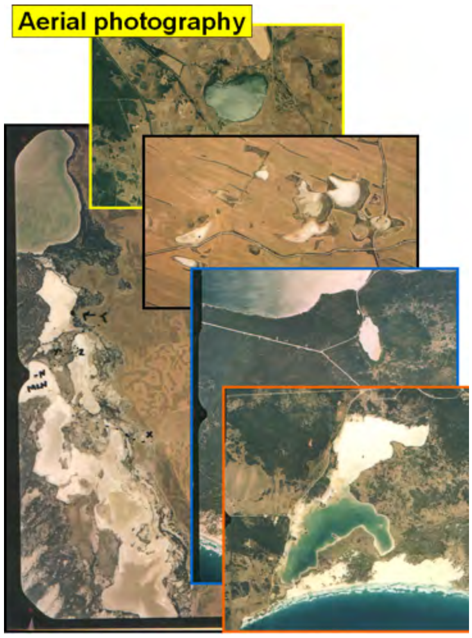
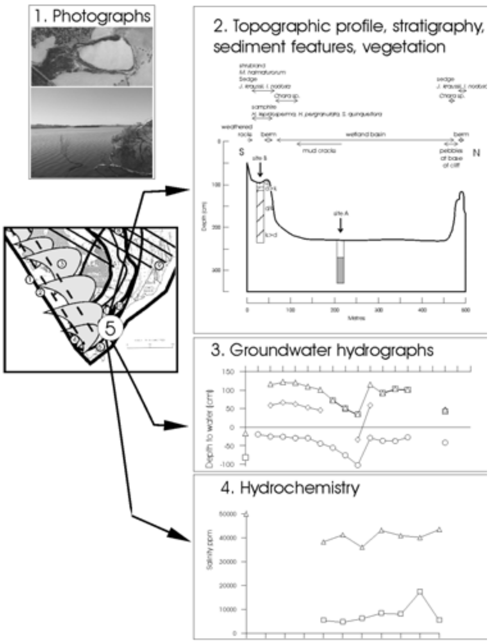
A BASELINE SURVEY OF THE WETLANDS OF EYRE PENINSULA 2005-2007

Report to: Eyre Peninsula Natural Resource Management
Jobomi House,
50 Liverpool Street
Port Lincoln, SA 5606



Report by: V & C Semeniuk Research Group
21 Glenmere Rd
Warwick, WA 6024



July 2007

A BASELINE SURVEY OF THE WETLANDS OF EYRE PENINSULA

Table of Contents

A BASELINE SURVEY OF THE WETLANDS OF EYRE PENINSULA 2005-2007

1.0 Introduction

1.1 Background

The Eyre Peninsula Catchment Water Management Board (EPCWMB), as part of a project funded by the Natural Heritage Trust entitled "A Co-ordinated Approach to Wetland Management" commissioned the V & C Semeniuk Research Group (VCSRG) to undertake a baseline survey of wetlands on the Eyre Peninsula. This also was the major component of the work of the Steering Committee overseeing the project. The EPCWMB was later replaced by the Eyre Peninsula Natural Resources Management Board (EPNRMB). Through this report, while we are aware that the EPCWMB evolved to become the EPNRMB, we will generally refer to the Steering Committee body by its latest name, *i.e.*, EPNRMB, unless specifically wanting to address the EPCWMB.

The project encompasses the area defined by the Eyre Peninsula Natural Resources Management Board boundaries in South Australia (Fig. 1).

Before this project, data on the wetlands of Eyre Peninsula had consisted of independent and un co-ordinated reports on various wetlands in response to necessity, community interest, and available funding. This current project aims to improve understanding of wetlands on Eyre Peninsula and to provide information to develop a strategic management for wetlands, and a community monitoring programme.

1.2 History of Project

When VCSRG first became involved in this project its scope were quite broad, ranging from inland wetlands, to coastal (estuarine) wetlands, and marine wetlands (including mangrove, tidal flat and beach environments), for which we were to provide baseline data for monitoring in terms of water levels, water quality, wetland vegetation, aquatic macroinvertebrates, and opportunistic data on waterbirds. VCSRG had a large experience in estuarine, tidal flat and beach environments (*e.g.*, Semeniuk & Johnson 1982; Semeniuk 1986; Semeniuk & Wurm 1987; C A Semeniuk & Semeniuk 1990; Semeniuk & Withers 2000; Semeniuk 2000; Semeniuk *et al*. 2000; Semeniuk 2004). Estuarine and coastal systems are complex. They often show land to sea gradients in salinity and inundation (with concomitant changes in biotic assemblages, structure and composition; Semeniuk 1983; Semeniuk & Wurm 1987). They commonly exhibit a multiplicity of internal habitats (Semeniuk 1986; Semeniuk & Wurm 1987; Wurm & Semeniuk 2000), reflecting complex physicochemical and biological processes (Semeniuk 2004). They may be dynamic due to wave and tidal activity (and hence show temporal variation in habitats; Semeniuk 1996; Pen *et al.* 2000). They may exhibit variation in species composition *within* assemblages due to population dynamics and/or habitat variations (Pen *et al.* 2000; Semeniuk & Wurm 2000; Cresswell *et al.* 2000). Accordingly, they are difficult to monitor, and with the variation in land-to-sea dynamics, and population dynamics driven by marine and by freshwater influences in terms of species composition and abiotic factors, they require an inordinate number of sampling sites and replication at each sampling site to capture their spatial and temporal variability (see

Semeniuk & Wurm 2000). Essentially, the entire project budget could have been taken up with only establishing a monitoring programmes along the coast and estuaries.

As a result, VCSRG suggested that the project concentrate on inland wetlands, and the EPCWMB Steering Committee agreed with this suggestion.

At the next stage, VCSRG advised that in order to establish a baseline monitoring programme of inland wetlands of the Eyre Peninsula, it would be important to determine what was the variety of wetlands therein, and select wetlands that were representative of the diversity of wetlands in the region. This meant a change in focus in the project, from one in which wetlands were selected *ad hoc*, or on an "already-known-to-exist" basis, to one in which the full suite of wetlands were assessed as to their variability across the region, and a representative example was selected from the variable set. This entailed using the "consanguineous wetland" approach (to be described later). With this approach, the wide range of wetlands in the region are aggregated into natural groups ("consanguineous suites"), and a representative example, or two, of the suite was selected for description and monitoring. In this manner, capturing and recognizing the wide variety of wetlands on the Eyre Peninsula would be the framework for the design, establishment, and implementation of a baseline monitoring programme in the region. Early in the project, VCSRG undertook two workshops with the EPCWMB Steering Committee and community groups to explain this approach to the design of baseline monitoring. The suggestion, that the project veer from the traditional hydroperiod, water quality, and biota monitoring to one of determining the natural variability of wetlands in the region prior to selecting wetlands for monitoring, was adopted by the EPCWMB Steering Committee and community groups.

VCSRG's approach was to establish the physicochemical attributes of a wetland in terms of its landform setting, hydrological setting, and stratigraphy as a basis to installing piezometers, then installing those piezometers, and taking water level measurements on a monthly basis, as well as collecting water samples, also on a monthly basis. This provides a framework to determining how the wetland functions and how it responds to hydrological and climatic events, before embarking on the design of a biological monitoring programme. In this context, the first surveys needed to be at the end of the dry season (before winter rains set in) to have access to the wetland centre and to ensure that the piezometers were installed as deeply as possible to accommodate the lowest end-of-summer water levels. Essentially, therefore, establishing hydrological monitoring in the dry season excludes sampling of aquatic invertebrates, whose communities are manifest in the wet season when piezometers installation would be extremely difficult. As a result, documentation and monitoring of macroinvertebrates and setting up of a baseline monitoring programme for vegetation were excluded (see later). The emphasis was to determine the diversity of wetland types on the Eyre Peninsula, select one or more of these wetlands as representative of that diversity, (ideally) establish topographic, stratigraphic, hydrological, hydrochemical, and vegetation profiles and transects across the selected wetlands, and collect at least a year of water level data and water samples for later analyses.

This approach would provide geomorphic, stratigraphic, physicochemical and hydrological information about the various wetlands in the region (*viz*., what they are, how they function, how different they are from others in the region, their basic hydrology and hydrochemistry), and some information on their vegetation. This also would provide the framework to design a more robust monitoring programme for vegetation and for aquatic macroinvertebrates.

Historically, during this project, selection of sites for establishing the baseline monitoring was largely based on the consanguineous suite approach, but also incorporated specific wetlands recommended by the EPCWMB Steering Committee and community groups that they had assessed as being important. Consequently, the final list of wetlands that were selected for developing a baseline monitoring programme combined community group and EPCWMB Steering Committee requirements, and those wetlands that emerged during this study as being representative of consanguineous suites. Hence, some consanguineous suites have only one wetland selected as being representative of the suite, while others have several.

Thus, a decision was made to use the consanguineous approach to focus on the fundamental attributes of wetlands such as wetland type, its setting, hydrology, and some aspects of hydrochemistry. This would ensure a representative selection of wetland types and processes for future monitoring and research; and to build data into a framework of physical and chemical wetland functions and processes. These data are to be used to construct a framework for biological population distributions and variable wetland community composition in order to clarify the diversity and dynamics of biological response.

1.3 Scope

The purpose of the project was to undertake a baseline survey of inland wetlands within the region of the Eyre Peninsula (Figure1), although mutual discussion between the EPCWMB Steering Committee and VCSRG restricted the area under consideration to the triangle of land south of the line of latitude that intersects Whyalla. The project was to identify the different types of wetlands in this region, select one or more wetlands representative of the diversity in the region for monitoring, and through this process incorporate the physical characteristics of scale, geometry, hydrological processes, sedimentological processes, vegetation cover and plant community composition, and some aspects of the hydrochemistry of the wetlands and their setting, as a framework for future more detailed surveys and numerical data on the biological components.

As noted above the scope of the project was to include only wetlands that are categorised as "land locked," *i.e.*, wetlands which are subject to prevailing continental wetland processes. Wetlands formed and maintained by marine agents such as waves and tides (tidal flats, embayments) were excluded. Wetlands which bridged land and marine settings and were maintained by hydrological processes from both sources, such as estuaries, also were excluded, but selected wetlands which were wholly land based but retained a subterranean hydrological contact with marine waters, such as Little Seagull Lake (see later), were included. Additionally, artificially constructed wetlands such as reservoirs, dams, and ponds were omitted. The land based, or "land-locked" wetlands included basins, flats, and channels, ranging from permanently to intermittently inundated habitats to habitats which are permanently or seasonally waterlogged, and of variable salinity, *viz*., hypersaline, saline, brackish, or freshwater.

1.4 Objectives

In the light of the above history of the project and its unfolding, the objectives for this project evolved to the following:

- Improve understanding of the wetland types on Eyre Peninsula *i.e.*, document the diversity of types in the region;
- Relate wetlands to their geomorphic and hydrological setting, *i.e.*, establish consanguineous suites in the region, and hence set up a framework for determining wetland diversity on Eyre Peninsula;
- Within the context of consanguineous suites, undertake a baseline survey of selected wetlands (a subsample of the region, but representative of a given consanguineous suite), which would incorporate the following components: wetland type, water level measurements, water salinity and pH, description of vegetation communities using Semeniuk *et al*. (1990 - see later), or transect profile of plant distribution, listing absence/presence of key or dominant species in the vegetation, and opportunistic recordings of any sightings of fauna;
- Ideally, obtain a year of monthly data on water levels and salinity and pH, to determine how each of the selected wetlands function hydrologically, and hydrochemically;
- Based on setting, landuses in the local region, wetland maintenance processes, wetland behaviour, wetland status, and an assessment of degradation and threats at each wetland site in the subsample, provide recommendations for management;
- Provide suggestions for future community monitoring.

1.5 Limits of the Study

Wetlands are complex geomorphic, hydrological, hydrochemical systems, and complex biologically-responding entities. Often, beneath a seemingly simple surficial system, the hydrogeology may be complex (with spatially variable input and outflow of water), causing the wetland biota to reflect this in their distribution and composition (see C A Semeniuk 2007). Also, the sedimentary fill in a wetland, responding to asymmetry in throughflow or other aspects of hydrology and hydrochemistry, itself becomes asymmetrical (Semeniuk & C A Semeniuk 2006), with feedback on hydrological processes and hydrochemistry. Again, the biota respond to these forms of complexity. This is the type of complexity presenting itself in the wetlands of the Eyre Peninsula.

As such, we would like to identify the various limits to this study.

Firstly, while personnel of the V & C Semeniuk Research Group, to date, have spent some 105 man-days in field work, with some additional 25 man-days of technical assistance from community groups, hired helpers, and government agency personnel in augering, sampling, and installing piezometers, and while VCSRG have endeavoured to range as widely as possible across the Eyre Peninsula to view landscapes and wetlands, and visit and sample a range of wetlands before committing to the selection of the preferred list, it was not possible within the allocated time frame to exhaustively view/visit every wetland in the region. Hence there has been a stratified and accessibility driven selection process, with the information obtained from those sites that *were visited* extrapolated to those that were not. In addition, community group and government agency personnel to date have expended some 3-4 days per months over the past two years monitoring the wetlands wherein staff gauges and piezometers have been installed.

