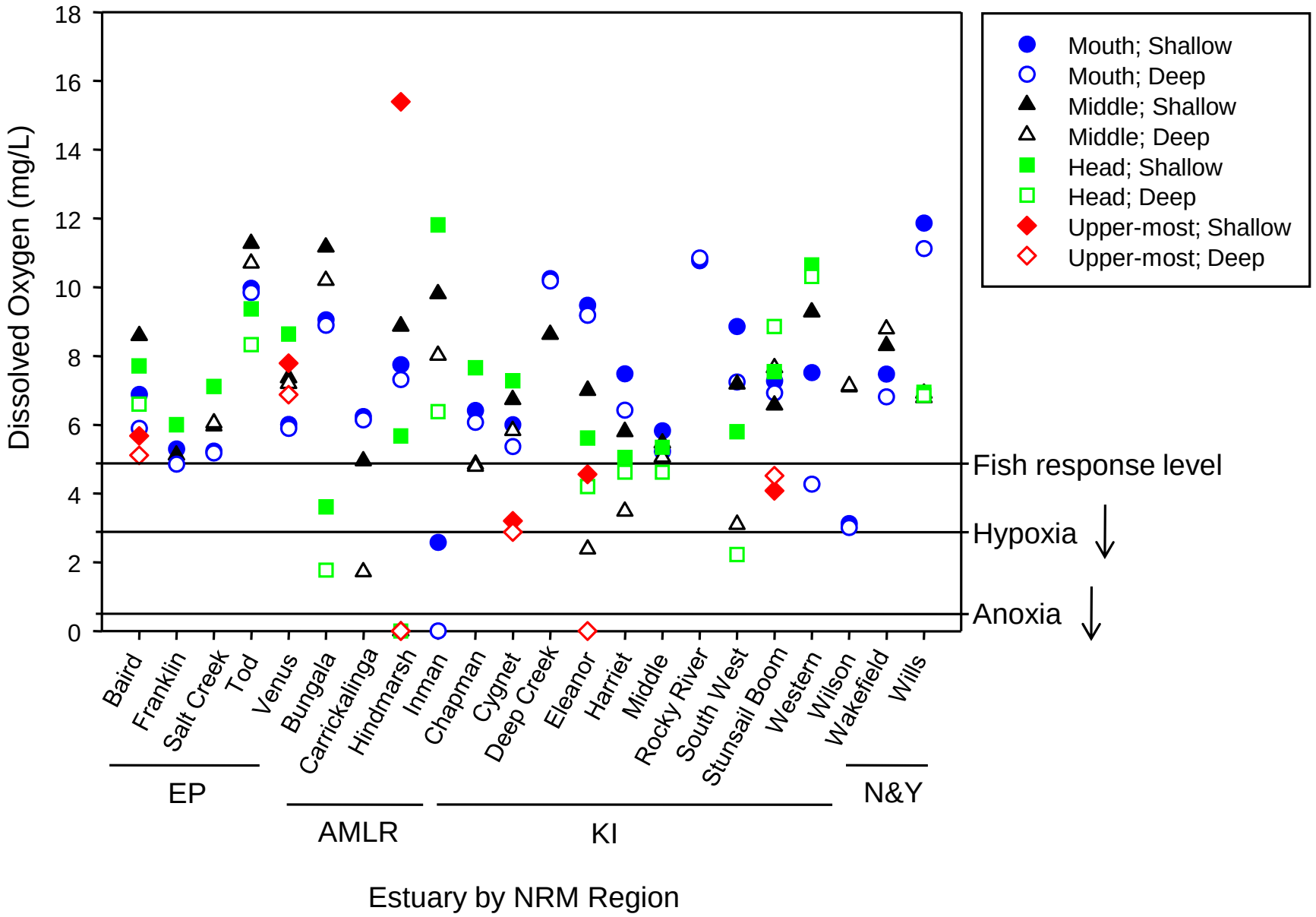


Figure 37. Dissolved oxygen measurements taken during field surveys.

Turbidity

Turbidity is a measure of water clarity and can be affected by the amount of suspended particles of clay, silt, plankton, industrial wastes and sewage in the water. Turbidity is caused by particles which are too small to settle out, but big enough to scatter light. These particles reduce light penetration and trap heat from the sun, which increases the temperature of the water. Reduced light penetration results in diminished photosynthesis, which then leads to a decrease in dissolved oxygen (DO) in the water (Harding, 2005). At higher levels of turbidity, water loses its ability to support a high diversity of aquatic organisms (Munson *et al.,* 2004). Turbidity can be measured in Nephelometric Turbidity Units (NTU), which are calculated by measuring the dispersion of a light beam through a sample of water. NTU have been put into categories by the EPA so as to rate the condition of water bodies in South Australia; good (<20NTU), fair (20 – 50 NTU) or poor (>50 NTU).

Secchi depth measurements were originally set as the main mechanism in this project to assess water clarity but it was found in a majority of cases that the secchi disc was still visible when at the bottom of the estuary. In some cases the estuaries were very shallow in sections due to the summer conditions. As a result the turbidity measurements taken by the water quality meter provide a comparable indication of the turbidity of the various sites and depths at each estuary.

The four sites able to be adequately measured using the secchi disc are indicated in Table 7 along with the results. There was considerable variation in turbidity within sites and between depths (see Figure 38). The turbidity levels measured during the survey process ranged from very clear and close to 0 to very turbid and nearly 90 NTU. Figure 38 also indicates that turbidity levels can differ between site and depth within an individual estuary. An example of this is Eleanor River on KI, where the NTU at the surface of the mouth was 55, but at depth it was 0.6, and at the head it was close to 20 at both the surface and at depth.

Table 7. Secchi depth measurements at the head of estuaries where the disc was able to be used.

Estuary	Secchi Depth (m)
Eleanor River	0.45
Middle River	1.25
Hindmarsh River	0.40
Wakefield River	0.7

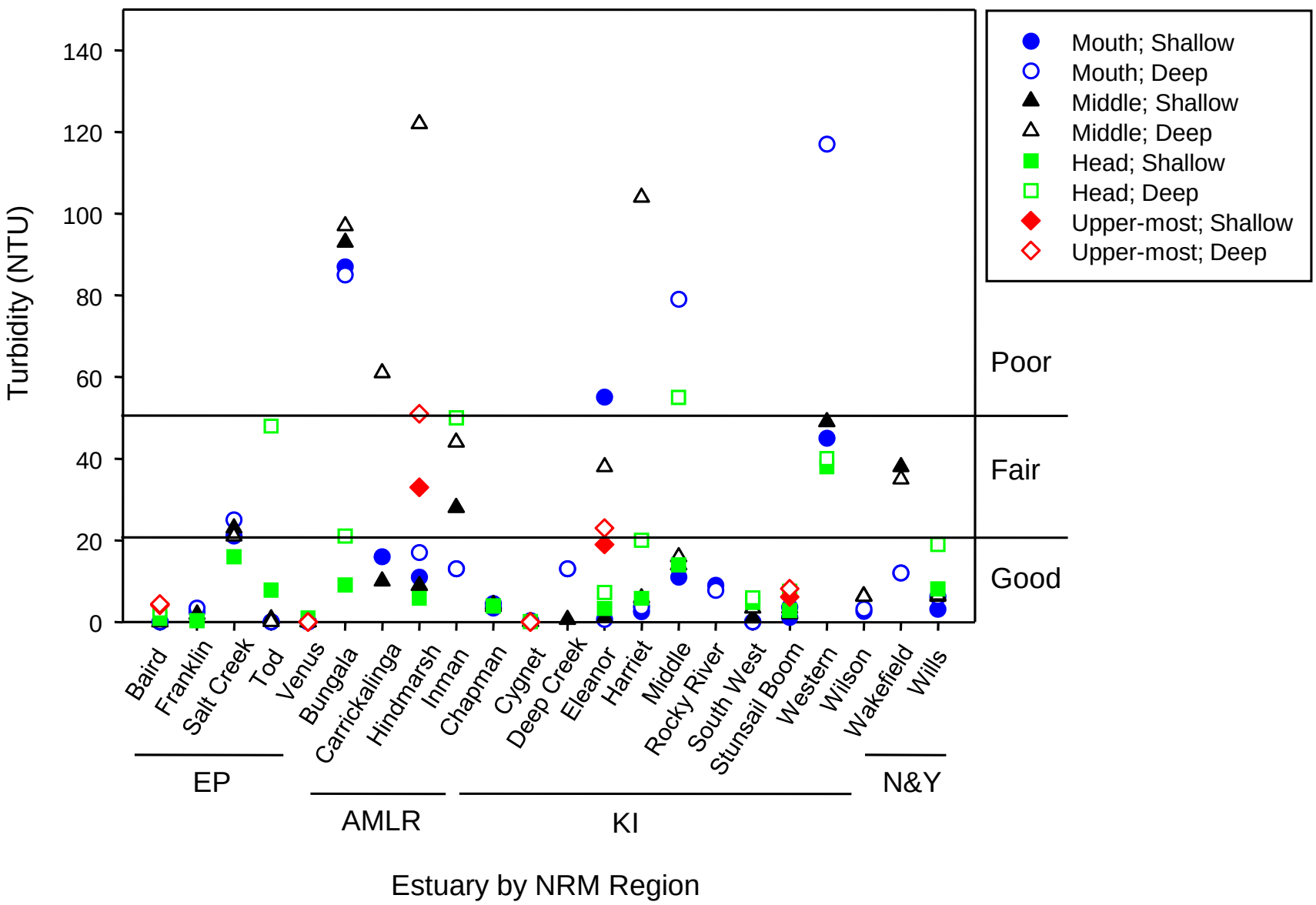


Figure 38. Turbidity measurements taken during field surveys, showing only those below 150 NTU.

Multivariate Analysis

In order to focus estuary inventory and monitoring in the future, some exploratory multivariate analysis was done on the water quality variables discussed above. In particular it was pertinent to see if the water quality variables varied collectively across the NRM regions and among sites within estuaries.