Secondly, for a number of wetlands, the monthly water level monitoring was undertaken consistently for two years, but for others it was not. Some wetlands were not monitored during the summer because of bushfire danger. Some, for the first winter were not consistently monitored because they were rapidly flooded after the first rains and the tops of the piezometers were inundated. Monitoring continued after the piezometers became emergent during the ensuing dry season, but high water monitoring data were lost. Also, as the study unfolded with more surveys, additional wetlands in newly discovered consanguineous suites were selected and visited in the fourth survey in April 2006, so that less than one year of data have been collected from these.

Thirdly, consistent collection of water quality data was restricted to determining salinity and pH on a monthly basis. For a limited number of samples, representative samples were analysed for major cations (Na, K, Ca, Mg), some heavy metals (*e.g.*, Pb, Cr, As; indicative of urbanization effects, or fertilizer effects), and total P and N. Such latter detailed water analyses, however, were not comprehensive, nor exhaustive, and were undertaken to provide indications of regional water quality status on a once-off sampling basis.

Fourthly, this project was not an in-depth wetland vegetation study. Consequently, only the main components of the vegetation that characterized a given wetland were identified. The vegetation within a given wetland also was classified as to its organizational structure and patterns following Semeniuk *et al*. (1990), *i.e.*, the style of vegetation distribution was described. In this study, no attempt was made to identify wetland vegetation assemblages, map wetland plant communities, establish permanent quadrats around the piezometers, or provide abundance data (*i.e.*, it did not quantify the vegetation in terms of structure and floristics).

1.6 Acknowledgements
We would like to acknowledge the assistance given to us during this project by staff of the Eyre Peninsula Catchment Water Management Board and the replacement Eyre Peninsula Natural Resource Management, members of the community, and residents of Port Lincoln itself.

Tansy Boggon, Illonna Evans nee Foster, and Jonathan Clark are particularly thanked for their assistance in this project for their administrative and logistic help, and in organising the workshops. We wish to thank EPNRM for use of their vehicles provided from time to time for fieldwork, for the use of topographic maps, for administrating permits to National Parks and Reserves, for contacting land owners, and for collating and storing monthly data and water samples.

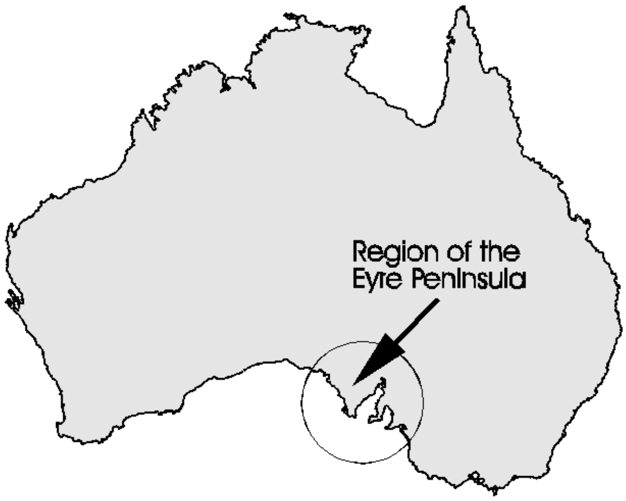
We also wish to thank Tansy Boggon, James Cowden, Illonna Evans nee Foster, Sophie Keen, and Justine Graham for carrying out monthly water level measurements and water sampling in the various wetlands. Without their assistance and monitoring the report would have been bereft of water level data!

Thanks go to Dr Paul Wilson at WA Herbarium for identification of species of *Halosarcia* and other samphire species. Thanks also go to Brian Saunders, Janet Smythe, Paul Wainwright of DEH, Simon Bey of Green Australia, and Helen Vonow of DEH for identification of plants at Coffin Bay, Sleaford Mere, Lake Hamilton, Samphire, Wudinna, Lake Newland, and the Uley Basin.

The excursion in the Uley Basin, with Scott Evans, organised by Illonna Evans nee Foster and Jonathan Clark, was particularly useful, and gratefully acknowledged.

Warm thanks also go to Justine Graham, Brian Foster, Janet Smythe, David and Julie Bassham and Christine and Jim Wilcox who offered generous and excellent hospitality to us both in the field and in Port Lincoln itself.

1.7 VCSRG R&D contribution
VCSRG undertook this project in a collaborative and co-operative research capacity. As a Research & Development Firm, registered with AusIndustry as VCSRG P/L Project # 3, our Firm is committed to raising the consciousness of scientists, community groups, and the general public to the issues of wetlands. In this context, VCSRG embarked on this project in a co-operative manner, contributing in-kind research in addition to the financial input provided by the EPNRMB. The ratio of in-kind contribution VCSRG to EPNRMB was 1:1.



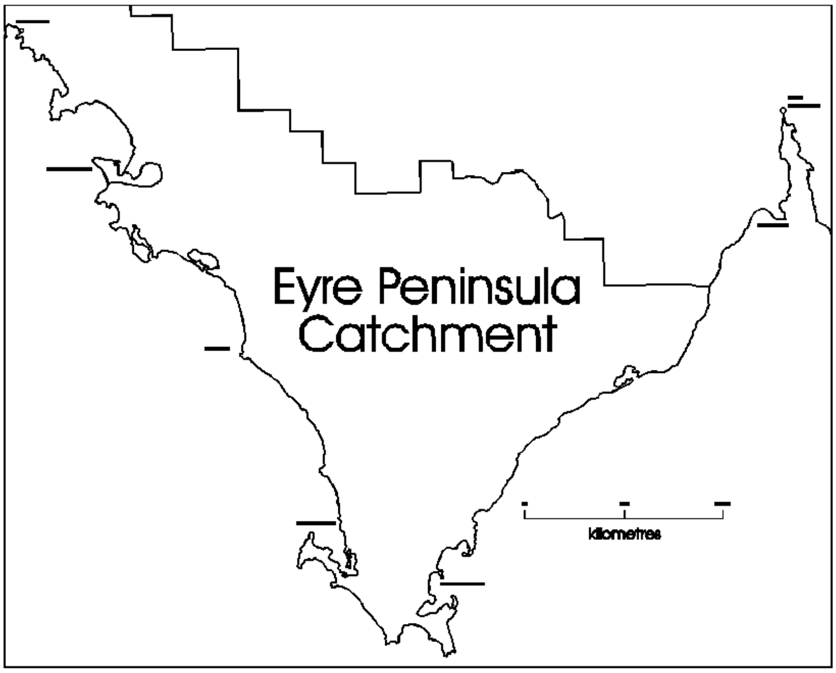


Figure 1: Location of study area

2.0 Literature Review

For this report, a review was undertaken of published information on the Eyre Peninsula inland wetlands included in this project. The review was largely drawn from the scientific literature and departmental assessments and management plans. This review is very briefly summarised here using three broad divisions in line with the main report: natural history, biodiversity and geodiversity values of the wetlands, and management principles. The scope of this project did not involve a major component of review of literature, and hence only the most relevant literature was noted. However, most literature was accessed, and information where relevant was referred to.

The most up-to-date literature review involving wetlands is by Boggon (2005) and Boggon & Evans (2006), and the reader is referred to this work for details. A more thorough literature review of a specific area was presented in the report on the Lake Newland area (V & C Semeniuk Research Group 2007), and again, the reader is referred to that work.

In terms of the natural history of Eyre Peninsula, environmental regions were first designated for the Eyre and Yorke Peninsulas by Laut *et al*. (1977). There were six environmental regions designated for these provinces and they were based on vegetation criteria. These environmental regions were most recently used for the wetland inventory on Eyre Peninsula reported by Seaman (2002). In other studies, Eyre Peninsula has been viewed from the perspective of a geological/geomorphic and soils framework.

Background data on geology, landforms, climate, soils, sediments and hydrology for this report were derived from De Deckker *et al*. (1982), Williams (1984), Twidale *et al.* (1985), Wright (1985), Dutkiewicz & von der Borch (1994, 2002), and Dutkiewicz *et al*. (2002). Geological information was supplemented by Drexel *et al*. (1995) and Drexel & Priess (1995). Regional information was obtained from several authors in Twidale *et al*. (1985): Parker *et al*. (1985) on tectonic setting and geological history, Twidale & Campbell (1985) on physiographic regions, Schwerdtfeger (1985) on rainfall and winds, Wright (1985) on soils, and Shepherd (1985) on hydrology. Shepherd (1985) noted that surface water is the most common source of water for recharging wetlands on Eyre Peninsula, with important groundwater resources in the Precambrian, Tertiary and Quaternary geological formations. Spring (September) water quality data was available from Williams (1984) for some basin wetlands (Lakes Newland, Hamilton and Malata). Detailed information on the Holocene history, sediment composition and stratigraphic interpretation of wetland sediments was provided by De Deckker *et al*. (1982) for Pillie Lake, and by Dutkiewicz & von der Borch (1995), (2002), and Dutkiewicz *et al*. (2002) for Lakes Malata and Greenly. In addition, Dutkiewicz *et al*. (2002) produced a geomorphologic map for the Lake Malata-Lake Greenly Complex.

It was more difficult to obtain data on biodiversity values, as site specific reports were often unpublished. Reports reviewed for this section included DEH (2002) and Day *et al.* (2004, 2005). In these reports, two main points were reiterated: 1) the role of inland wetlands in supporting listed migratory waders and threatened species of avifauna, and 2) the importance on the Eyre Peninsula of freshwater habitats, their aquatic communities and macrophytic plant communities (Day *et al.* 2004, 2005). Some examples were highlighted, such as the importance of Lakes Newland and Hamilton as feeding grounds for international and national migratory waders and as near permanent water habitats for avifauna during drought periods (for review see V & C Semeniuk Research Group 2007). Other examples related to the importance of freshwater habitats for a diverse number of aquatic macroinvertebrates (Little Swamp) and to the occurrences of fresh to hyposaline sedgeland communities of *Gahnia trifida* and *Gahnia filum* noted to support priority fauna, *e.g.*, *Hesperilla flavescens* during crucial growth stages.

Other sites to achieve particular mention were rillen and gnammas on the granite monadnocks in the Wudinna region. Sleaford Mere is recognised as being a regionally significant wetland type (DEH 2002) and the stromatolites which occur there as having heritage significance. The vegetated gnamma habitats in granite monadnocks potentially contain rare and endemic species of flora and fauna, *e.g.*, the granite mud wort (*Limosella granitica*) and endemic species of amphibia (Day *et al.* 2004).

Of the wetlands included in this study, those designated as regionally significant in key biodiversity areas of Eyre Peninsula were Sleaford Mere, Pillie Lake, Tod River, Lake Hamp Round Lake and Lake Malata (Day *et al.* 2004).

In terms of management, evaluation of wetlands has been the most common type of reporting, using definitions and frameworks provided by ANZECC and Ramsar Technical Committees (Morelli & de Jong 1996, Seaman 2002, DEH 2002, Boggon 2005). The Directory of important wetlands for South Australia (1996) lists the following wetlands relevant to this study as wetlands of national significance: Tod River, Lake Hamilton and the Lake Newland system. In the Seaman report, 27 inland wetlands were surveyed. Using ANZECC criteria, several wetlands were identified as good examples of a wetland type occurring within a biogeographic region in Australia: Sleaford Mere, Pillie Lake, Lake Hamp and Lake Newland. Using a rapid assessment designed for their survey, the following wetlands were identified as having high scores for environmental values: Sleaford Mere, Lake Greenly, Lake Hamp, and Lake Newland.

Several warnings and recommendations were also made in the Seaman report. These are summarised below.

- With respect to aquatic invertebrate fauna, a warning was issued with regard to anthropogenically increasing salinity levels in wetlands because of the negative effect this would be likely to have on their biodiversity and biological activity.
- Five activities contributing to overall deteriorating water quality were identified.
- It was perceived that there exists an urgent need for investigations regarding water requirements for biodiversity as most of the information available regarding water resources on Eyre Peninsula is for human consumption.
- Specific threats to woodlands of *Melaleuca halmaturorum* were identified (Greenway 1997).

When putting together a district plan for soil conservation, some of the reports made little mention of naturally inundated or waterlogged areas, particularly flats (Anon 1995). This is regretful considering that many risks to maintaining wetlands and maintaining soil conservation for agriculture are held in common, *e.g.*, erosion and increasing salinity due to vegetation clearing. However, the reports did highlight the wetland region of Wanilla, the Miltalie/Salt Creek area and the Tod River catchment as potential high risk areas for water erosion and saline seepage. Fencing and re-vegetation are widely recommended as the means to rehabilitate affected areas. Most of the areas designated as having the potential for soil acidity were not included as sites for this project because they already exhibited strong signs of degradation, such as clearing, and salt scalds, and appeared to have little ecological value.

In the Eyre Peninsula Catchment Water Management Plans (Day *et al.* 2004, 2005), special mention was made of the Tod River system, citing variability in erosion effects, turbidity effects and hydrochemical composition. In this report all parameters cited pertain to the site at Koppio and are not intended for general application.

3.0 Classification & Terminology

Before progressing further, it is necessary to provide some introduction to and discussion of the terms used throughout this report with respect to wetland description and classification.