Not all of the data collected were analyzed in this section. Several sites had very shallow water and so a deeper-water instrumental reading was not possible. Therefore sites within estuaries where only one reading was taken were excluded from the analyses. Estuaries without two sites with two depth readings each were also excluded from the analyses. For complete details on methodology employed please see Appendix 5.

Results

NRM Regions

Water quality variables did vary with NRM region across the state (see Figure 39) and region was a significant factor in statistical analysis ($p < 0.05$, PERMANOVA; Anderson *et al.,* 2008). However some NRM regions had similar water quality variables. The AMLR was similar to N&Y and KI in water quality variables, but different from Eyre. The Eyre NRM region had similar water quality variables to N&Y but was different from AMLR and KI. N&Y and KI were also different from each other. These regional differences can be seen in the Principle Components Analysis ordination graph (Figure 39), which plots multiple water quality data-sets in 2-dimensional space and it calculates which variables are more correlated with each axis. The points for Eyre were tightly grouped together, indicating little variation among estuaries or sites. AMLR and KI had more dispersed points; however, neither region's points overlapped to a large degree with Eyre, showing that the two regions had different water quality from Eyre. KI similarly has little overlap with N&Y, indicating different water quality.

The x-axis or PC1 on the PCA ordination plot (Figure 39) was highly and positively correlated with pH and dissolved oxygen. The y-axis or PC2 was highly and positively correlated with temperature and turbidity. For full details on PCA refer to Appendix 5. The PCA indicates that the estuaries in the AMLR generally had higher temperature and turbidity than estuaries in Eyre. This interpretation stems from the AMLR estuaries being more concentrated in the upper half of the PCA plot and the Eyre estuaries being in the centre to lower half. The estuaries in Eyre and N&Y had typically higher dissolved oxygen, pH, temperature and turbidity than estuaries on KI.

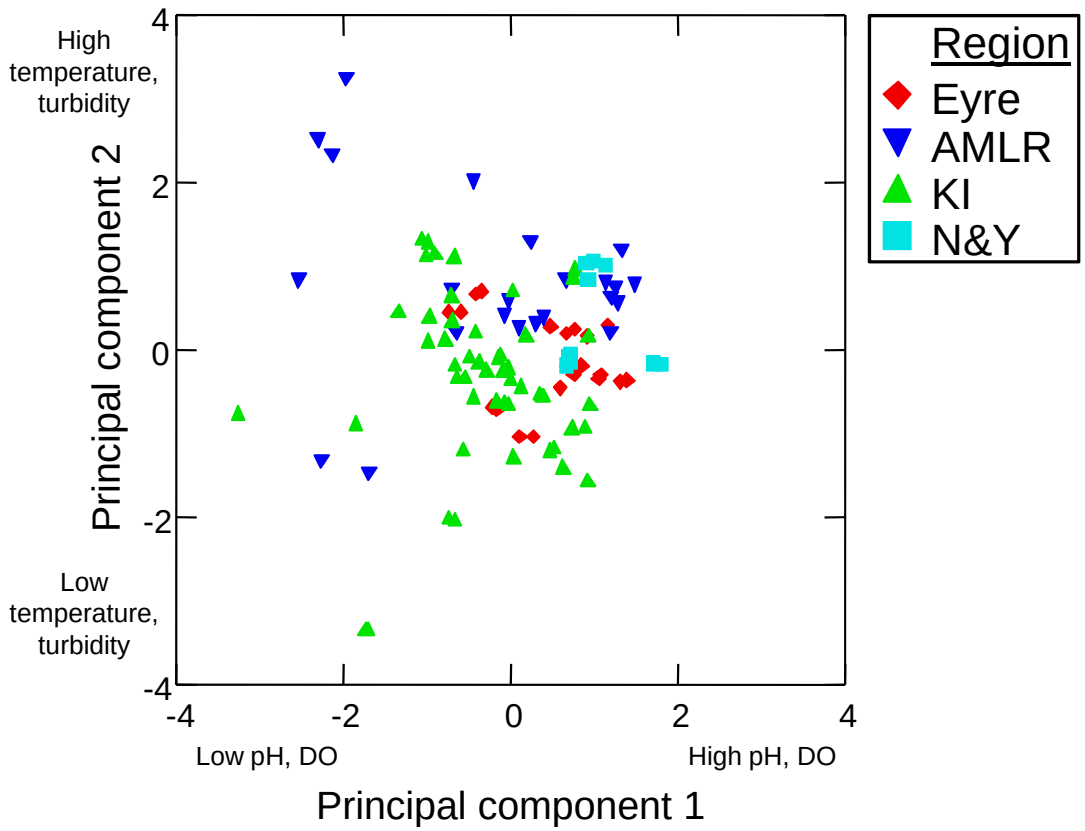


Figure 39. Principal component analysis ordination graph showing data by region. Factor 1 was highly correlated with pH (rotated loading = 0.777) and dissolved oxygen (rotated loading = 0.846). Factor 2 was highly correlated with temperature (rotated loading = 0.810) and turbidity (rotated loading = 0.600). These two components together explained 58% of the total variation in the five raw variables.

Estuaries

Significant differences among estuaries were also detected by PERMANOVA ($p = 0.001$). This means that the water quality varies among estuaries even within regions and provides reason to survey all estuaries in South Australia to gather a solid baseline of data at all estuaries. Figure 40 shows the individual estuaries in the same graph as Figure 39. Several estuary data points are grouped together for each estuary, such as Salt Creek, Middle and Carrickalinga Rivers; indicating that there was little overall variation in water quality at different sites within the estuaries. Other estuaries show large variation among data points such as Hindmarsh, Inman and South West Rivers.

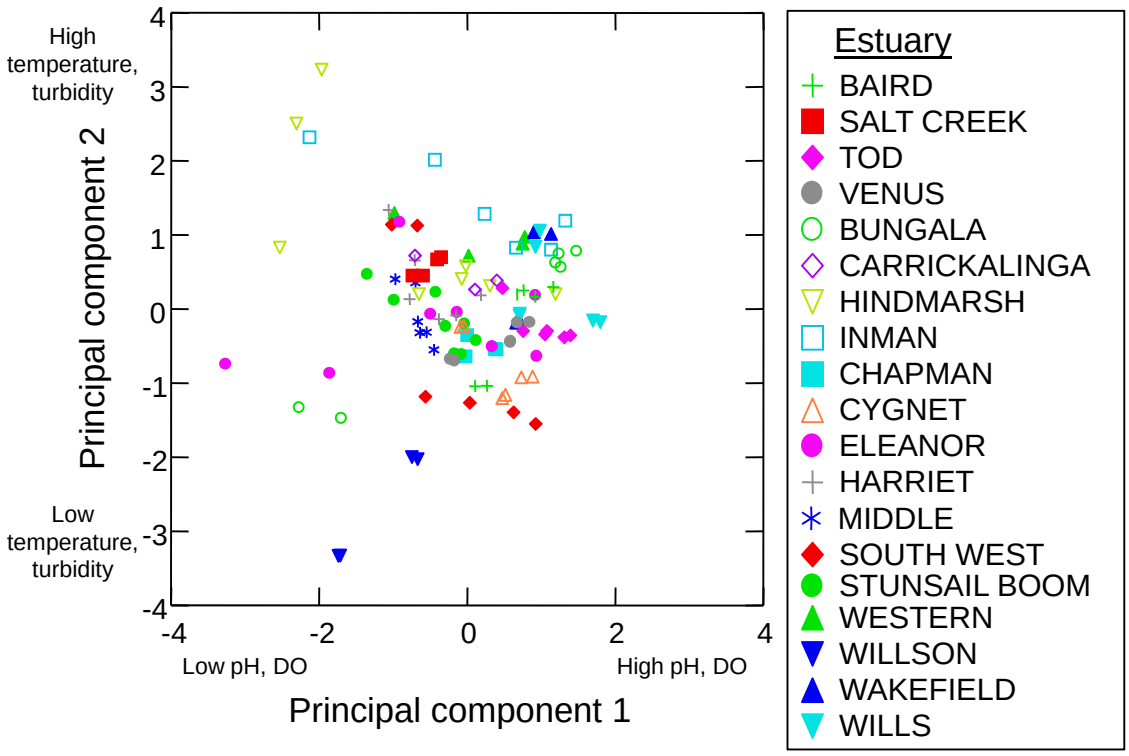


Figure 40. Principal component analysis ordination graph showing data by estuary.

Sites

Site was detected having a significant effect on water quality (p = 0.001). This means that sampling an estuary at one site will not characterize the estuary's water variables and that sampling at more than one site along an estuary is needed.

Reading depth

The depth of water in which the reading was taken was not found to be a significant factor in PERMANOVA analysis (P = 0.621). This indicates that very few estuaries surveyed were stratified at the time. However, looking at the individual data above, it is clear that the Hindmarsh and Inman Rivers were stratified at some sampling sites.

Threatening processes and management issues

South Australia uses a vast majority of its estuaries and their surrounding environments resulting in obvious modifications. Figure 41 is a summary of the results from the field survey. At the time of survey the outer boundaries for the estuaries had been established and threats and disturbances indicated in this section are limited to areas within the outer boundaries. Any further disturbance within the wider catchment area were not considered when collecting data for this section.

It should be noted that these are observations taken during the rapid field assessment process and as a result, are subjective in nature. Therefore any use of the data should reflect this fact.

The overall impression of Figure 41 is that most estuaries surveyed had visible disturbances at the time of the visit. The figure indicates that estuaries in South Australia are potentially under considerable pressure from a number of disturbances. It highlights that at many of the estuaries visited there are multiple uses and activites present, potentially impacting the estuary.

The noticeable message from the data in the graph is that a high percentage of sites visited have moderate to high levels of disturbance for the identified threatening processes. This indicates the disturbances are likely to have been present at the locations for some time, causing prolonged impacts on the system.

The data indicates that water regimes have been altered to some degree at all the sites visited. This is mainly due to the construction of physical barriers that have interfered with the natural flows of water, whether they are from freshwater flows or tidal inflows. Examples include bridges, roads with inadequate culverts, levee banks, jetties and rocks walls.

In addition to these data, it was also recorded that 77% of this disturbance was located closer to the mouth of the estuary than the head. This would put greater pressure around the area where most water mixing and flow would naturally occur.