3.1 Definition of a wetland

A preamble of "what is a wetland" is provided here so that what has been captured as a wetland in this study is clear.

Even today, the concept of a "wetland" is still rather imprecise, and the term "wetland" carries with it an accumulation of diverse opinions and experience, and a contrast between the northern hemisphere history of wetland terms, *versus* southern hemisphere history of wetland terms. This is the result of several factors. Firstly, although there is recognition that wetlands are habitats with unique properties of land and water, in practice, most are recognised by the occurrence of their hygrophytic vegetation. This pragmatic approach has been translated into a theoretical construct which then accords wetland vegetation a place in the definition of wet lands. No other landform is defined or classified according to the vegetation which grows upon it, *e.g.*, in current classifications, mountains are classified into their various types based on their shapes and underlying material, and dunes are classified on geometry and their relation to wind fields. However, with wetlands there has been an over-emphasis on vegetation as the criterion for definition and classification. The other factors that contribute to an imprecise concept and definition of wetlands include wetland water regimes, the range of landform types that may constitute "wetlands", and the emphasis on underground water resulting from various perceptions of the word "land".

Thus, although definitions of the term "wetland" have been provided by a number of authors (UNESCO 1971; Golet and Larson 1974; Lefor & Kennard 1977; Cowardin *et al.* 1979; Zoltai and Pollet 1983; Coventry & Williams 1984), it has proven difficult to construct a formal and concise meaning in the midst of confusion of terms, debate about what constitutes a "wetland", and in what location lies its boundary.

The definition of wetland used by the Ramsar Convention (UNESCO 1971), presented below, is one that emphasizes waterfowl habitat. It is the definition that is accepted generally around the world, though it has several weaknesses. According to the Ramsar Convention (UNESCO 1971), wetlands are:

> *areas of marsh, fen and 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 6 m.*

The most robust definition of wetlands, and the one that best encapsulates the variability of natural inland wetlands (*e.g.*, using existing diverse terminology from the literature: lakes, swamps, mires, moors, pans, fens, bogs, forested swamps, meadows, mineral mounds, mound springs, peat mounds, "salt lakes", various types of fluvial channels and fluvial plains, palusplains, marsh, saline water bodies, amongst others), in our experience both Australia-wide and globally, is that developed by the Wetlands Advisory Committee (1977).

It was developed on a foundation of variability of inland wetlands in Western Australia, and was the one adopted by C A Semeniuk (1987), by the Water & Rivers Commission (Hill *et al.* 1996), and globally by C A Semeniuk & Semeniuk (1995) and Semeniuk & C A Semeniuk (1997). Here, wetlands are defined as:

> "*areas of seasonally, intermittently, or permanently waterlogged soils or inundated land, whether natural or artificial, fresh or saline*"

However, to capture coastal wetlands, and to address the broader idea that wetland basins are underlain by wetland sediments and/or wetland soils, or by rock or non-wetland materials, the definition proposed is as follows (following Semeniuk & C A Semeniuk 2007):

> *areas of permanently, seasonally, intermittently, or tidally waterlogged to inundated soils, sediments, or land, whether natural or artificial, fresh to saline.*

This definition deals with "wet" lands, regardless of how they have become wet (via various inland hydrologic processes, or coastal marine processes), regardless of their vegetation cover, be it moss, heath, sedge, rush, meadows, forests, regardless of the soil, sediment, or substrate types that underlie them (be they *in situ* organically derived, or *in situ* precipitates, or water-transported materials, such as peat, humic soils, gypsum, carbonate precipitates, alluvium), and regardless of the extent of inundation, permanence of inundation and extent of waterlogging. As a definition of wetlands, in our experience globally and in Australia, it captures virtually *all* wetlands that have been documented to date.

As such, it can be seen that water, whether it is static, or flowing determines whether a terrain is a "wet" land, and therefore on the Eyre Peninsula there are a wide range of wetland types, *viz*., using common or colloquial terms: lakes, swamps, samphire flats, floodplains, rivers, creeks, and meres (*e.g.*, Sleaford Mere), amongst others.

3.1 Local scale (site-specific) wetland classification

A system is in use for classification of *in situ* wetlands which is based on the dual fundamental aspects of wetlands, the water and land components (C A Semeniuk 1987, C A Semeniuk & Semeniuk 1995, Semeniuk & C A Semeniuk 1997). The water component is the major attribute that distinguishes the wetland habitat from other terrestrial habitats, and also the components which influences biological response by its presence, depth, chemistry and movement. The landform is essentially the water container, or the host to the wetland, and it determines wetland size, shape, and depth.

The component of water can be categorised on the basis of its persistence or longevity, its quality, its constancy of water quality and the mechanism by which water maintains the wetland. In the classification, the fundamental water attribute used is water permanence or longevity (or hydrological regime). This essentially is the length of time that surface water, or near-surface groundwater resides in a wetland, and is subdivided into several categories: permanent inundation, seasonal inundation, intermittent inundation, and seasonal waterlogging. Under conditions of climatic variability it is the *prevailing* hydrological condition which is used. The landform component can be categorised on the basis of cross-sectional wetland geometry, scale and plan geometry. In the classification, the fundamental land attribute used is cross-sectional landform geometry, and following C A Semeniuk & Semeniuk (1995) these are hill, slope, flat, channel, and basin.

Combining the landform attributes and hydrological regime, a matrix was constructed providing 13 categories of common wetlands (Table 1; and Fig.2):

Table 1 Classification of inland wetlands

HYDROLOGICAL REGIME	**LANDFORM HOST TO WETLAND**				
	hill	**slope**	**flat**	**channel**	**basin**
permanent inundation	-	-	-	river	lake
seasonal inundation	-	-	floodplain	creek	sumpland
intermittent inundation	-	-	barlkarra	wadi	playa
seasonal waterlogging	palusmont	paluslope	palusplain	trough	dampland

Table 1 and Figure 2A show the construction and the nomenclature of 13 possible categories using C A Semeniuk & Semeniuk (1995). For instance, hills, slopes, flats, channels, and basins may be seasonally waterlogged and the wetlands formed in these situations are palusmonts, paluslopes, palusplains, troughs, and damplands, respectively; seasonally inundated flats, channels and basins are termed floodplains, creeks, and sumplands, respectively.

Figure 2B shows the relationship of wetland landform to three different hydrological regimes. In this example, a landscape with basins being located progressively higher in the landscape, in a situation of a seasonally fluctuating water table, generates three wetland types:

1. those basins that are permanently intersecting their water table are permanently inundated, but with a seasonally fluctuating water level - these are *lakes*;

2. those basins that intersect the water table only when the water tables are highest, and are seasonally inundated - these are *sumplands*;

3. those basins located above a water table with a seasonally fluctuating water level and the highest level of the water table waterlogs the floor of the basins - these are *damplands*.

Once a wetland is assigned to one of the 13 primary wetland types, it can be further differentiated by use of descriptors. That is, water and landform descriptors are used to further augment the nomenclature of the primary categories and discriminate individual wetlands, and Figure 2C illustrates the ranges of adjectival descriptors used to augment description of the basic 13 wetland types. The adjectival descriptors on the right relates to landform; those on the left relate to water. Thus, using water descriptors and landform descriptors, a (theoretical) lake and a sumpland may be described fully as megascale, round, mesosaline, poikilohaline lake, and a microscale, irregular, freshwater, stasohaline sumpland, respectively.

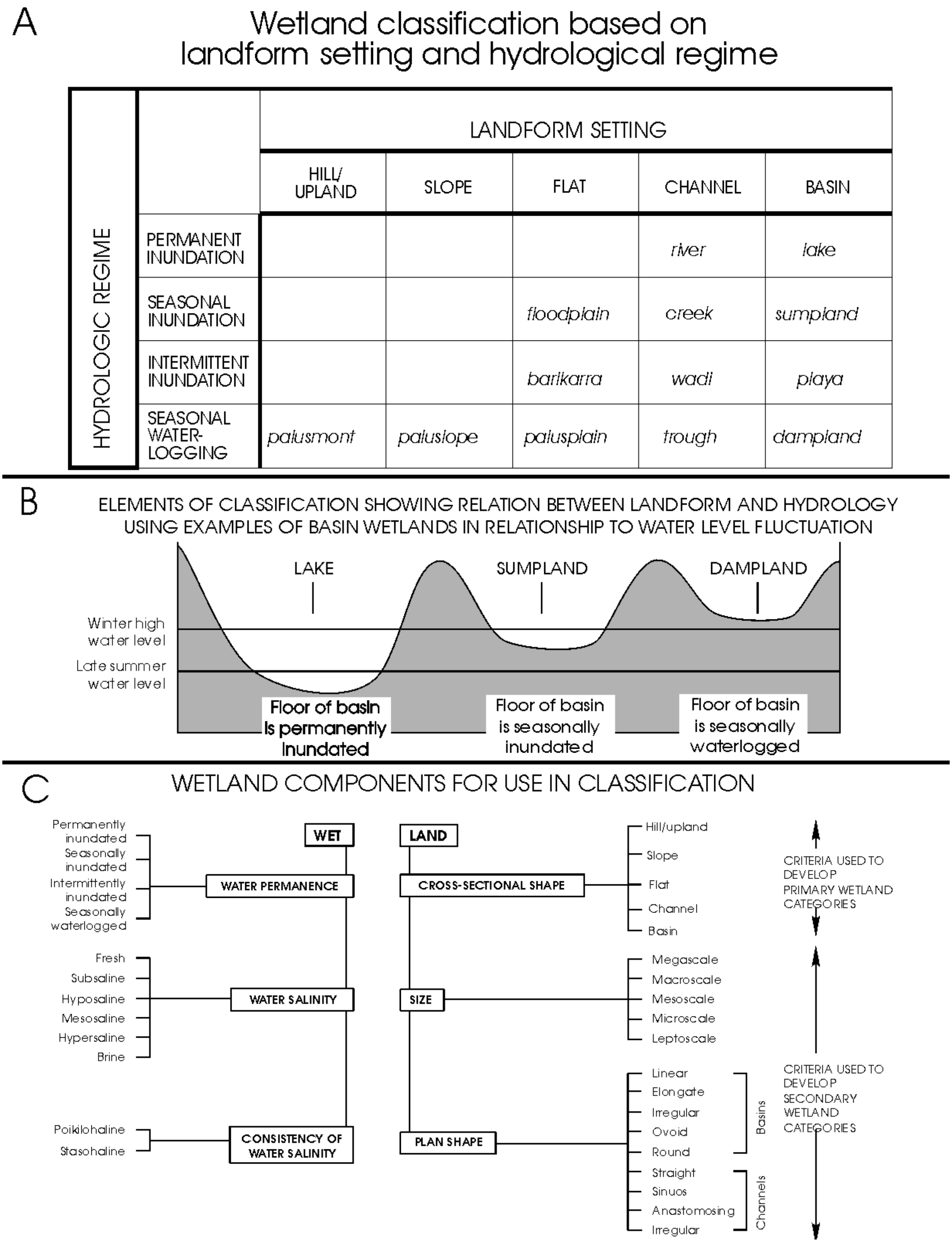


Figure 2: System used to classify and describe wetlands in the study area

One of the most important descriptors of landform is that of scale. The various categories of scale referred to herein are as follows:

- Macroscale: Large scale wetlands encompassed by a frame of reference 1000 m x 1000 m to 10 km x 10 km
- Mesoscale: Medium scale wetlands encompassed by a frame of reference 500 m x 500 m to 1000 m x 1000 m
- Microscale: Small scale wetlands encompassed by a frame of reference 100 m x 100 m to 500 m x 500 m
- Leptoscale: Fine scale wetlands encompassed by a frame of reference several metres by tens of metres

These scales do not refer to the exact size of the wetland (axiomatically), but refer to the size of the square that could envelope a given wetland.

One of the most important descriptors of water is that of salinity. Water salinity is classified according to Hammer (1986); see Table 2.

Table 2 Classification of water salinity based on total dissolved solids (after Hammer 1986)

Salinity mg/l	**Water category**
< 1,000	Fresh
1,000-3,000	Subhaline
3,000-20,000	Hyposaline
20,000-50,000	Mesosaline
50,000-100,000	Hypersaline

3.2 Local scale wetland vegetation classification system

Vegetation in a wetland can be complex, with varying structure, spatial organization, and extent of cover, with variable zonation, homogeneity, or heterogeneity, and with various community assemblages, and species aggregations, and depending on the size of the wetland, it can cover many hectares, or only several square metres. Semeniuk *et al*. (1990) devised a system of classifying wetland vegetation that addresses this complexity. It has a binomial structure. The first part classifies the wetland vegetation in terms of extent of cover and the internal organization of that wetland vegetation. From the classification, a land manager, or researcher, or wetland scientist could determine how much of the wetland was covered in vegetation (*e.g.*, only peripherally, or mottled throughout, or totally covering the wetland), and how that cover was internally organized (zones, homogeneous, mottled, or heterogeneous). This type of information was useful, for instance in assessing the significance of the wetland vegetation to waterfowl, or other fauna, as it essentially described the secondary (vegetation-developed) habitats across the wetland. The second part of the classification listed the structural and floristic components of the vegetation, and these could be related to the type of internal vegetation organisation that the wetland exhibited.