In the light of future changes to sea level and rainfall (and thus flow) patterns in South Australia, physical barriers will become an increasingly critical issue. Particularly, levee banks are designed to hold back tidal flows, such as those around the Port River/Barker Inlet system.

Access to estuaries is also causing degradation issues. In many cases these coastal areas have been developed gradually over time by visitors. The result is a lack of organised planning and structure with a lack of clear primary access tracks and fencing to restrict access to sensitive areas. It was often found that a number of self-created tracks criss-crossed at sites resulting in greater degradation. The myriad of tracks spread the damage to all parts of the estuary allowing access to all areas by vehicles. As well as vehicle tracks, an unrestricted number of walking tracks criss-cross sites causing vegetation destruction, erosion and weed dispersal.

Closely related to the disturbance caused by unrestricted access tracks are the threats posed by recreational visitors to these locations. Fishing and camping are popular recreational pastimes undertaken at estuaries, increasing pressure on these environments and they result in a high concentration of impacts during peak times that include: vegetation damage; rubbish; pollution; and interruptions to breeding cycles of local fauna.

Figure 41 indicates that vegetation buffer disturbance and habitat fragmentation both rate extremely high in occurrence at most sites visited. As mentioned, a high proportion of vegetation destruction witnessed at each location was caused by vehicle damage due to unrestricted track construction or driving over vegetation where there was no track existing. The other major cause was development, whether it is for urbanisation or other developments such as campsite enlargement, path construction or upgrading of facilities.

Habitat fragmentation has the highest extent of disturbance at most sites surveyed within this inventory. The biggest cause of habitat fragmentation was vegetation clearance for primary production which was identified at 80% of estuaries visited. Roads were also a considerable cause of habitat fragmentation at these sites with 48% of sites experiencing fragmentation due to the presence of roads. Powerlines and fencelines were also prevalent in causing this disturbance. The NLWRA (2001) concluded that a strong correlation existed between catchment land use and estuarine condition, so this level of land clearance and disturbance is concerning and points to the need for improved catchment practices.

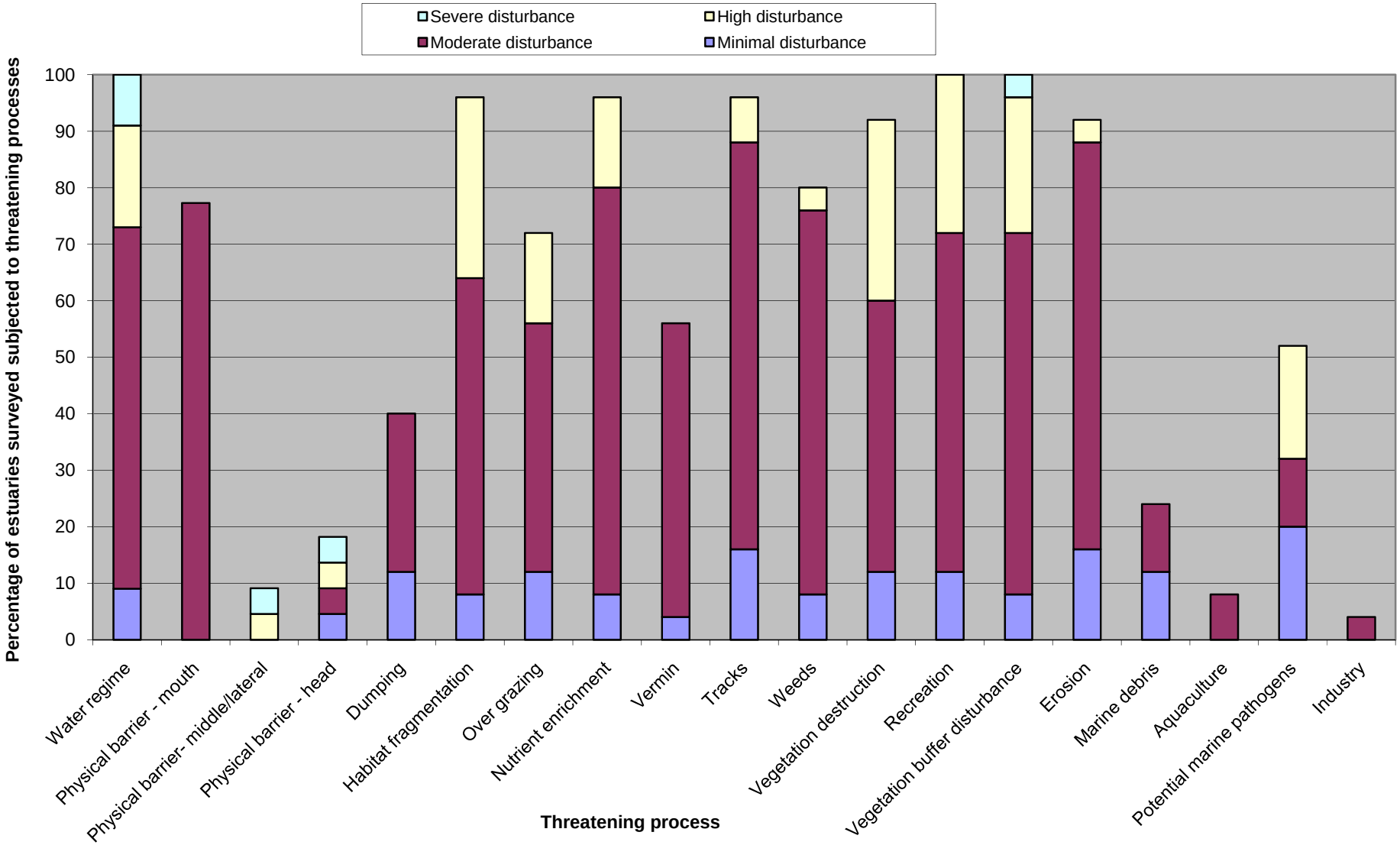


Figure 41 Extent of threatening processes across estuaries surveyed in South Australia based on field observations.

For greater detail on the disturbances causing the threatening processes outlined in Figure 41, please see the included estuary survey data on line at the Naturemaps website: http://www.naturemaps.sa.gov.au/

As mentioned, many of the disturbances were identified in a subjective manner while on site conducting the surveys. Nutrient enrichment is formulated from presence of farmland and urban areas surrounding the boundaries of the estuary. It is an indication of the number of sites subjectively determined to have some form of increased nutrient load due to the land use and inputs from surrounding land. Of the locations visited during the survey it was found that 80% had influences due to agriculture, 60% by urban runoff, 24% by stormwater discharge and 4% by dairy farming. Interestingly we found that 4%, or only one estuary had no nutrient enrichment above natural sources from surrounding land, as it was located entirely within a National Park.

Due to the variable and usually low level of rainfall experienced by the majority of South Australia, surface water resources are always utilised to their fullest. In many cases it is this interception and use of the surface water that is reducing flows from entering these estuary systems in the volumes that once would have occurred (Harding, 2005). The existence of dams, land clearance and primary production has also affected low flows and the quality for the water entering the system (Harding, 2005). It has been estimated in the Onkaparinga Estuary that 75% of the natural pre-European flows have been diverted (DEH, 2003b). Decreased water flow causes individual systems to become more simplified and less dynamic (Baird, 1999).

Figure 41 indicates that weeds and erosion issues are threatening processes that have a moderate effect in a large percentage of the estuaries visited during the survey process. Any management and conservation works would require planning for control of weed issues and sand erosion problems at a number of sites. As each site is quite variable, it is best to seek the weed and erosion component of the estuary specific data to assess the specific issues arising at each site.

In many cases climate change will exacerbate the threats and disturbances highlighted by Figure 41, some more so than others. This needs to be considered and planned for in any management actions for estuarine sites. Being a location that will be highly vulnerable to climate change impacts, such as sea level rise and changing water regimes, it is imperative that estuaries are conserved to be as resilient as possible or in the best possible position to be able to adapt successfully to the new conditions. This will be achieved if the estuary is managed and conserved to be as ecologically healthy as possible with natural diversity and stable populations of flora and fauna.

The following photos highlight some of the pressures, threats and disturbances witnessed during the rapid assessment field survey visits.

Figure 42 Remnants of aquaculture (DENR).

Figure 43 Grazing and bare soils (DENR).

Figure 44 Physical barriers (DENR).

Figure 45 Weed threats (DENR).

Figure 46 Erosion (DENR).

Figure 47 Recreational threats (DENR).

Conclusion

As outlined in this report, the Estuaries Inventory Project had four clear objectives;

- GIS Mapping of outer boundaries and internal habitat facies;
- Development of field survey methodology and template;
- Survey of representative estuaries in SA; and
- Recommendations on monitoring protocols for estuaries.

The mapping has been completed for all 102 estuaries outlined in the Draft Estuaries Policy and Action Plan, except the Murray Mouth, during this project. To date, this is the most comprehensive mapping of estuaries performed in the state and covers all habitats within the outer estuarine boundaries.

The new estuary layers for the state have been included on DENR's web based mapping tool 'Naturemaps' (http://www.naturemaps.sa.gov.au/) as of August of 2009.

The rapid assessment methodology and template was successfully developed, tested and then utilised in the field as part of the survey process.

The inventory field survey process was conducted on 25 representative and priority estuaries from four of the five coastal NRM regions. Information gained from this data has been represented in the results section of this report and will be part of the data connected to the mapping products.

The survey data collected during the inventory produced interesting results that further enhance our understanding of these systems. The results found many estuaries had closed mouths during the time of survey, yet surprisingly some others did not have closed mouths and flowed into the sea with relatively 'fresh' water during summer. Interesting results were gathered through the water quality testing with some locations delivering alarmingly low dissolved oxygen levels, and quite high salinity, temperature and turbidity readings during the survey.

One of the most alarming figures found during the survey process was the presence of a high number of disturbances at each site visited. This information highlights how estuarine systems around the state are considerably impacted from a number of sources, whether it is from recreation, industry, altered water regimes or introduced pests. Each of the 25 sites surveyed indicated multiple distrubances and many were above a low level of impact. This clearly highlights the level of impacts to these systems and the changes that need to take place regarding how these locations are viewed within the community. It also highlights issues with the level of protection allocated to estuarine systems in South Australia.