Thus the classification of Semeniuk *et al*. (1990) was designed for wetlands based on the attributes of: scale of wetland vegetation complexes; extent of vegetation cover over the wetland; internal organisation of vegetation in plan; vegetation structure; and details of the floristic/structural components. Only emergent, perennial, woody or herbaceous macrophytes are considered in this classification.

Figure 3 illustrates the elements of the primary part of the classification. It shows that the wetland vegetation cover is described in two ways, firstly by extent of cover, and secondly by the complexity of organisation. The vegetation cover is classified as peripheral, mosaic, or complete. The classes are gradational but there is no implication that the classes necessarily reflect increasing percentage cover. The use of percentage cover has been deliberately avoided when erecting classes. Wetland pattern is described as homogeneous, zoned or heterogeneous. The combination of areal extent and internal organisation of the wetland vegetation results in 9 basic wetland categories (Figure 3 and Table 3).

While the terms shown in Figure 3 and Table 3 form the primary part of the binary terminology, the second part comprises structural terms after Specht (1981) combined with floristic (species composition) information. Where the wetland vegetation is composed of several structural types arranged in zonal pattern, these are listed in order of their occurrence from margin to centre of wetland, essentially mirroring some environmental gradient. The information on the floristics of the assemblages may be added to the main binary wetland classification terminology as a suffix, or secondary adjunct. This approach provides a structured way in which to systematically describe and compile an inventory of wetland vegetation units (see Semeniuk *et al*. 1990 for more detailed description of this method).

Table 3 Classification of wetland vegetation cover

TERMS FOR CATEGORISING WETLAND VEGETATION			
ORGANISATION OF VEGETATION	**AREAL EXTENT OF VEGETATION COVER**		
	peripheral	**mosaic**	**complete (> 90%)**
homogeneous	periform	paniform	latiform
zoned	zoniform	gradiform	concentriform
heterogeneous	bacataform	heteroform	maculiform
USE OF THE CATEGORIES OF WETLAND VEGETATION AS DESCRIPTORS			
ORGANISATION OF VEGETATION	**AREAL EXTENT OF VEGETATION COVER**		
	peripheral	**mosaic**	**complete (> 90%)**
homogeneous	periphytic	paniphytic	latiphytic
zoned	zoniphytic	gradiphytic	concentriphytic
heterogeneous	bacataphytic	heterophytic	maculiphytic

o

In this report, only the primary part of the vegetation classification, describing extent of cover and organisation of vegetation, was used.

The categories of scale, outlined above to describe the size of a wetland, also are used to describe the scale of wetland vegetation. That is, if a wetland is a megascale wetland, and has peripheral vegetation, or alternatively, to use another hypothetical example, the wetland is microscale with latiform vegetation, the descriptors of megascale periphytic wetland and microscale latiphytic wetland convey description of the size, extent of vegetation cover, and internal organisation of vegetation cover for each of the wetland examples.

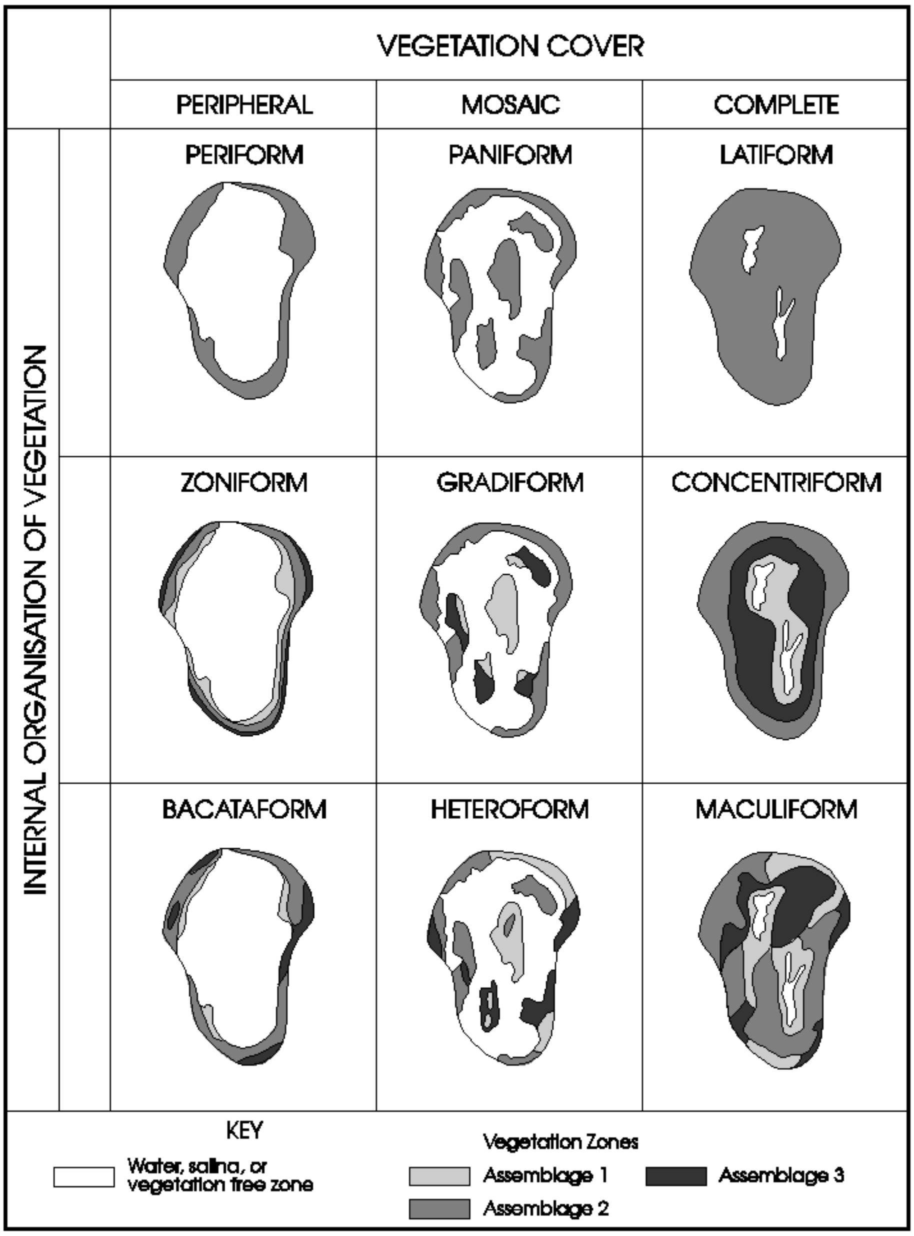


Figure 3: System used to classify wetland vegetation in the study area

4.0 Philosophy of approach to this study

One of the outcomes following the initial workshops and discussions with the EPCWMB at the design stage of this project was that the wetlands selected for baseline monitoring were to be a representative subsample of all the inland wetland types on Eyre Peninsula. This required a planning strategy and approach which incorporated the following three components: 1) the determination of the range of inland wetlands on the Eyre Peninsula, 2) the design of a systematic scheme for comparing wetland diversity, and 3) a reliable subsampling method. In effect, this was a sequential and stratified approach, as will be described more fully in the section on Methods.

The philosophy of approach with respect to the range of wetland types was to firstly identify the climatic and physiographic regions on Eyre Peninsula. Geological, geomorphic and hydrological attributes, in particular, those which give rise to wetlands, were used to identify these climatic and physiographic regions, which were zones most likely to contain different wetland types. Then, within each of these regions, individual wetlands were classified according to the classification of the *in situ* wetland types nominated in Semeniuk (1987), C A Semeniuk & Semeniuk (1995), and Semeniuk & C A Semeniuk (1999). Throughout this process, there was deliberate emphasis on diversity of wetland type as opposed to diversity of wetland plant communities (a common substitution).

Many diverse characteristics of wetlands are the result of multiple causative factors. For instance, geometry of wetlands is dependent upon geomorphic setting. Wetland size is related to ancestral geomorphology, wetland origin, evolutionary stage and amount of water. Water recharge and water maintenance mechanisms, and wetland salinity depend on wetland stratigraphy, hydrochemical setting, geomorphic setting and present hydrologic regime. Wetland stratigraphy is related to wetland origin, hydrochemistry and invertebrate fauna, algae, and macrophytic vegetation, and wetland vegetation depends on water depth, water permanence, water chemistry and sediments/soils.

A systematic scheme for comparing wetland diversity was drawn from the concept of consanguinity. [Consanguinity, a word deriving from "blood related", in the context of the earth sciences and wetlands means naturally related wetlands, or "natural groups"]. In this context, consanguinity intends to convey the notion of relationship between wetlands, relationship due to a similarity of causative factors and physical setting. Thus, if there is a similarity of climate, hydrology, geology, and geomorphic processes, it may be expected that a suite of similar wetlands, or consanguineous wetlands, will result.

The notion of consanguineous suites is based on the application of established criteria which results in the segregation of wetlands into groups, which are internally similar in regard to causative factors, and at the same time, different from every other group in terms of the fundamental attributes of its wetland members. Thus, wetland diversity is compared systematically. The identification of consanguineous suites is a powerful first step in comparing similar or “like” wetlands for evaluation, survey and assessment procedures. Using the approach of consanguineous suites, and given that consanguineous suites imply differences between natural wetland groups, it follows that, in order to capture diversity, at least one wetland within each wetland suite needs to be selected for the study. For this study, a number of wetlands within a suite have been selected as study sites in order to replicate research results and also to capture the habitat diversity that is present in each suite.

4.1 The concept of consanguinity and its application to wetlands

The concept, criteria, and framework of consanguineous wetland suites were designed for the purpose of categorising large numbers of wetlands into groups based on their similarity, using fundamental and relatively stable wetland attributes. For practical purposes, the attributes selected for differentiation should also be ones which are not dependent on the time of year or the seasonal regime of any wetland. Geologic and hydrologic setting were found to be underlying causes of many aspects of wetland development and their similarity, *i.e.*, shape, depth, landform type, hydrological processes, water quality, water regime, sediment types, sediment and groundwater chemistry and origin. And many of these attributes are directly linked to invertebrate assemblages (water quality, water regime), vegetation distribution pattern (depth, water regime, sediment and groundwater chemistry), and the dynamic biological changes from season to season.

The notion of consanguineous suites essentially recognises that there are different types of wetlands residing in different settings, and each setting results in a similarity of wetlands therein. Recognition of these differences is important for comparative, managerial, and representative conservation purposes.

4.2 The criteria for establishing consanguinity

In general, seven criteria are used to establish wetland consanguinity (Semeniuk 1988):

1. *Wetlands should occur in reasonable proximity* (Fig. 4)
2. *Wetlands should be similar in size and shape* (Fig. 4)
3. *There should be a recurring pattern of similar wetland types or a spectral range of inter-related wetland types resulting from a single dynamic process* (Fig. 4)
4. *Wetlands should have a similar stratigraphy*
5. *Wetlands should have similar water salinity regimes*
6. *Wetlands should have similar hydrological dynamics* (Fig. 4)
7. *Wetlands should have similar origin* (Fig. 4)

For the Eyre Peninsula region, the extent to which the criteria were applied, and the sources of data are explained below.

1. *Wetlands should occur in reasonable proximity*
   Information was obtained from 1:50,000 topographic maps, and 1:40,000 aerial photographs.

2. *Wetlands should be similar in size and shape*
   Information was obtained from 1:50,000 topographic maps, and 1:40,000 aerial photographs.

3. *There should be a recurring pattern of similar wetland forms or a spectral range of inter-related wetland forms resulting from a dynamic process*
   Information was obtained from 1:50,000 topographic maps, 1:40,000 aerial photographs and from field visits to determine the geomorphic setting.

4. *Wetlands should have a similar stratigraphy*
   Information was obtained from the following sources: published geology maps and field investigations.

5. *Wetlands should have similar water salinity regimes*
   Information was obtained from the following sources: field investigations into sediments and stratigraphic sequences of wetlands, surrounding areas and regional sites and from hydrographs and surface and groundwater samples.

6. *Wetlands should have similar hydrological dynamics*
   Information was obtained from the following sources: field investigations into sediments and stratigraphic sequences of wetlands, surrounding areas and regional sites and from hydrographs in selected wetlands.

7. *Wetlands should have similar origin*
   Data were obtained from publications and field investigations into parent materials and sites exhibiting various stages of wetland development.

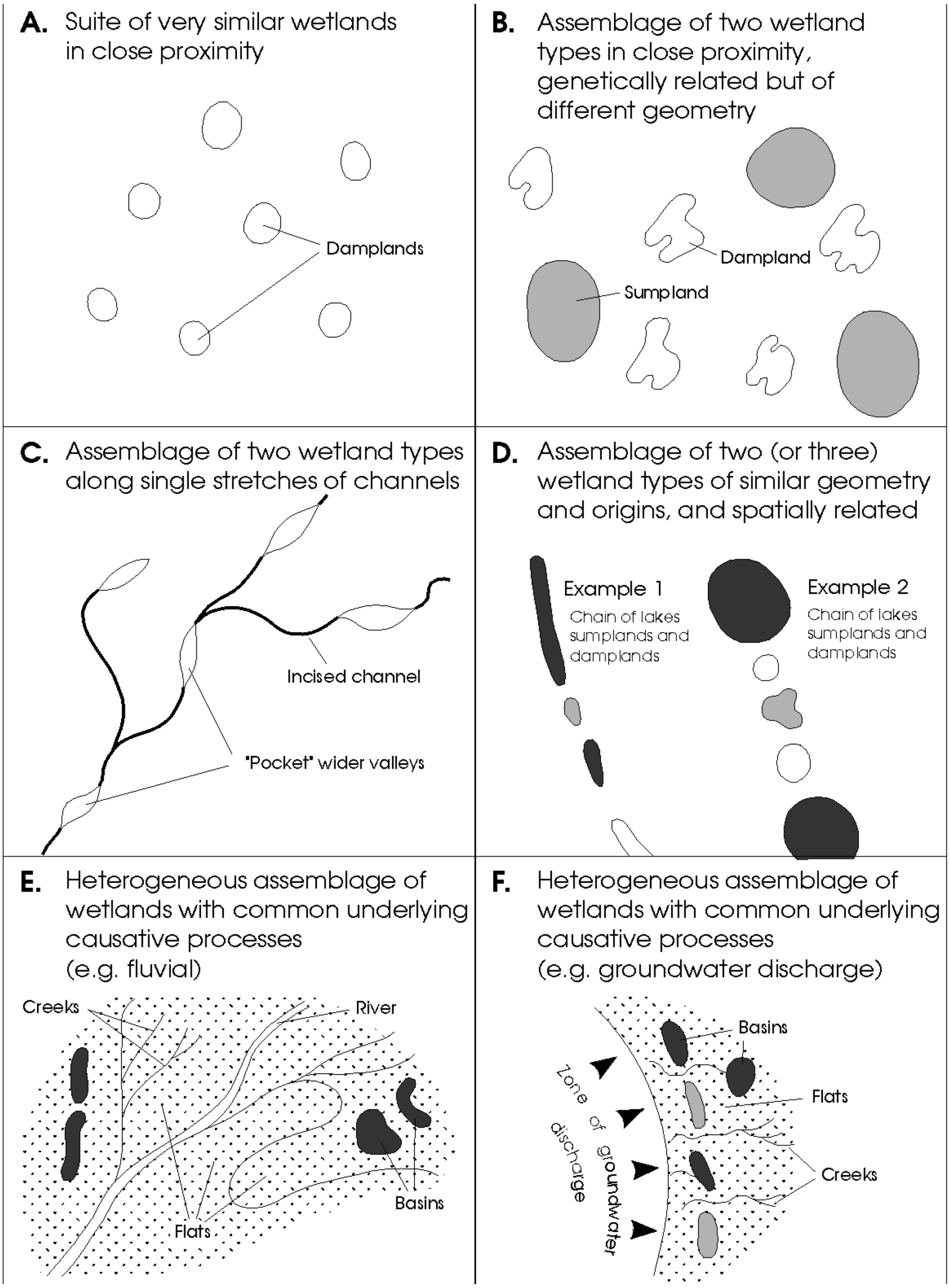


Figure 4: Examples of criteria used to identify consanguineous wetland suites (after C A Semeniuk 1988)

5.0 Methods

5.1 Preamble

The initial task was to become familiar with the wetlands on Eyre Peninsula through map analysis, photographic analysis, field visits, consultation, and literature review. The second task was to apply a systematic method for subsampling wetlands such that the sample encompassed their diversity and exemplified wetland attributes on Eyre Peninsula. The method selected was to group *all* wetlands into a number of consanguineous wetland suites, which were defined as groups of wetlands having in common their geographic location, landscape setting, hydrological processes and geochemical attributes - all of these factors being known to influence their biology. From each of the consanguineous wetland suites one or two wetlands were selected to form the subsample. The wetlands in the subsample were described and assessed using site specific investigative techniques, monitoring, and review of databases and publications. Recommendations for management and future monitoring were derived for each wetland in the subsample and extrapolated to the whole suite.

5.2 Information base and data base

The report for this study was based on reviews of published literature, in-house reports and studies undertaken by staff in the Department of Environment and Heritage, consultants and university personnel, as well as on climatic, geological and topographic maps, aerial photographs, regional reconnaissance field trips, site investigations, transect work, wetland surveys, and sampling of waters, soils and vegetation.

- Location and geometry of wetlands was obtained from the topographic map series 1501 1:25,000 Royal Australian Survey Corps (1984-2002) and the topographic 1:50,000 series for Eyre Peninsula.

- Aerial photographic interpretation was based on 1993, 1996, 1997, 1:40,000 colour aerial photographs.

- Monthly water level data were collected between June 2005 and November 2006 by the wetland project officer, volunteers and staff from EPNRMB.

- Water sampling was undertaken opportunistically at some sites and at monthly intervals at other sites.

- Information and data on geology were obtained from regional reconnaissance field trips, Bulletin 54 of the Department of Mines and Energy South Australia (Drexel *et al*. 1995; and Drexel & Priess 1995), and geology map series S1 53 1:25,000 Geological Survey SA (1983-2003), and from cliff cuts, trenches, dams and excavations in the field.

- Stratigraphy was determined from auger holes on-site in the centres and margins of the wetland basins, flats, and channels and from selected coastal and dune sites.

- Vegetation assemblages and condition: data was collected in the field along transects during on site studies of the wetlands.

- Aquatic invertebrates and waterbirds: data was obtained by literature search and observation.

Five field surveys and site visits were undertaken for this study, corresponding to beginning of winter, end of winter, middle summer, end of summer, and end of winter, to capture low water levels, maximum water levels, and prevailing mid-summer conditions. The timing for the surveys were:

June 2005	= beginning of winter 2005
September 2005	= end of winter 2005
January 2006	= middle summer 2005/2006
April 2006	= end of summer 2005/2006
April 2007	= end of summer 2006/2007

Generally, each survey was undertaken by two principals from VCSRG, with two technical assistants from VCSRG, the project officer from EPNRM, and ad hoc assistance from hired assistants, or community group personnel.

5.3 Sequential procedure adopted in this study

To ensure that many wetland settings were investigated, and a full range of consanguineous suites were captured from which representative wetlands could be selected, a sequential procedure was adopted in this study. This involved:

1. study of topographic maps to determine landscape types and occurrences of wetlands (Fig. 5);
2. study of geological maps to determine geological setting and hence consanguineous setting (Fig. 6);
3. undertaking numerous road traverses to obtain regional familiarity, and to intersect as many wetlands as possible in the region (Fig. 7);
4. examination of aerial photographs to obtain regional familiarity, and to assess the regional variability of wetlands (Fig. 8);
5. undertaking a more detailed study of selected wetland regions to obtain subregional familiarity with the wetlands (Fig. 9);
6. from the information obtained in points 1-5 above, delineate the consanguineous suites; this was based on geological setting, topography, hydrological setting, and interfaces between the regional units (Fig. 10)
7. selection of the study sites from within the designated consanguineous suites, and advice obtained from the Steering Committee and community groups,.

Figure 5: Topographic maps used in the study (1:50,000 scale)

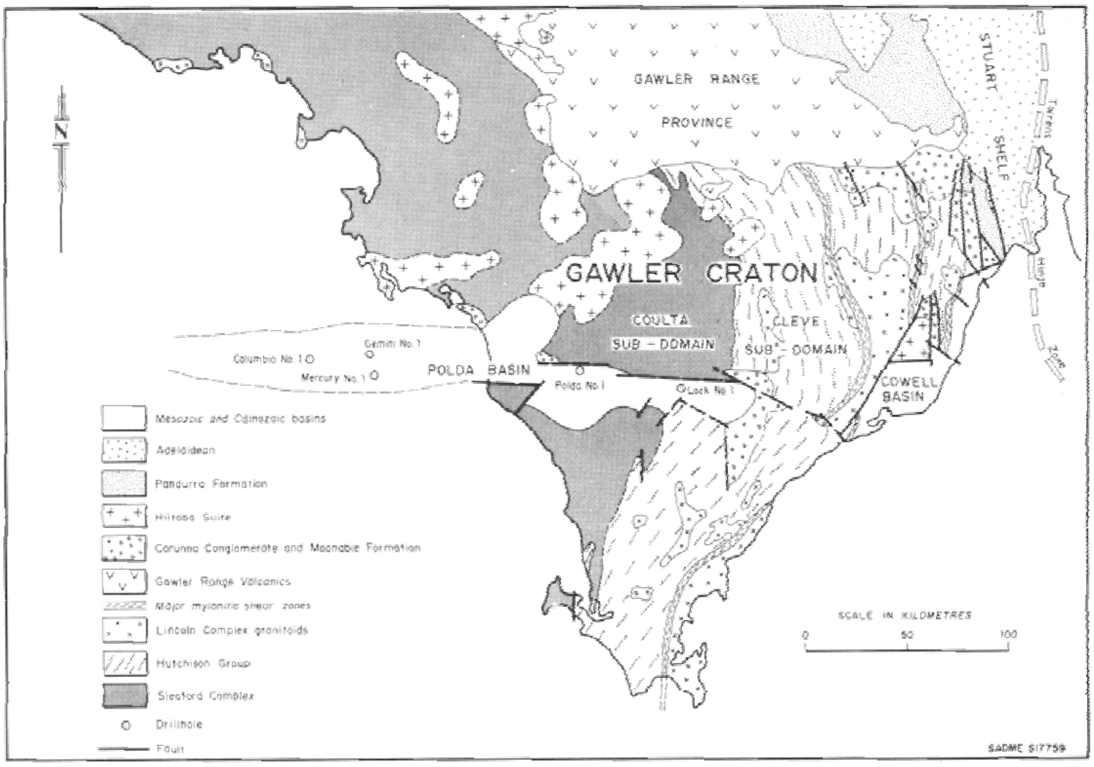


Figure 6: Use of geological maps in the study - this particular map outlines the Precambrian bedrock geology but in addition, maps delineating outcrop/occurrence of younger geological materials such as Quaternary limestones were also used.

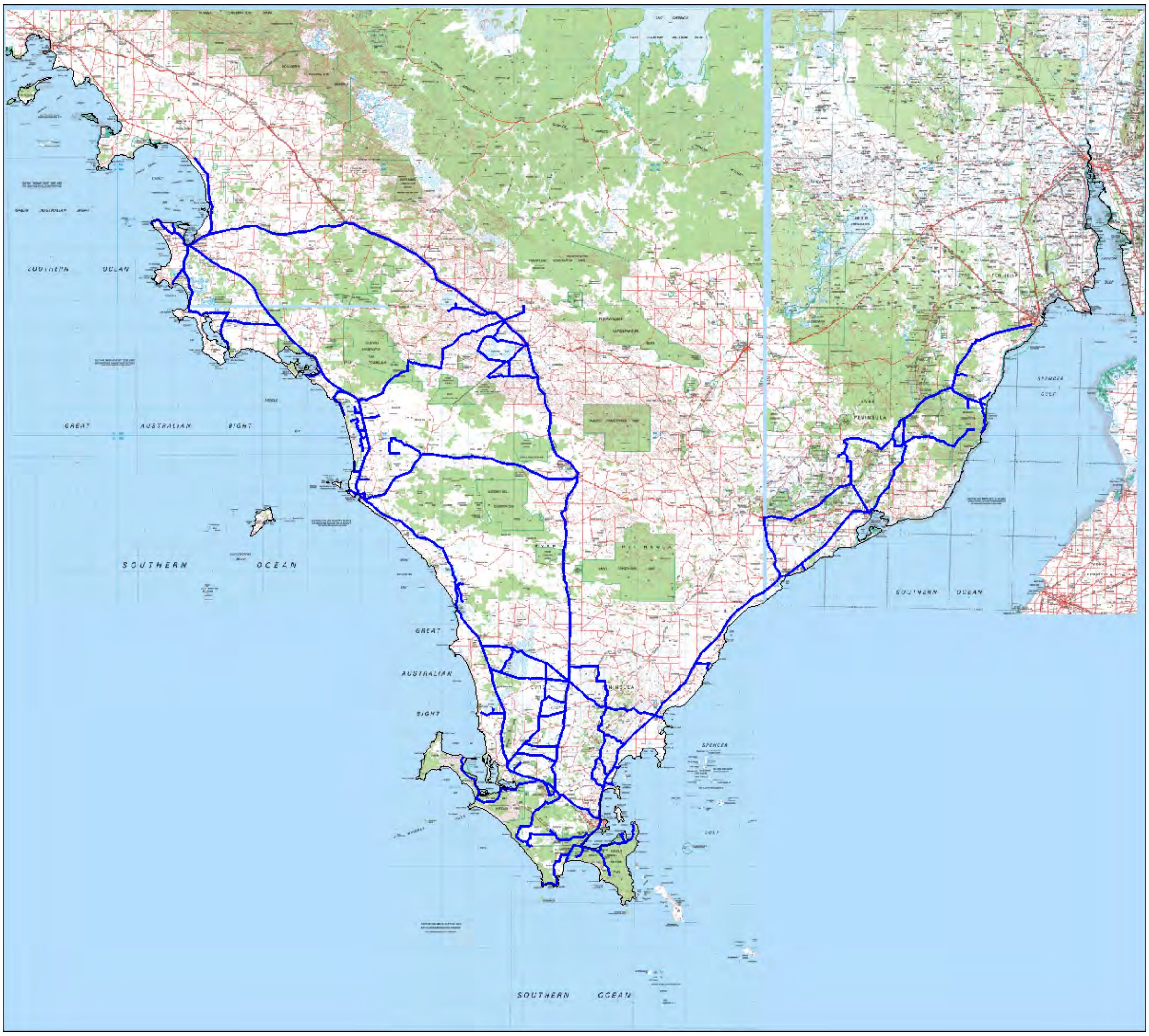


Figure 7: Traverses that were undertaken by road in the region to obtain a regional picture of terrain and wetland types, and to visit wetlands intersected by roads.