This project's scope was to work towards an inventory for this state and succeeded in creating two mapping layers covering the whole state and conducting rapid assessment of 25% of priority representative estuaries in South Australia. In these figures alone, the project has completely reached the objectives it set out to achieve. It is imperative that the recommendations set out in this report are considered carefully by State government departments and regional NRM bodies.

Much has been written about the importance of estuaries as transition zones for fish stocks and fauna of many kinds that live in both fresh and marine environments. It is concerning that even with all the literature available supporting the importance of

estuaries that more is not done to protect them from the range of threats posed both from within their own boundaries and from those that enter from rivers, oceans and land opposing them. It is clear that more emphasis needs to be placed on improving the conservation of representative estuarine systems around SA using the current Comprehensive, Adequate and Representative (CAR) reserve system process.

It is interesting to note that there is no singular estuary group in South Australia and that monitoring of these systems are left to a number of agencies and the community, all focusing on their key areas with very little communication. Estuaries management falls within a number of groups with differing levels of importance, knoweldge, resources and focus in the EPA, DWLBC, DENR, Local Government, NRM Boards, PIRSA and the community. Improved and more frequent communication is required along with strategic direction. Strategic direction at present is in the form of the Draft Estuaries Policy and Action Plan which needs to be updated and endorsed as soon as possible.

This project has clearly shown that there is a lack of protection of estuary sites within South Australia yet they are currently systems under considerable threat and pressure. It was not within the scope of this project to investigate climate change impacts on these systems in the future, but it is clear that being situated on the coast and often low lying, they are the front line in sea level rise and other climate change implications. It is quite possible that estuarine ecosystems are under such threat or strain already that they may not be resilient enough to adapt successfully in the face of the impacts of climate change. Among the most at risk ecosystems in the world to sea level rises as a result of climate change are mangrove systems (McLeod & Salm, 2006). Building resilience into mangrove communities requires an understanding of how mangroves will respond to climate change, what factors help them survive these changes and which mangroves are most likely to survive these changes (McLeod & Salm, 2006). Closely associated with this is the loss of saltmarsh communities, mangrove colonisation and changes to surface water flows due to sealevel rises (Coleman & Eden, 2005). Other threats as part of climate change include increased sea temperature, changes in hydrology and the increases in frequency of extreme events (NSW DECC, 2008). It is clear more research needs to be centred on these issues.

This project has made progress towards developing a baseline inventory for estuaries in this state. The reality is we still know very little about these systems and the changes that have occurred to these systems since colonisation. It is hoped this project is a springboard from which further monitoring and baseline projects can progress in the future. This does rely on greater significance being placed on these systems coupled with improved policy clarity and direction. Support in the form of funding and project development will also be required but will stem from clear policy support.

Recommendations

- Continued funding support for focused estuarine protection, monitoring and leadership on a statewide level.
- The extension of inventory information collection to other representative and priority sites around the state – the inventory survey process is repeatable and can be used to carryout this function in a consistent matter across the state.

- Official adoption of the Estuaries Policy and Action Plan so there is an official document available to guide whole of government policy and actions regarding estuarine conservation in this state.
- Clarification and distinction within government sectors on which department and branch is the lead agency for the protection and monitoring of estuaries as well as the implementation of the Policy and Action Plan.
- Encourage strong partnerships between management agencies (DSE Vic., 2003).
- Estuaries identified as highly significant and regionally notable to be targeted for protection and management actions/plans.
- Continued support to state projects focusing on developing classification schemes and conceptual models of SA estuarine systems.
- Inclusion to the reserve system / Heritage Agreements (formal conservation agreements) of priority sites that fit unders the CAR framework.
- To determine the influence of ground water on the embayments on EP and to clarify with the regions how and why these systems come under the definition of an estuary.
- Identify water regimes and environmental flow requirements of estuaries in SA.
- Monitoring, prioritisation and a streamlined approach as suggested in monitoring protocols to allow monitoring of more sites with less parameters.
- That historical flows and periods of mouth closure/opening to be investigated to determine changes in frequency and period of time that mouths were open and closed. Feed this information into developing a strategy regarding artificial opening of estuary mouths.
- Continue the improvment in land planning surrounding estuaries. More consideration still needs to be taken into the impacts on estuarine systems, particulalty the cumulative effect of activities undertaken in a catchment.
- Analyse data to determine changes in flow into the system through fresh flows and tidal fushes to determine environmental water requirements for water dependant ecosystems.
- Increase the scientific understanding of the wetland ecosystems and their management requirements (DSE Vic., 2003).
- Further work needs to be undertaken on a number of other parameters to gain baseline information, such as aquatic fauna, nutrients and pesticides.
- Identify likely climate change impacts on estuarine systems and potential major threats to the different classification types in SA.
- Improve community education programs regarding estuaries and engage them in a program to improve capacity for the community to manage these sites.
- Ensure that recreation use is consistent with the protection of natural and cultural assets (DSE Vic., 2003).

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APPENDIX 1. SURVEY SHEETS

Data Mgt ADMIN ONLY	Data Entered		Plant ID		Photo		Entered by *(initials)*		Date Entered	/ / 2009

ESTUARY DATA COLLECTION SHEET 1 – Desktop Estuary Inventory SA

LOCATION REFERENCE DATA

Date / Time	/ /09 : am/pm	Estuary ID	S N N N N 000
Compiler details		Estuary Name	
Organisation		Biol Survey No	Survey : STATE ESTUARY INVENTORY
Location Description	*(GPS position – GDA 94)*		
Zone (circle) 52-53-54	E 0 : : : : : :	N : : : : : :	Photo no's
Landholder(s) (See map for locations)	CONFIDENTIAL (08) CONFIDENTIAL CONFIDENTIAL	Landholder(s)	CONFIDENTIAL (08) CONFIDENTIAL CONFIDENTIAL

GENERAL HYDROLOGY & LANDFORM – within Estuary Boundaries ONLY

Estuary Classification (based on National Ozecoasts classification) *(circle)*	Wave Dominated Estuary	Wave Dominated Delta	Embayment	Coastal Lagoon	Strandplain Creeks	Tide Dominated Estuaries	Tide Dominated Deltas
	Tidal Creeks	Drowned River Valley					
Water Regime *(circle where appropriate)*	Permanent	Seasonal	Episodic	Artificially dry	OTHER		
Water Source *(circle where appropriate)*	Local runoff	Stream fed	Artificial channel	Spring	Irrigation	Groundwater	
Flow control structures	Yes	No	DESCRIBE				

LAND TENURE & USE

Tenure *(tick where applicable)*	private	public
On-site		
Surrounding		

Landuse *(tick where applicable)*	Cons. Park	Roadside Res.	National Park	Cropping	Vineyard	Orchard – fruit	Orchard – veg	Grazing – sheep	Grazing – cattle - diary	aquaculture	Grazing – horses	Heritage Agreement	Residential	Industry	Camping/holiday accommodation	Recreation	Sewage Treatment	Irrigation	Council Reserve	Private Conservation	Unknown		
On-site																							
Surrounding																							

Other *(specify)* | Other *(specify)* | On-site: | Surrounding:

Management Authority on-site *(circle)*	Freehold	NPWS	DEH	DTEI	Forestry	SA Water	Local gov	Unknown/ none	Transport SA	PIRSA

Comments		**Social & Cultural Values** *(tick & describe)*	Indigenous	DESCRIBE
			Non-Indigenous	DESCRIBE
		Recreation Facilities / uses *(circle)*	Walking trail	Bird hide	BBQ / picnic	Campsite	Interpretation	Hunting
			Fishing	Surfing	Boating	Golf	OTHER	

Fauna Survey information gained from BDBSA or other NRM sources – please see specific lists for reference

ESTUARY FAUNA				**GENERAL COMMENTS ON SURVEY**
Fauna Survey intensity *(tick methods used for fauna survey)*		**Noteworthy fauna** *(list)*	**Noteworthy fauna** *(list)*	
BDBSA				
Birds Australia				
NRM				
Other				

Riparian Veg Width (from Mapping)	

Conservation measures *(tick where applicable & describe)*	**Action**	Current	Suggested	**Notes on conservation measures**
	Management Plan – in prep / implemented			
	Environmental burning / slashing / grazing			
	Listed Nationally Important			
	Privately managed for conservation			
	Within formal reserve system			
	Other (specify)			

Data Mgt ADMIN ONLY	Data Entered		Plant ID		Photo		Entered by *(initials)*		Date Entered	/ / 2009

ESTUARY DATA COLLECTION SHEET 2 – Field Survey

LOCATION REFERENCE DATA

Date / Time	/ /09 : am/pm	Estuary ID	S N N N N 000
Compiler details		Estuary Name	
Organisation		Biol Survey No	Survey : STATE ESTUARY INVENTORY
Location Description	*(GPS position – GDA 94)*		Sector
Zone (circle) 52-53-54	E 0	N	Photo no.s
Landholder(s) (See map for locations)	CONFIDENTIAL (08) CONFIDENTIAL CONFIDENTIAL	Landholder(s)	CONFIDENTIAL (08) CONFIDENTIAL CONFIDENTIAL

Mouth (circle)	Open	Closed		
Tide Status	High	Low	Mid	OTHER
Water Flow	Standing	Slow flow	Rapid flow	OTHER
Water Course Channel	Natural	Combination - natural channel with some elements of physical alteration	Chanellised	

Comments

WEATHER CONDITIONS

Now		Storm (heavy rain)	Rain (steady rain)	Showers (intermittent)	% Cloud cover	Clear/sunny
Past 24 hours		Storm (heavy rain)	Rain (steady rain)	Showers (intermittent)	% Cloud cover	Clear/sunny
Has there been heavy rain in the last 7 days	Yes	No	**Air Temp**			
Other						

GENERAL DESCRIPTION AND COMMENTS ABOUT THE ESTUARY AS A WHOLE – at this time add any details to aerials/maps available

WATER CHEMISTRY & SUBSTRATE TYPE

Site 1	**Max Depth**		m	Estimated width of Estuary	m	GPS		
Depth 1	**pH**		**Conductivity**	uS/cm	**Temperature**	°C	**Reading Depth - 1**	m
			Water Depth	m	**Secchi Depth**		**Dissolved O²**	ppm
Depth 2	*pH*		*Conductivity*	*uS/cm*	*Temperature*	°C	*Reading Depth - 2*	*m*
					Secchi Depth		*Dissolved O²*	*ppm*
Site 2	**Max Depth**		m	Estimated width of Estuary	m	*GPS*		
	pH		**Conductivity**	uS/cm	**Temperature**	°C	**Reading Depth - 1**	m
			Water Depth	m	**Secchi Depth**		**Dissolved O²**	ppm
Site 2	*pH*		*Conductivity*	*uS/cm*	*Temperature*	°C	*Reading Depth - 2*	*m*
					Secchi Depth		*Dissolved O²*	*ppm*
Site 3	**Max Depth**		m	Estimated width of Estuary	m	*GPS*		
	pH		**Conductivity**	uS/cm	**Temperature**	°C	**Reading Depth - 1**	m
			Water Depth	m	**Secchi Depth**		**Dissolved O²**	ppm
Site 3	*pH*		*Conductivity*	*uS/cm*	*Temperature*	°C	*Reading Depth - 2*	*m*
					Secchi Depth		*Dissolved O²*	*ppm*
Water Quality Instrument used								

Sediment	**0-2 cm** (give estimated %)	Sand	Loam	Clay	Silt	Peat	Anaerobic sediments	Pebbles/rocks
Sediment	**> 2 cm** (give estimated %)	Sand	Loam	Clay	Silt	Peat	Anaerobic sediments	Pebbles/rocks

THREATENING PROCESSES – WITHIN ESTURINE BOUNDARY *ONLY*

Disturbance / Management Issue *(circle where applicable)*						Current extent of disturbance *(tick where applicable)*				
						Min	Mod	High	Severe	Potential
Altered water regime	Physical Barriers	Decreased	Increased	Flooded	Water extraction					
Comments										
Physical Barriers/ Water Obstruction	Levee	Lock	Beach/sand	Silt	Dense reedbed	Natural					
	OTHER									
Barrier Location	Near mouth	Creating lateral boundary	Creating inland boundary	OTHER						
Dumping	Fill	Garden refuse	Household refuse	OTHER						
Habitat Fragmentation	Roads	Clearing	Fenceline	Powerline	Isolation	OTHER				
Over-grazing	Stock	Native	OTHER							
Nutrient enrichment	Agricultural	Dairy effluent	Urban runoff	Stormwater discharge	WWTP	OTHER				
Vermin	Cats	Foxes	Rabbits	Introduced birds	Introduced fish	Deer	OTHER			
Tracks	Vehicle	Bicycle	Motorbike	Walking	OTHER					
Weeds	Woody	Pasture	Noxious	Garden	OTHER					
Vegetation Destruction	Herbicide	Ploughing	Slashing	Blasting	Grading	OTHER				
	Vehicle impact	Development	Illegal clearing							
Recreational	Fishing hotspot	Camp-sites	Visitor disturbance	OTHER						
Industry Pollution	Describe									
Physical opening of mouth	yes	no	Describe							
Vegetation Buffer	Absent	Good condition	Semi Degraded	Degraded	OTHER					
Erosion	Channel	Bank	Flood	OTHER						
Marine Debris & marine based pollutants	Describe									
Aquaculture Pollution (nutrient enrichment)	Land based	Marine	OTHER							
Potential for marine based pathogens	Proximity to Jetties	Proximity to aquaculture	Proximity to ports							
Dryland Salinity Issues										
Other *(specify)*										

Conservation measures *(tick where applicable & describe)*	Action	Current	Suggested	Notes on conservation measures
	Fencing			
	Re-vegetation			
	Pest control (weed/animal)			
	Restoration of water regime			
	Environmental burning / slashing / grazing			
	Privately managed for conservation			
	Within formal reserve system			
	Other (specify)			

ESTUARY FAUNA

Fauna Survey Intensity *(tick methods used for fauna survey)*

OP Sighting	
Call ID	
5 min point count	
None	

Noteworthy fauna *(list)*	No.	E	Noteworthy fauna *(list)*	No.	B

GENERAL COMMENTS ON SURVEY

Microhabitats *(circle)*

Algae mat	Banks with hollows	Burrows	Detritus	Freshwater soak	Tree hollows	Dense sedges	Dense shrubs	Surface aquatics	Mud flat	Pooling
Nesting area	Open water	Dense reeds	Undercut banks	Rocky areas	Perches /Roosting areas	Sandy areas	Sheltered areas	Structural diversity		
Undulations	snags	OTHER								

ESTUARY VEGETATION SUMMARY - Riparian (< 10 m from channel edge) and Aquatic only

Aquatic Veg.	Indicate dominant types	Rooted emergent	Rooted submergent	Rooted floating	Free floating	Floating algae	Attached algae	
Comment								

Portion of reach with Aquatic veg	%	
Comment		

Riparian Veg. - Indicate dominant types	Trees	Shrubs	Grasses	Sedges/rushes	Reeds
	Saltmarsh/samphire	Mangrove			
Comment					

SUBJECTIVE FIELD ASSESSMENT

Estuary condition	Completely degraded	Severely degraded	Degraded	Moderate	Intact	Pristine
Water Colour						

FLORA SPECIES RECORD – Estuary Inventory						Biol Survey No	Survey :	ESTUARY INVENTORY
Sector				Estuary ID	S	2	N N N	Survey N N N
A *(Braun-Blanquet cover abundance)*	N (not many)	T (sparse, <5%)	1 (many, <5%)	2 (5 – 25%)	3 (25-50%)	4 (50-75%)	5 (>75%)	
Indicate Veg Association	O – Dominant / Codominant overstorey (max 3)		E - Emergent (max 3)	U – Dominant / Codominant understorey (max 5)		S – Submergent dominant (max 3)		

Species	H	A	Species	H	A	Species	H	A	Species	H	A

Habitat types
1/ Dune
2/ Riparian
3/ Aquatic/Channel/subtidal
4/ Supratidal
5/ Intertidal
6/ Floodplain
7/ Beach

APPENDIX 2. INSTRUCTIONS FOR COMPLETING ESTUARINE INVENTORY SURVEY PROTOCOL

General Field Instructions

- Data collected from the field survey of estuaries for this inventory is baseline data and is not required to be overly comprehensive or time consuming to collect. Try to keep actual time spent surveying a particular estuary (or sector) under 1.5 hours if possible.
- Use lead pencil or other water resistant ink when filling out field survey sheets and annotating field maps.
- Staple all sheets relating to each estuary together and store in a safe dry place.

Estuary Data Collection – SHEET 1 – Desktop

Location Reference Data

Date/Time	The date of data collection should be stated (day/month/year) including the time of field survey to the nearest half hour.
Estuary ID	A code specific to the estuary being surveyed must identify each estuary. Estuaries are to be numbered using State-wide numbering protocols (see report). Specific estuary ID's are identified from GIS estuary layers. Estuary ID includes a single character (S), followed by a 4-digit number. The first digit relates to the region the estuary occurs within. (E.g. 2 – Mt Lofty Ranges). Note that the estuary ID number is to be provided on all sheets of the survey form.
Survey No	Where an individual estuary is very large or has differing character, conditions and management, it may be appropriate to assess individual sectors of estuaries separately (ie, different surveys). In this instance surveys of the estuary should be numbered sequentially (sector 1, 2, 3 etc.). Note that a separate survey form should be completed for each survey. Leave *Survey no.* box blank if the estuary is not assessed in sectors.
Compiler Details	State the name/s of person/s undertaking data collection.
Organisation	State the organisation that is managing the data collection.
Biol Survey No	Record the Biological Survey Number assigned to the survey (DEH, Biological Survey Team), if applicable.
Location Description	Provide a general description of the location of the estuary using landscape features or closest roads.
Estuary Name	The name of the estuary should be stated. Where multiple names exist use them all.
GPS Position	(WGS 84). Geographic location of estuaries should be recorded using GPS (WGS 84, Zone's 53 & 54 projection). In such a system, the coordinates would be expressed as metres of Easting's and Northing's. All boxes provided should contain a number if recorded correctly. GPS locations of estuaries should reflect the approximate centre of the estuary. If the estuary is assessed in sectors, the GPS location should reflect the approximate centre of the sector area being assessed. Maps provided will indicate an AMG position for each estuary. This location data can be used on the data sheet if considered accurate enough.
Photo no.s	Digital photographs are to be taken where possible of estuaries surveyed. Record number/s of photo/s on data sheet to identify estuaries when downloading. Rename downloaded photos using respective estuary ID numbers and survey numbers where appropriate.
Landholder	Record landholder information. This is for reference purposes only and is regarded as confidential. Landholder details will not be entered into databases.