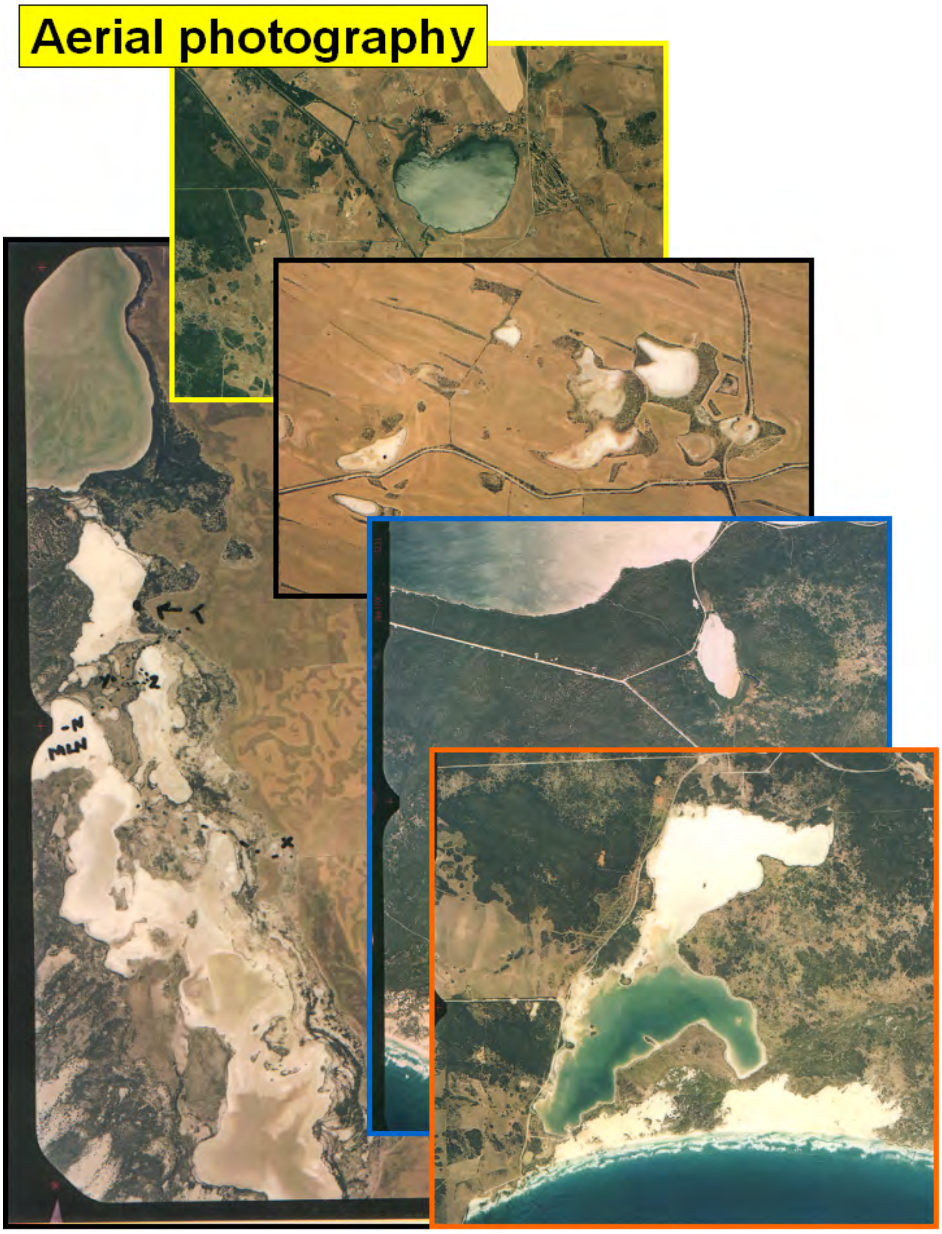


Figure 8: Aerial photographs were used to obtain regional familiarity, and to assess the regional variability of wetlands.

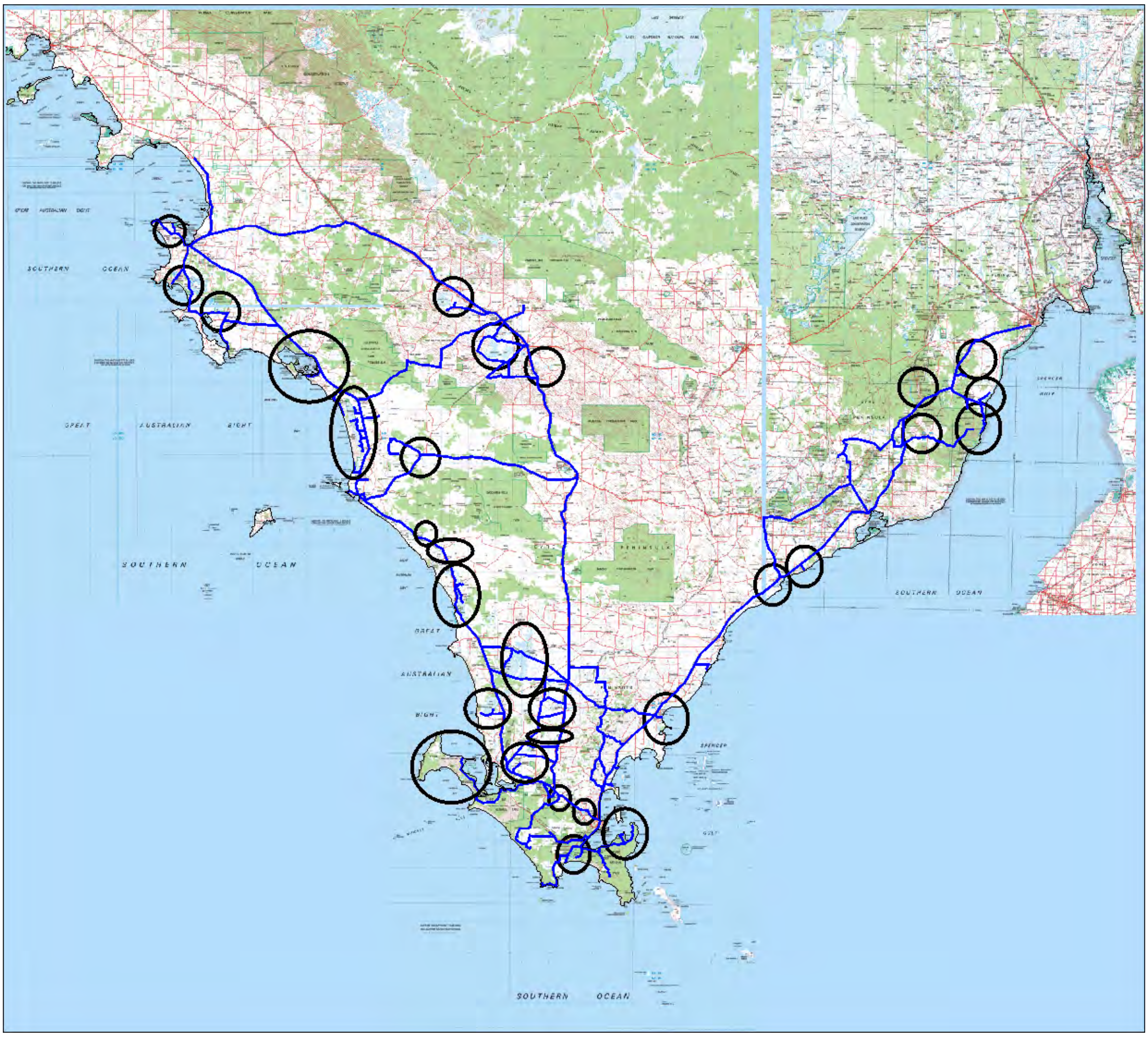


Figure 9: Locations where more focused study of wetlands was undertaken.

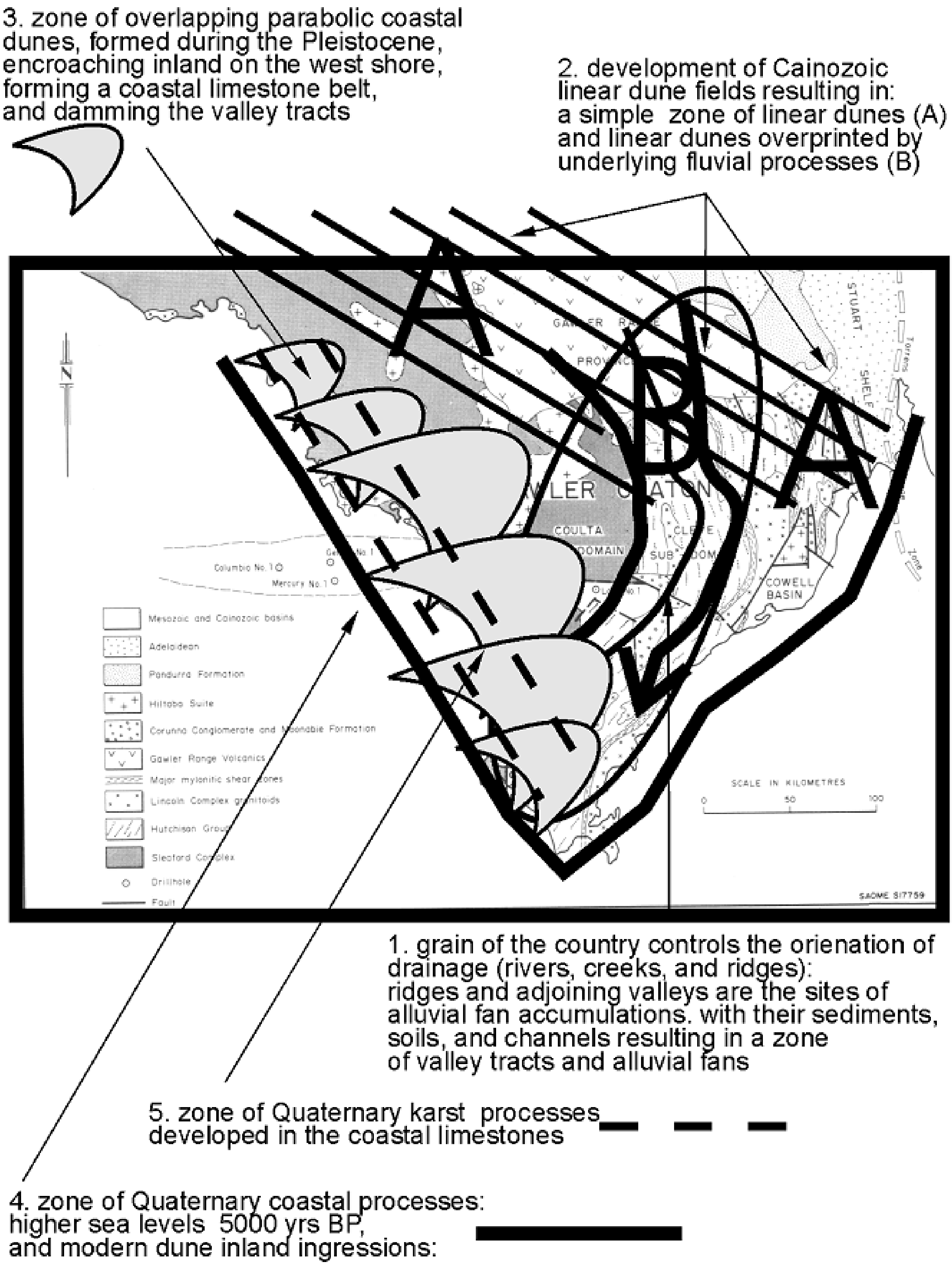


Figure 10: Delineation of some of the consanguineous wetland suites.

5.4 Field studies

Once a wetland was selected as representative for a consanguineous suite, a further series of procedures were undertaken:

1. the wetland basin, channel, or flat was topographically surveyed to an accuracy of 1 cm height, on a spacing of 1-10 metres, the latter depending on the slope or flatness of the land; the profile was surveyed in, to a temporary datum (*e.g.*, a prominent fence post that was marked) for later surveying in, to AHD;
2. the stratigraphy of the upland and wetland, *i.e.*, within and around the wetland, was determined from outcrop, or augering; with augering, sediment samples were collected every 10 cm; the auger holes penetrated the sedimentary sequences within the wetlands to depths of up to 6 m, or to the base of the wetland fill (whichever came first);
3. the stratigraphy determined whether one or more piezometers were installed across the profile, and whether multiple depth-determined piezometers (also termed "nested piezometers") were installed at the one site; complex stratigraphy had multiple piezometers ("nested piezometers") to test for different hydraulic heads in the possibly different aquifers in a wetland;
4. piezometers installation was undertaken during the dry season when the wetland could be negotiated by walking, and water tables were at their lowest seasonally; piezometers are PVC pipes, slotted in their lower 20 cm, capped at their end (but slotted to allow water to drain if levels fell below the base of the pipe); the lower 20 cm of the hole around the PVC pipe was filled with gravel to facilitate water movement into the pipe and this was covered with 50 cm of bentonite to seal the lower part of the pipe from water that potentially could infiltrate down the auger hole and confound the water level readings; the upper part of the hole was backfilled with material augered out of the hole, but in an order to replicate the original stratigraphy; the pipe was cut either to be 150 cm, 100 cm or 50 cm above the ground (depending on the predicted depth of water that may inundate the wetland), and capped at the top to eliminate rain; piezometers were then surveyed in, to the datum;
5. for some wetlands, 150cm or 200 cm staff gauges (marked in 1 cm intervals) were installed to monitor surface water levels;
6. water levels were measured in the piezometers once they had stabilized, and thereafter on a monthly basis;
7. water samples were collected from any surface water present, and from inside the piezometers by use of a sampling vial; water samples were collected on a monthly basis; these samples were frozen and stored for later analysis;
8. in an overview, using aerial photography and site visit, vegetation was characterised in the wetland according to one of the nine classification categories shown in Figure 3;
9. dominant species in the vegetation along the surveyed transect were noted, and collected; and species present around a piezometer also were documented with respect to presence/absence, and dominance;
10. routine archival and documentary photography of sites was undertaken.

5.5 Laboratory work
Samples taken back to the laboratory were processed in the following manner:

1. all sediment samples were examined under binocular dissecting microscope, and by petrographic microscope using sediment mounts, to determine sediment type and composition (see Semeniuk & C A Semeniuk 2004); carbonate grains were determined by petrographic microscope or by acid under binocular dissecting microscope; sediments were characterised as to gravel, sand or mud. and muddy sand, and as to composition (*viz*., quartz sand, gypsum sand, gypsum mud, kaolinite mud, carbonate mud;
2. selected sediments were analysed by XRD to determine their mud-sized mineralogy;
3. all water samples that were collected monthly were analysed using a conductivity meter to determine total dissolved solids (TDS);
4. the pH of all water samples were determined using a water proof pH meter (pHScan 2™);
5. selected water samples, representative of suites and settings, and of surrounding land uses were sent to a commercial laboratory for determination of Na, K, Ca, Mg, and potential contaminants such as Pb, As, Cr, P, and N;
6. plant species were sent to the WA Herbarium for identification, or to a botanist in the Eyre Peninsula region for determination;
7. sediments, water samples, and photographs were catalogued and archived.

5.6 Desk-top work
Desk-top work involved:

1. literature review, as outlined above;
2. aerial photographic interpretation;
3. data manipulation using Excel spreadsheets to produce water level graphs and salinity graphs;
4. reduction of topographic data into topographic profiles, and with the stratigraphic data, production of stratigraphic cross-sections.

6.0 Regional setting

The setting of Eyre Peninsula is described below as a framework for the consanguineous wetland suites. The regional setting of Eyre Peninsula is described in terms of:

6.1 Geological framework
6.2 Wetland regional climatic setting
6.3 Wetland geological and hydrological setting

The geology of Eyre Peninsula underpins the geomorphology, and the various landforms in the region are the result of weathering, erosion, and sedimentary accretion that have been, or still are operating. Both geology and geomorphology influence the hydrology in terms of surface water and groundwater dynamics, recharge type, transmissivity, and aquifer types. The interaction of geology, landscape, and hydrology develops the various wetland types.

Climate plays a major role in wetland development in that it influences water availability through precipitation, and water discharge through evaporation. Rainfall and evaporation influence the hydrochemical evolution of wetlands. Climate also plays a role in wetland development through agencies of wind and waves in coastal zones. Former climates played a role in the development of weathering profiles and weathered landscapes, and in the development of desert dune fields.

6.1 Geological framework
The geological framework is important to understand as it forms the template for landscape and hydrologic development and its diversity. Essentially, the geologic/ geomorphic setting of Eyre Peninsula underpins the wetland suites.

The Eyre Peninsula owes its striking geometry and geomorphology to the underlying geological features which make up its core structure (Fig. 11). Although sedimentary veneers have covered many older geological features, the understanding of the types of provinces and physiographic regions to which this report refers, and which form its framework, necessitate the reader being familiar with the underlying geologic setting, geological processes, and rock types.

In summary, the Eyre Peninsula is underlain by rocks of the central southern part of the Gawler Craton (Gravestock *et al*. 1995), and its oldest rocks (Archaean to early Proterozoic), which are in the western sector, are located in this Craton. The grain of the craton runs in a NW, N to NE direction, following a regional warp. This grain determines the orientation of the ranges in the region, similarly running NW, N and NE. The Archaean rocks of the Gawler Craton were overlaid in turn by Early to Middle Proterozoic iron bearing quartz feldspathic sediments, and intruded by post tectonic granitoids, and then, during the Cainozoic, blanketed firstly, by alluvial deposits and then by aeolian dune sands (Parker *et al*. 1985).

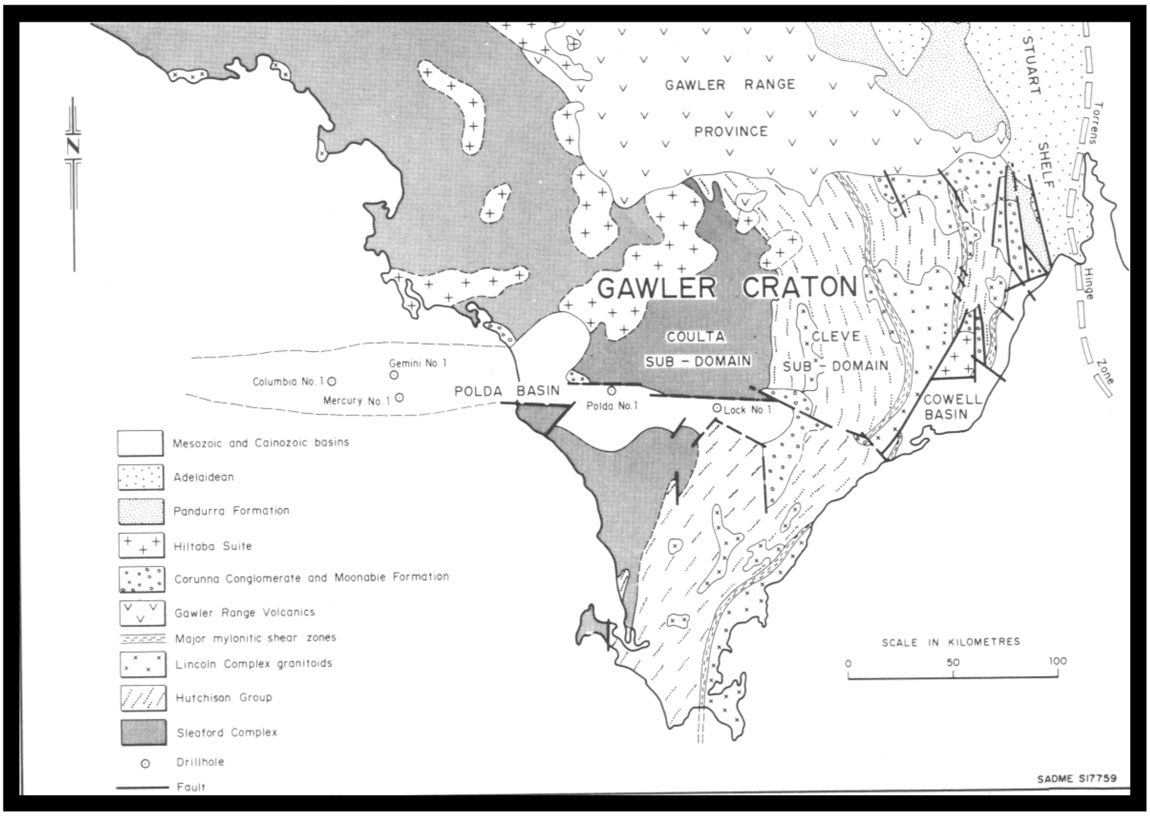


Figure 11: Regional Geology of South Australia (after Parker *et al*. 1985)

Today, the Archaean to early Proterozoic rocks largely are covered in regolith, and best exposed mainly around the southern and southwestern coastlines. Deformed gneisses, schists, quartzite, and intrusive granitoids crop out as hills (Middleback Range, Lincoln Hills), on Coffin Bay Peninsula, in the Cowell-Cleve region, and south and west of Lake Hamilton. A widespread episode of post tectonic magmatism has resulted in scattered batholiths, and through weathering/erosion today are represented by discrete granite inselbergs on an eroded plain (Mt. Wudinna). Tertiary sediments, representing a variety of lithologies, including fluviatile, lacustrine, and marginal marine sediments, are widely distributed over Eyre Peninsula in basins and shallow channels in the irregularly eroded palaeosurface over the Precambrian rocks, *e.g.*, Uley Basin, Wanilla Basin, Cummins Basin and Cowell Basin (Parker *et al*. 1985). On central and western Eyre Peninsula, thin veneers of Quaternary sediments mask deposits from earlier sedimentary episodes as well as the Precambrian rocks. Cliffs of Pleistocene limestone (calcretised and cemented calcareous sand) occur along the southern and western coasts and Pleistocene/Holocene clayey sands underlie inland longitudinal dunes and sand sheets.

Firman (2006) provides the most recent descriptions and review of the Cainozoic history of weathering and products of the South Australian region, including Eyre Peninsula dealing with the ancient weathering zones, mottled zones, pedocretes and palaeosols on the Australian Precambrian Shield and in adjoining sedimentary basins. Much of this information is relevant to the Eyre Peninsula. The weathered zones, pedocretes, mottled zones and palaeosol units are described by Firman (2006) in a chronological framework from Palaeozoic to Late Quaternary. The weathering products of the Palaeozoic include the Playfair Weathering Zone. The Mesozoic weathering sequences include development of pallid zones, laterite profiles, bauxite profiles, and silcrete profiles. Early and Middle Cainozoic weathering sequences encompass bauxite, ferricrete and silcrete. Cainozoic sequences contain pisolitic deposits, siliceous pans and mottled zones, and Pleistocene-Recent sediments and soils of the Quaternary surface. The weathered zones, pedocretes and palaeosols were formed under different climatic regimes.

Physiographic Regions

The underlying lithologies and geological structures in Eyre Peninsula give rise to geomorphic features, which in this report are used to define physiographic regions. Seven physiographic regions have been identified in this study, which correspond with regions 2-8 of Twidale & Campbell (1985).

1. Hills/Uplands: The main occurrence of the Middle Proterozoic post tectonic granitoids and early Phanerozoic iron bearing quartz feldspathic sediments, is on the eastern part of Eyre Peninsula where they express as the Lincoln Uplands and Cleve Hills, with a second smaller expression at Marble Range and North and South Blocks in the west. The orientation of these two series of ranges is northeast to southwest.
2. Valley tracts: Between these uplands is the eroded palaeosurface of a depression or valley underlain by Tertiary sediments. Overlying the Archaean to early Proterozoic rocks and Tertiary sediments elsewhere on the Peninsula are Quaternary sediments.
3. Alluvial fans: On either side of the ranges at the base are large alluvial fans extending eastward to the coast and smaller ones spreading inland to the west forming undulating plains and composed of colluvial gravelly, clayey sand.
4. Coastal dunes and limestone terrain: Along the southern and western parts of Eyre Peninsula, wholly to partially cemented calcareous sand underlies extensive parabolic dunes, cliffs, and plains extending for kilometres inland.
5. Linear sand dunes and sand plain: In the central part of Eyre Peninsula, a belt of linear sand ridge covered plains extends from the northwest to the coast composed of siliceous and gypseous sand and clay.
6. Linear sand dunes and assorted terrains: Some of these sand ridges overlie bedrock, Pleistocene limestone (cemented calcareous sand) and alluvium.
7. Coastal plains: At the seaward margins coastal plains have developed composed of materials from marine, hinterland and fluvial sources.

6.2 Wetland regional climatic setting
Climate is described herein only in so far as it effects wetland development, either through annual precipitation, evaporation, or wind. With respect to wetlands, rainfall is of paramount importance. On Eyre Peninsula the rainfall patterns are relatively simple in that the high rainfall areas are to the SW of the Peninsula, and progressively decrease to the NE, with a broad parallelism in isohyets. Annual rainfall is moderate, 550-250 mm (Fig. 12), predominantly occurs in winter as a result of low pressure systems from the west, and diminishes steadily and almost evenly in volume from southwest to northeast. The gradient in rainfall shown in Figure 12 means that wetlands in the southern areas and western areas of the Eyre Peninsula are subject to more rain than those in the more arid NE parts of the area. Also, with increasing aridity to east and north, wetland sediments progressively change from carbonate dominated to gypsum dominated.