General Hydrology & Landform

Estuary System Classification (Based on the National Ozecoasts Estuary Classifications)	**Wave Dominated Estuary**	Feature a supra tidal (or sub-aerial) barrier at the mouth that encloses a broad central basin. The barrier creates a constricted entrance (which can be periodically closed) that allows the exchange of water between the central basin and the sea.
	Wave Dominated Delta	Comprise a river that is directly connected to the sea via a channel(s) that is usually flanked by low-lying vegetated floodplain and swampy areas. Entrances of wave dominated deltas are relatively narrow due to constriction by a barrier (or sandbar) and, due to the relatively high river influence throughout the system, are rarely closed from the ocean.
	Embayment	Embayments may comprise wide and rounded bays, highly indented bays with convolute shorelines, or narrow tapered drowned river valley systems. Embayments are generally bound by steep, rocky shorelines, have relatively wide, unconstricted entrances with free exchange to the ocean, and are deep relative to other coastal waterway types.
	Coastal Lagoon	Small shallow basin with no or little fresh water input and strong tidal currents. The entrances are intermittently or permanently closed, resulting in isolation from marine influence for long periods. Geomorphology is similar to wave-dominated estuaries; however they lack a distinct fluvial bay-head delta.
	Strandplain Creeks	Strandplain associated coastal creeks are narrow, generally shallow water bodies that occur on wave dominated coasts. They are generally oriented parallel to the coast, and develop on prograding coastal sequences formed from beach ridges, dunes and barriers.
	Tide Dominated Estuaries	Generally consist of a landward tapering funnel shaped valley, bounded by various intertidal sedimentary environments such as intertidal flats, mangroves, saltmarshes and saltflats. Depending on degree of sediment filling, the boundaries of tide dominated estuaries may follow the irregular outline of the drowned river valley, or in more mature cases are smooth and intersected by small tidal creek dendritic drainage networks. Elongate tidal sandbanks are a major structural element within the wide entrance and are orientated perpendicular to the coast, and usually dissected by deep channels containing strong tidal currents
	Tide Dominated Deltas	Comprised of a river that is directly connected to the sea via channels that are typically flanked by low lying vegetated floodplains and swamp areas. Because of the dominance of tidal processes, the geomorphology of tide dominated deltas features a landward tapering funnel-shaped valley, and the river is connected to the sea via a series of distributary channels. Channels may be separated by large expanses of low-gradient vegetated swamps. Tidal sandbanks are a major structural element within entrance and are orientated perpendicular to the coast, and usually dissected by deep channels containing strong tidal currents
	Tidal Creeks	Usually comprise a straight, sinuous, or dendritic tidal channel(s) that taper (in a negative-exponential fashion upstream) and shoal to landward. Coastal mudflats that generally surround tidal creeks tend to be at or above the limit of high tide, and seawater is mainly confined to the tidal channel, except during spring tides. Because of their relatively small size, and low freshwater input, they lack the major structural elements such as tidal sandbanks that are characteristic of tide-dominated estuaries and deltas. Tidal channels are frequently interconnected and flanked by large areas of low-gradient intertidal flats, mangroves, saltmarsh and salt flat environments.
	Drowned River Valley	Similar to geomorphology of Embayments
Water Regime	Indicate the dominant water regime for the estuary. These are divided into Inland and Marine systems. (Select only one dominant water regime for the estuary).	

Water regime codes	Permanent	Contains water throughout the year, although the level may vary.
	Semi-permanent	Contains water throughout the year but dries out in dry years (e.g. 1 year in 10)
	Seasonal	Floods and dries in most years.
	Intermittent	Floods irregularly but can be expected to have water at least once per decade and possibly even for several years more or less continuously. This frequency is high enough to influence the type of vegetation present.
	Episodic	Only contains water at infrequent and irregular intervals (less than 1 year in 10). Such episodic events hardly influence the type of vegetation (except when water is present).
	Artificially dry	Water source cut off or estuary drained.
Water Source	The source of water inflow should be recorded. (Multiple sources can be selected).	
Water source codes	Local runoff	Fed by runoff and infiltration generated by precipitation in the vicinity plus rainfall on the estuary surface; no defined stream.
	Stream-fed	Fed by river/stream with a continuous connection.
	Artificial channel	Fed by local runoff entering estuary in artificial channel.
	Spring	Fed by groundwater coming to surface at a spring beyond the estuary boundary.
	Irrigation	Fed by runoff generated from irrigation isolated from its natural source. Irrigation runoff will be through a channel so this is a subset of Channel-fed.
	Groundwater	Fed by groundwater from underground aquifer.
Flow Control Structures	Indicate Yes or No if flow control structures are in place that affect the estuary and its boundaries. Describe the type of flow control structures (e.g. weir).	

Land Tenure & Use

Tenure	Indicate if the estuary (on-site and surrounding) is privately or publicly owned by ticking the appropriate box. Specify other option if private and public are not applicable (e.g. Commonwealth land). (note that more than one tenure can be indicated).
Landuse	Indicate the on-site use and surrounding use of the estuary by ticking appropriate landuse. Specify other landuse if appropriate description is not listed. (note that more than one landuse code can be indicated).
Management Authority	Indicate the appropriate management authority responsible for the management of the estuary.
Social & Cultural Values	Record any social and cultural values relevant to the estuary. This may require consultation with the landholder (where possible) or review of literature.
Recreation Facilities / Uses	Record any recreational facilities present at the estuary site by circling appropriate attributes. Specify other recreation uses / facilities in the space provided.

Estuary Fauna

Noteworthy Fauna	List any rare or threatened fauna species that are present at the site, including species listed under JAMBA and CAMBA. Also include any species that occur in notable numbers or that are regionally significant.
Fauna Survey Intensity	Indicate the amount of effort involved in fauna survey by listing methods used to determine fauna species present within the estuary boundaries (i.e. BDBSA, Birds Australia, NRM, or other references)

Riparian Veg Width

From ArcMap……..

Conservation measures

Indicate where known conservation efforts have occurred / or are suggested by ticking appropriate boxes. Complete any notes to clarify conservation measures currently in progress or those that are suggested.

Estuary Data Collection – SHEET 2 – Field Survey

Location Reference Data

Location reference data should be recorded using the exact method as described previously for the desktop survey (sheet 1).

General Hydrology & Landform

Estuary Mouth Status	Indicate whether the estuary systems mouth to the marine system is open or closed at the time of the survey. (circle only one option)
Tide Status	Circle the tide status at the time of survey (High/Low/Mid). The Bureau of Meteorology (Ocean Services) website can provide this information any time following the field survey. Use the time and date provided in the "Location Reference Data" section to establish what the tide status was at the data collection time.
Water Flow	Record the flow of water at the site where water chemistry readings are taken. Circle appropriate description of flow: Standing / Slow flow / Rapid flow.
Water Course Channel	Circle the appropriate description of the main water course channel.

Natural	Channel was formed completely by natural elements
Combination	Channel is predominantly natural with some components of alteration
Chanellised	Channel is solely man-made (e.g. drains)

Weather Conditions

Now	Circle the appropriate weather conditions at the time of the survey. If cloudy, approximate the percentage of cloud cover present.
Past 24 Hours	Circle the appropriate weather conditions in the 24 hours prior to the survey. If cloudy, approximate the percentage of cloud cover that was present.
Rain	Circle yes or no depending on whether there was been any heavy rain the past 7days. If unsure, consult local farmers/rangers or alternatively, the Bureau of Meteorology website.
Air Temp	Record the air temperature at the time of the survey.

General Comments

Record any general comments, or descriptions, about the estuary as a whole. Provide any comments/sketch maps that assist in describing the estuary / estuary complex.

Water Chemistry & Substrate Type

This should be undertaken at multiple depth levels as well as a minimum of 2 sites within the estuary to identify any stratification and salinity level variation across the system. GPS points of testing locations and the depth the measurements were taken at are to be noted.

Water chemistry readings are taken from specified equipment. The survey sheet allows for testing at 2 sites. If more are completed at certain estuaries, complete a new survey sheet for each additional water chemistry survey. Where an estuary is dry or has insufficient water at the time of survey, no water chemistry data can be collected.
Mark the point of each water quality collection site on a Personal Digital Assistant (PDA) using ArcPad 7.1 and connected blue tooth GPS unit.

Max Depth	Recorded using Horiba Multi Water Quality Checker U-50 series. Record the maximum depth of water at the site where water chemistry readings are taken (value in meters).
Estimated Width Of Estuary	The width of the estuary (bank to bank) at the site of water quality testing can be estimated using the measuring device on ArcPad (PDA), or ArcMap (PC). AcrMap can only be used if the water quality sites have been uploaded onto the system from the PDA.
GPS	Record the GPS location of the water quality testing site using the Horiba Multi Water Quality Checker U-50 series or a handheld GPS device.
Secchi Depth	Lower the secchi deck into the water until the black and white bandings are no longer visible. Slowly pull the deck up to the point where the contrasting black and white colours can just be distinguished. Record the depth of water at this point using the colour-coding system on the secchi deck line.
pH	Recorded using Horiba Multi Water Quality Checker U-50 series. Equipment should be calibrated regularly as specified in the instruction manuals. Recommend at least weekly calibration.
Turbidity	Recorded using Horiba Multi Water Quality Checker U-50 series. Equipment should be calibrated regularly as specified in the instruction manuals.
Conductivity	Recorded using Horiba Multi Water Quality Checker U-50 series. Equipment should be calibrated regularly as specified in the instruction manuals.
Dissolved O^2	Recorded using Horiba Multi Water Quality Checker U-50 series. Equipment should be calibrated regularly as specified in the instruction manuals.
Temperature	Recorded using Horiba Multi Water Quality Checker U-50 series.
Reading Depth	Record the depth at which the water chemistry readings were taken within the available depth (value in meters).

Sediment Type	Using visual and textural methods, record the sediment type in the top layer of soil (0-2cm), and again at a layer greater than 2cm deep. Estimate the percentage of each sediment type using the categories defined below.	
Substrate definitions	Sand	Individual sand grains can be seen. Disintegrates readily. Shell fragments are common.
	Loam	
	Clay	Sand not evident. Stiff and tenacious material, greasy when moist. Solid grey to blue grey in colour.
	Silt	Silty material, loose when moist, with traces of sand.
	Peat	Organically laden substrata containing partly decomposed plant remains. Spongy when wet.
	Anaerobic sediments	Fine black, organically laden sludge, generally smelling of hydrogen sulphide.
	Pebbles/rocks	Evidence of small stones and pebbles

Threatening Processes

Disturbance / Management Issues	Disturbances and management issues are listed. A number of these have been divided into sub-categories of a particular disturbance. Circle the particular type of disturbance present at the site. More than one disturbance sub-category can be indicated where necessary. Leave blank where no disturbance exists. Specify threatening processes that are not included on the data sheet in the "other" row.
Current Extent Of Disturbance	Indicate the extent of disturbance caused by respective threatening process at the time of survey by indicating the level of disturbance (potential – severe). Leave boxes blank where no disturbance was evident.

Level of disturbance descriptions

Potential	Indicate where it is considered that the estuary could potentially be threatened by a disturbance factor in the future, however is currently not effected.
Minimum	Minimal evidence of the disturbance factor. Disturbance has little impact on estuary values, easily rectifiable.
Moderate	Moderate evidence of disturbance. Disturbance has noticeable effect on estuary values although is rectifiable.
High	Significant disturbance to estuary values. Verging on unrectifiable damage, although some of original estuary values evident.
Severe	Disturbance at such a level that estuary values are destroyed (e.g. estuary completely drained or blocked to marine env, completely dominated by exotic species, biologically dead etc.)

Conservation Measures Taken	Indicate where known conservation efforts have occurred / or are suggested by ticking appropriate boxes. Complete any notes to clarify conservation measures currently in progress or those that are suggested.

Estuary Fauna

Noteworthy Fauna	List any rare or threatened fauna species that are present at the site, including species listed under JAMBA and CAMBA. Also include any species that occur in notable numbers or that are regionally significant. Provide approximate numbers of individuals of each species observed at the time of survey in the No. column. Indicate evidence of breeding (B) by ticking.
Fauna Survey Intensity	Indicate the amount of effort involved in fauna survey by listing methods used to locate fauna species. Due to the rapid nature of estuary inventory, this is mostly confined to casual observations. List other methods used where applicable.
Microhabitats	Indicate micro-habitats that are present within the estuary. Micro-habitats refer to habitat components that have relevance for their importance to fauna. Specify other un-listed micro-habitats where relevant.

Estuary Vegetation (Riparian and Aquatic Habitats only) - Summary

Aquatic Veg Type	Circle the dominant aquatic vegetation types present within the estuary boundaries. If no aquatic vegetation is present then leave blank.
Total Veg Cover	Indicate the cover of aquatic vegetation as a percentage of the estuary area. This should be estimated by eye.
Riparian Veg	Circle the dominant types of vegetation present in the riparian zone (within the estuary boundaries).

Subjective Assessment

The rapid assessment component of the survey provides a snap shot of the condition of the estuary. Scores are subjective and should provide an indication of the condition of estuaries at time of survey as determined by the surveyor.

Estuary Condition	The overall estuary condition score should reflect the parameters recorded during the survey (such as land degradation and water chemistry) to form the basis of the estuary condition score.

Estuary condition descriptions

Severely degraded	Very high level of disturbance evident to the extent that estuary values are destroyed or irreversibly modified (e.g. estuaries drained, eutrophication).
Degraded	High level of disturbance evident. Verging on unrectifiable damage.
Moderate	Significant level of disturbance evident although some natural values present. Most damage rectifiable.
Intact	Small amounts of disturbance evident, with high native species diversity. Damage easily rectifiable.
Pristine	No obvious disturbance, with high native species diversity. Usually formally conserved within the reserve system.

Water Colour	Print a copy of the water colour chart from the "Estuarine Monitoring Guidance Manual" (Coleman, 2003) prior to field work. Collect estuarine water in a glass jar and compare to the water colour chart. Determine the closest colour match and record the number in the corresponding square.

Flora Species Record

Flora species present at the site within the estuarine associated habitats are to be identified. Species should be listed in the spaces provided. Note that detailed quadrats are **not** to be completed for this estuary inventory. However, the most dominant species should be identified in each vegetation/habitat zone, including incidentals and any rare or threatened species noted. Unknown specimens are to be collected, vouchers attached and pressed for identification by the State Herbarium. List any unidentified species voucher numbers in the blank spaces, for later identification.

Estuary ID	Insert the same estuary ID number for the site as shown on Sheet 1 of the survey form.
Sector	Insert the sector number if the estuary is being assessed in sectors as shown on Sheet 1 of the survey form. If the estuary is not being assessed in sectors leave this box blank.
Flora Species Present	Indicate species present by naming them in the space provided. Species rare or threatened status is shown in square brackets. (NC) refers to species names which are non-current. The current nomenclature needs to be sought. Asterisk (*) at the beginning of the species name refers to introduced species.
H (Habitat Zone #)	A numbered list of associated habitats based on the mapping will be available so that species can be allocated within their relevant habitat zones. Where a species is identified at a site, indicate which Habitat zone the species occurs in.
A (cover abundance)	Indicate cover abundance for each species present using cover abundance scale. (Note that an abbreviated version of the cover abundance scale is included at the top of the survey form (SHEET 2)).

Braun-Blanquet cover abundance descriptions		
	N	Not many, 1 – 10 individuals, insignificant cover.
	T	Sparsely or very sparsely present; cover less than 5%.
	1	Plentiful, but of small cover: less than 5% cover.
	2	Any number of individuals, 6-25% cover.
	3	Any number of individuals, 26-50% cover.
	4	Any number of individuals, 51-75% cover.
	5	Any number of individuals, 76-100% cover.

Veg Association	Indicate the vegetation association by marking the dominant species in the overstorey, understorey and emergent categories. Mark species by writing in the appropriate code next to relevant species names. e.g. Baumea tetragona [U] *O* Observe the maximum number of species that can be listed within each category. An abbreviated version of category descriptions is provided at the top of the survey form (SHEET 2).

Veg Association codes		
	O	Dominant / Co-dominant overstorey species (max 3)
	E	Emergent species (max 3)
	U	Dominant / Co-dominant understorey species (max 5)
	S	Dominant / Co-dominant submerge species (max 3)

APPENDIX 3. STATE MANGROVE AND SALTMARSH LAYER – METADATA

DATA SUPPLY REPORT

Dataset Number :	254	**Class :**	ENV
Title :	Coastal Saltmarsh and Mangrove Mapping	**ANZLIC ID :**	1027000013
Dataset Category :	Vegetation		
Theme :	Native vegetation		
Dataset Type :	Spatial		
Description :	Mapping of individual coastal saltmarsh and mangrove habitats throughout SA, providing landform, lifeform and condition categories. In addition this layer also holds an Acid Sulfate Soil classification for each landform/lifeform category.		
Dataset Use :	For use at the regional /local scale, for the purpose of conservation, coastal management and planning.		

Custodians

DENR - Conservation Policy and Programs - Coastal Management

Data Quality

Lineage : Landform and Lifeform boundaries for individual saltmarsh complexes were initially interpreted from predominantly 1:10,000 or 1:15,000 colour aerial photography (sometimes 1:40,000 aerial photography is used where the more detailed aerial photography is not avialable) and drafted onto a stable film base. Environmental boundaries are digitised in Map Grid of Australia (MGA) coordinates and coded with a specific landform / lifeform code. Individial salt marsh complex data sets are then re-projected into a Lambert Conformal Conic coordinate system and appended into a statewide data set.
In 2004 the Upper Spencer Gulf was updated using Orthophotography consisting of 1:80000 air-photos scanned at 25 microns, which produced 2m pixel imagery with a resolution of 1:7500. This 2002 imagery formed the foundation to locate, then digitise habitat boundaries identified using air-photo pairs and a stereoscope. Habitat boundaries were created within a newESRI Geodatabase model implemented within the department's SDE environment allowing multi-user editing. Acid Sulfate Soil codes were determined by CSIRO Land and Water, based on field sampling.

Data Capture Method Digitising

Digitising from boundaries drafted onto stable film base, and heads-up digitising from orthophotography.

Field survey

Data Capture Scale 1:10 000

1:40 000

1:80 000

Completeness : Field verification has been undertaken for Eyre Peninsula, Yorke Peninsula, Spencer Gulf, Kangaroo Island and parts of Gulf St. Vincent. Minor alterations to boundaries and coding may be required post field verification.

Positional Accuracy : The majority of mapping is based on unrectified 1:10,000, 1:15,000 and 1:40,000 aerial photography. The Upper Spencer Gulf was updated from Orthophotography(in 2004) obtained as part of a program of :opographic update. The positional accuracy may vary from +/- 20m to +/- 50m.

Attribute Accuracy : Classification based on aerial photo interpretation, survey data, ground truthing and expert knowledge.

Consistency : The GIS package ARC/INFO was used to do topological consistency checks to detect flaws in the spatial
data structure. This check ensures that all classified polygons are closed, nodes are formed at the

Comments : This data set is not finalised and mapping boundaries and coding are likely to change with futher field verification. This data set should be considered INTERIM only.

Geographic Extent

Extent Name :	Coastal SA		
Min Easting :	129.000	**Min Northing :**	-38.000
Max Easting :	141.000	**Max Northing :**	-31.000

Status

Date Acquired :	01-SEP-1997	**Last Update Date :**	12-NOV-2007
Update Frequency :	As required		
Maintenance Method :	Update coding and / or mapping boundaries from aerial photographic interpretation and heads up digitising using orthophotos.		
Progress :	Complete		
Ending Date :	12-NOV-2007		
Restrictions :	No restrictions - subject to license agreement. Require acknowledgement of data source, ownership of digital data is not transferred and digital data is not to be supplied to any third party.		

Specifications

PRINTED : 06-SEP-2010 **PAGE : 1**

Format Type: ARC/INFO
ArcSDE Feature Class

Data Type : ARC/INFO Polygons
ARC/INFO Arcs
ArcSDE Feature Class - Polygons

Available Format Type : ARC/INFO
ESRI Personal GeoDataBase
ESRI Shapefile

Precision : Double **Data Size :** 50 - 100 Mb

Table Name : Coastal Saltmarsh and Mangrove ArcSDE Feature Class Table

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
ASSCLASS	Integer	2	2	0	>90	>90

Description : Acid Sulfate Soil class

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
ASSDESC	Character	300	300	0	>90	>90

Description : Acid Sulfate Soil description

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
ASSLEGEND	Character	10	10	0	>90	>90

Description : Acid Sulfate Soil legend - used to display / classify

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
COMPLEX	Character	50	50	0	>90	>90

Description : Saltmarsh complex name

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
COVER	Character	50	50	0	>90	>90

Description : Defines the cover type of the mapped habitat polygon - e.g. sand, mangrove, samphire etc.

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
ESTUARINE	Character	15	15	0	>90	>90

Description : Key work defining if the saltmarsh mapping unit is estuarine or non estuarine

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
INTEGRITY	Character	15	15	0	>90	>90

Description : Defines the condition of the cover type e.g. intact, degraded, prograding etc.

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
LANDFORM	Character	30	30	0	>90	>90

Description : Coastal landform - e.g. flat, beach, shore platform, stream chenier/ beach ridge etc.

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
LOCNAME	Character	50	50	0	>90	>90

Description : The name of the specific mapped location e.g. Tourville Bay

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
LOCNR	Character	5	5	0	>90	>90

Description : A unique identifier number for a specific mapped location. Made up by concatenating REGION and UNITSEQ

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
LOCSEQ	Character	2	2	0	>90	>90

Description : A mapped location sequence number within a specific Coastal Region - numbered from east to west.

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
LONGDESC	Character	100	100	0	>90	80-90

Description : Saltmarsh habitat description e.g. intertidal samphire - intact

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
MAPUNIT	Character	8	8	0	>90	80-90

Description : Mapping code representing the saltmarsh / mangrove habitat interpreted from aerial photography. This is an 8 digit number representing the landform, estuarine, tidalclass, cover and integrity of the mapped habitat polygon.

Table Name: Coastal Saltmarsh and Mangrove ArcSDE Feature Class Table

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
REGION	Character	3	3	0	>90	>90

Description: A 3 letter code defining the specific coastal region e.g. EPW - Eyre Peninsula West

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
SHORTDESC	Character	100	100	0	>90	>90

Description: Shortened saltmarsh habitat description e.g. intertidal samphire

Name:	Datatype:	Width:	Output:	No Dec:	Percentage Completed	Percentage Accuracy
TIDALCLASS	Character	25	25	0	>90	>90

Description: Defines the tidal regime of the mapping unit polygon e.g. intertidal, supratidal, stranded tidal etc.

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APPENDIX 4. STATE ESTUARIES BOUNDARY LAYER AND HABITAT LAYER – METADATA

DATA SUPPLY REPORT

Dataset Number :	1202	**Class :**	ENV
Title :	Estuarine Habitats of South Australia	**ANZLIC ID:**	
Dataset Category :	Coasts		
Theme :	Coastal features		
Dataset Type :	Spatial		
Description :	This dataset contains habitat mapping for estuaries of South Australia. These estuaries were identified in the draft 'Estuaries Policy and Action Plan.'		
Dataset Use :	Used to identify the estuarine habitats within South Australia for use in natural resource management and conservaton planning.		

Custodians

DEH - Conservation Policy and Programs - Coast and Marine Conservation

Data Quality

Lineage : Using estuaries that have been identified as part of the draft 'Estuaries Policy and Action Plan for South Australia' habitat boundaries were deliniated using existing benthic habitat mapping and saltmarsh and mangrove habitat mapping and additonal line work digitized from aerial photography. Digitization was undertaken in the DEH's SDE edit environment to map vegetation and landform boundaries that were located by a combination of air photo interpretaion, heads-up orthophoto digitisation, field capture and integrated line work from the above mentioned existing spatial data sets.
Imagery was sourced from the most up to date avaliable in the DEH image library at the time of completion and as such imagery was undertaken using images at a variety of scales (refer to positional accuarcy).

Data Capture Method

Digitising

GPS

Field survey

Generate

Data Capture Scale

1:2 500

1:10 000

1:40 000

1:80 000

Completeness : This dataset is complete for all of the estuaries identified in the draft 'Estuaries Policy and Action Plan' 2007.

Positional Accuracy : The majority of mapping is based on 1:25,00, 1:10,000, 1:15,000, 1:40,000 & 1:80,000 digital orthophotograhy. Due to the varying imagery used in capture the positional accuracy may vary but may be accepted to be +/- 15m for all purposes.

Attribute Accuracy : Classification based on orthophoto interpretation, survey data, ground truthing where undertaken and expert knowledge.

Consistency : ESRI ARC/INFO GIS software was used to conduct topological consistency checks to detect flaws in the spatial data structure, this check ensured that all classified polygons are closed, nodes are formed at the intersection of lines and that there is only one label in each polygon.

Comments :

Geographic Extent

Extent Name :	Coastal SA		
Min Easting :	129.000	**Min Northing :**	-38.000
Max Easting :	141.000	**Max Northing :**	-31.000

Status

Date Acquired :	30-JUN-2008	**Last Update Date :**	30-JUN-2009
Update Frequency :	As required		
Maintenance Method :	As required, funding dependent		
Progress :	In Progress		
Ending Date :	30-JUN-2009		
Restrictions :	No restrictions - subject to license agreement. Require acknowledgement of data source, ownership of digital data is not transferred and digital data is not to be supplied to any third party.		

Specifications

Format Type: ArcSDE Feature Class

Data Type : ARC/INFO Polygons

Available Format Type : ESRI Personal GeoDataBase

ESRI Shapefile

Precision : Double **Data Size :** 50 - 100 Mb

Table Name : Polygon Attribute Table

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
ASSCLASS	Character	5	5	0	>90	>90

Description : Acid Sulfate Soil Class

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
ASSDESC	Character	150	150	0	>90	>90

Description : Acid Sulfate Soil description

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
ASSLEGEND	Character	10	10	0	>90	>90

Description : Acid Sulfate Soil legend - used to display / classify

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
COVER	Character	50	50	0	>90	>90

Description : Defines the vegetative and sediment type of cover of the mapped habitat polygon e.g. gharnia, reeds, sand etc

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
DENSITY	Character	2	2	0	>90	>90

Description : The % of cover within each mapped habitat polygon

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
ESTUARINE	Character	15	15	0	>90	>90

Description : Defines each system as estuarine or stranded estuarine

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
GROUND TRUTH	Character	2	2	0	>90	>90

Description : Indicate sites that have and have not been visited or may need to be visited in the future.

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
INTEGRITY	Character	15	15	0	>90	>90

Description : Defines the condition of the cover type i.e. intact, patchy, uniform

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
LANDFORM	Character	30	30	0	>90	>90

Description : The landform classification of the mapped habitat.

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
LOCNAME	Character	50	50	0	>90	>90

Description : The name/ location of the estuary as determined in the the National Land and Water Audit.

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
MEDDESC	Character	100	100	0	>90	>90

Description : The overall estuary habitat description.

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
SHORTDESC	Character	100	100	0	>90	>90

Description : The old short description as described in the Saltmarsh & Mangrove habitat mapping

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
STRUCTURE	Character	50	50	0	>90	>90

Description : Refering to seagrass and algae only. A 'two-tier' cover classifier: - Tier 1:classifies each habitat (polygon) as having either continous (>50%) or patchy (>50%) cover, - Tier 2: classifies each habitat (polygon) cover as either dense, medium or sparse in appearance.

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
TIDAL CLASS	Character	25	25	0	>90	>90

Description : Defines the tidal regime of the mapping unit polygon e.g. intertidal, subtidal or supratidal

Name :	Datatype :	Width :	Output :	No Dec :	Percentage Completed	Percentage Accuracy
TYPECODE	Floating Point	10	10	0	>90	>90

Description : A general habitat type abbreviation.

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APPENDIX 5. MULTIVARIATE ANALYSES METHODOLOGY

Of the 22 estuaries that were sampled for water quality variables, three were excluded (Franklin, Deep Creek and Rocky River) because they did not have at least two sites with two depth readings. The data for the remaining 19 estuaries were investigated using PRIMER v6 with the PERMANOVA+ add on (Anderson, Gorley and Clarke 2008) and SYSTAT v12. Data were grouped by up to four factors: NRM region, estuary within region, site within estuary, and reading depth within site. Due to the large variation in water depth among estuaries reading depths were classified into shallow versus deep water readings.

Data pre-processing

Conductivity and total dissolved solids data were collected with the HORBIA U52 during surveys, however both variables were highly correlated with salinity and each other. Therefore some of these data were not used in multivariate analyses; only salinity was retained. One reading for turbidity at Carrickalinga was a distinctive outlier and was considered to be inaccurate (368 NTU). This data point was excluded and replaced using the 'Missing' function in PRIMER, which uses the EM (expectation-maximisation) algorithm to estimate a value based on the values of the surrounding cells (Anderson *et al.*, 2008). The estimate was deemed 'reasonable' as it was within the range of values of other samples for turbidity, and remained so even with the addition of 2 standard deviations to its value. The turbidity data were also heavily right-hand skewed and were therefore transformed by log (1 + x) to normally distribute the data.

Statistical data analysis

The data collected for this inventory only represents one collection event and is not replicated through time. Therefore in order to have replication for these exploratory statistical analyses, data from different reading depths were used as replicates within sites, and sites were used as replicates for comparing reading depths. A resemblance matrix was created using Euclidean distances on normalised data. Two, nested three-factor PERMANOVAs were done on the water quality data; one with region as a fixed factor, estuary nested within region as a random factor and site nested within estuary as a random factor. A second PERMANOVA was done with region as a fixed factor, estuary nested within region as a random factor and reading depth nested within estuary as a random factor as it could not be standardized across estuaries. Unrestricted permutations of raw data (999 per test) were done with Type III (partial) sums of squares and fixed effects summing to zero. Pair-wise tests for significant effects were also done. Please refer to Multivariate Analysis text (pg 69) for results.

Principal Components Analysis (PCA)

PCA was done on raw data values to reduce dimensionality in the data set and to determine the main variables that were driving the differences among regions, estuaries and sites. SYSTAT was used for this part of the analyses, based on linear correlations and Varimax rotation was used to separate variable loadings on the derived principal components. The PCA was rotated using Varimax in SYSTAT to more closely align the variable vectors with the axes. This resulted in Principal Component 1 explaining 33% of the variance and Principal Component 2 explaining 25% of the variance. The Latent Roots (Eigenvalues) were greater than 1 for the first two factors (1.776 and 1.140) and Eigenvalues were significantly different from each other for all factors ($P < 0.001$; Chi-square test). pH and dissolved oxygen had high and positive component loadings with Principal Component 1 and temperature had a high and positive component loading with Principal Component 2 (see Table 5).

Table 5. Component loadings for water quality variables in PCA (after rotation).

	PC1	PC2
pH	0.777	-0.384
Dissolved oxygen	0.846	-0.102
Temperature	0.084	0.810
Salinity	0.538	0.306
Turbidity	-0.173	0.600

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