Evapo-transpiration is related to temperatures and wind. Continental sites during summer exhibit a mean monthly temperature 8 degrees in excess of coastal sites, and in spring the corresponding difference is 6 degrees (Schwerdtfeger 1985). However, the effects of temperature on evapo-transpiration are subjugated by the effect of wind deriving from several wind systems which dominate the Eyre Peninsula. The primary wind system derives from the seasonal migration of the tropical high pressure belt which moves from the Great Australian Bight to the Tasman Sea in summer and then moves northward to sit over the Australian continent in winter. The winds, in consequence, then derive from the south in summer and the north in winter. The seabreeze/landbreeze system, deriving from the south west on the west coast and southeast on the east coast, enhances the effects of the high pressure system during the summer, and in the central Eyre Peninsula often the two seabreeze systems intersect. In addition, topographic features tend to funnel winds in some areas, *e.g.*, Driver River valley and Cleve Hills. In combination, the patterns of wind over the Eyre Peninsula ensure that evapo-transpiration effects are widespread, persistent and not confined to seasons.

6.3 Wetland geological and hydrological setting
Shepherd (1985), in summarising the early work of the Geology Survey of South Australia, noted that surface water is the most common source of water for recharging wetlands on Eyre Peninsula. He pinpointed the importance of groundwater in the Precambrian, Tertiary and Quaternary geological formations, *i.e.*, gneissic and other metamorphic rock outcrops from Cowell to Ceduna; sands, silts and clays north of Coffin Bay and in the Lincoln, Uley South and Polda Basins; alluvium and the partially cemented calcreted calcareous sand of the Bridgewater Fm. Some 20 wetland suites have been identified in this study, and their geological and hydrological setting, underpinned by fieldwork and literature review is briefly described here.

Wetlands situated in the ranges, *i.e.*, the Lincoln Uplands and Cleve Hills, and Marble Range and North and South Blocks in the west, are those associated with dissected topography and underlying metamorphic rocks. The metamorphic rocks commonly are hard and resistant to weathering, and also relatively resistant to water infiltration. Given these conditions, the main hydrological process is runoff and wetland types are channels and associated narrow seasonally inundated or waterlogged flats. The annual rainfall for the Lincoln Hills and Marble Range ranges from 450-550 mm and for the Cleve Hills is 350 mm, which is moderate to low (Schwerdtfeger 1985). This south to north gradient in rainfall is mirrored by a change in wetland form from incised channels with minimal development of riparian zones to shallow channels with well developed adjacent waterlogged flats. The geometry of the steep banked and deeper channels results from rapid seasonal runoff with concomitant sharp rises in channel discharge volume. The lower gradients in channel form further north are due to lower annual volumes of water and to a more balanced inflow of surface and groundwaters.

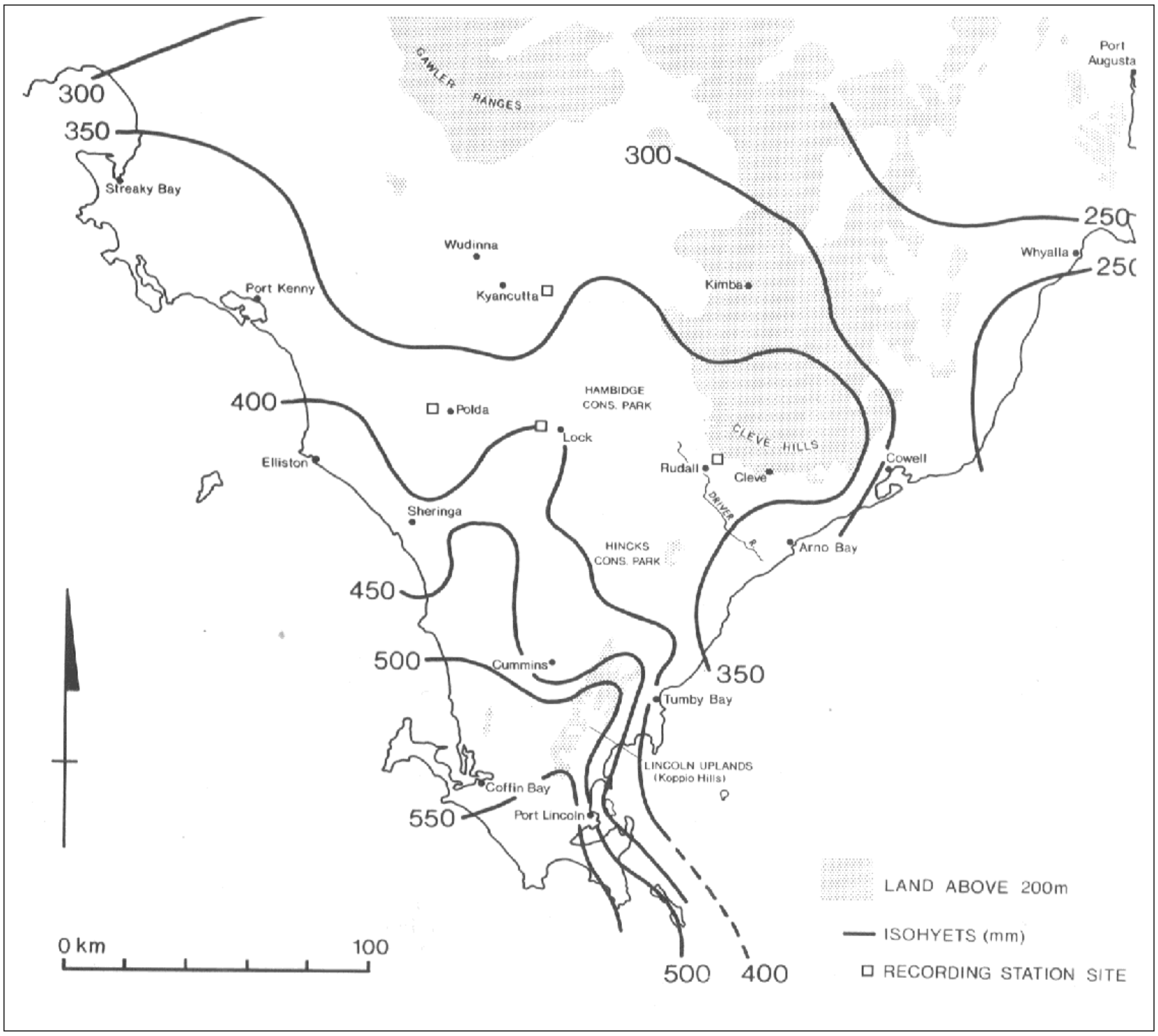


Figure 12: Regional climate of study area (after Schwerdtfeger 1985)
Rainfall isohyets are in mm.

From south to north, with decreasing rainfall and increasing evaporation, there is a gradient in the salinity of the groundwater. In the southern Lincoln Hills, it ranges just a little above freshwater (< 1000 mg/L) to hyposaline (3000-7000 mg/L), in response to the seasonal recharge of the groundwater by the winter rain; in the northern hills, annual rainfall decreases and groundwater becomes consistently hyposaline (7000-12000 mg/L) (Shepherd 1985). In areas underlain by the gneisses and other metamorphic rocks of Marble Range and North and South Block, the salinity is hyposaline (7000-12000 mg/L).

Wetlands in the valley tracts between these ranges, described above, are those associated with broad valley floors and alluvial and colluvial sedimentary fill (orange-brown quartz sand, sandy clay, clay, rare gravel and laterite nodules, all lithologies that are relatively more permeable than bedrock). The annual rainfall for this area lies between 500-550 mm, with a significant proportion occurring in the winter months (Schwerdtfeger 1985). The main hydrological processes are direct recharge from precipitation, perching of surface water above hardpans, groundwater rise, subsurface flow to low points in the landscape, and subsurface mounding along the contact zone with any limestone aquifer. In this setting, wetlands occur on flats and in depressions, where either perching of rainwater or rising groundwater inundate the land surface, and in small narrow channels that intermittently transport water to low lying areas of the valley. Wetlands tend to be seasonal, and include basins and influent seasonal channels with adjacent inundated or waterlogged flats. The salinity in the groundwater in this area is determined by the properties of the aquifers and particularly the occurrence of the limestone aquifer. In the valley tract groundwater concentrations are subhaline to hyposaline (3000-7000 mg/L). Along the southern contact between the valley's alluvial sediments and the limestone, there are two regions of fresh to subhaline water (0-1500 mg/L), the Lincoln Basin and the Uley Wanilla Basin (Shepherd 1985).

On the east side of the Minbrie and Middleback Ranges, from Franklin Bay to Whyalla, the coast comprises large alluvial fans forming undulating plains composed of colluvial gravelly, sandy clay, cemented by calcrete and gypcrete. This coastal zone is an area of groundwater discharge. Although the annual rainfall is low (250 mm), the main hydrological processes are direct precipitation, groundwater flow and evapo-transpiration. Wetlands occur on the coastal flats and interdune depressions as very shallow basins.

On the Western side of the Lincoln Hills, (*e.g.*, Wanilla), there are small alluvial fans bordering the valley tracts. Many short small scale channels flow from the rocky hills to the relatively flat valley tract, constructing sedimentary fan-shaped deposits along the line of the break in slope. On these hill slopes, and mounded alluvial deposits which gradually depress to an undulating plain, the main hydrological processes include direct seasonal precipitation, runoff, and groundwater flow. As a consequence, landforms host to wetlands are channels and flats. The annual rainfall ranges from 450-550 mm (Schwerdtfeger 1985). Under the alluvial fans of the Wanilla region groundwater concentrations are subhaline to hyposaline (3000-7000 mg/L) (Shepherd 1985).

From Cape Carnot to Ceduna along the western parts of Eyre Peninsula, there are extensive fields of Quaternary coastal parabolic dunes and broad plains. Some of the dunes are unconsolidated and migrating (and these are mostly Holocene), but a large proportion of the dunes and plains are Pleistocene and are now cemented to form limestone. This limestone consists of either comminuted shell fragments in a fine grained carbonate cement, sparry calcite cemented marine shell beds, or Holocene orange-fawn clayey sand and white sand. Annual rainfall ranges from 300-550 mm, much of which is captured within this limestone aquifer. Where limestone is overprinted by calcrete (in breccia to nodular to massive and laminated forms), it is generally impervious to water infiltration and subsurface flow. The hydrological processes are controlled by the nature of the aquifers, *i.e.*, whether they be calcareous sands or limestone and to what degree they are calcretised. In the sand aquifers, groundwater flows freely and may rise and fall seasonally. In the limestone aquifers, groundwater flows less freely and its flow appears to be through cavities.

Depending on the thickness and extent of the calcrete in the limestone, there may be some areas where groundwater is confined. Groundwater, however, can also create new cavities, and in this area active karstification and small scale dissolution are evident. Hydrological processes in this region pertain to both terrestrial and marine influences. Terrestrially based processes such as direct precipitation, surface water perching, seepage, cavern groundwater flow, semi-controlled subsurface flow (springs), and groundwater rise and fall, all occur here. So too, do marine processes such as tidal fluctuations and inundation by marine waters via subterranean conduits and vents. The wetland types are varied in this physiographic region but are most commonly basins and flats owing their origin to a combination of marine, aeolian and terrestrial processes. Salinity of the groundwater in this area is generally just slightly saltier than freshwater being subhaline (1500-3000 mg/L) (Shepherd 1985). The two exceptions are the groundwater inland from Elliston, which is fresh to subhaline (0-1500 mg/L), and the region around Streaky Bay which is hyposaline (3000-7000 mg/L).

Between the coastal dune belt and the Gawler Ranges, a zone of linear sand ridges, composed of quartz sand, and forming a plain, extends from the Great Victoria Desert to the east coast of Eyre Peninsula. Wetlands therein are underlain by quartz and gypseous sand, and clay. Unconsolidated and cemented layers are distributed throughout the dunes, the cementing agents in this area being silica, gypsum and calcrete. Here too, as in the western coastal dunes, the hydrological processes are controlled by the nature of the aquifers, *i.e.*, whether they be porous sands or gypsite and to what degree they are cemented. In the sand aquifers water is unconfined and groundwater flows freely and may rise and fall seasonally. However the land surface is often a mix of gypseous mud and sand, and is not as porous as quartz or lime sand. The main hydrological processes are direct precipitation, perching of surface water, evapo-transpiration and small scale groundwater rise and fall. The annual rainfall is between 300 and 350 mm but constant winds keep evapo-transpiration high, and consequently the groundwater salinity is hypersaline (47,000-270,000 mg/L). The resultant wetland types are basins which are seasonally or intermittently inundated.

Some of these sand ridges overlie bedrock, as well as Pleistocene limestone, and alluvium. For wetlands in these settings the hydrological processes are restricted to direct precipitation, brief perching of surface water, and evapo-transpiration. Wetlands are shallow basins and flats.

At the seaward margins of the sand plain described above, coastal tidally prograded plains and estuarine plains have developed and some have been partitioned into basins underlain by carbonate and gypsum mud, and terrigenous sand and mud. These peripheral flats and basins are formed and maintained by marine processes. Since they are maintained by marine processes, they are outside the scope of this study.

A summary of the history of the terrain of the Eyre Peninsula leading to the development of consanguineous wetland suites and the processes and products used to identify the suites are shown in Figure 13.

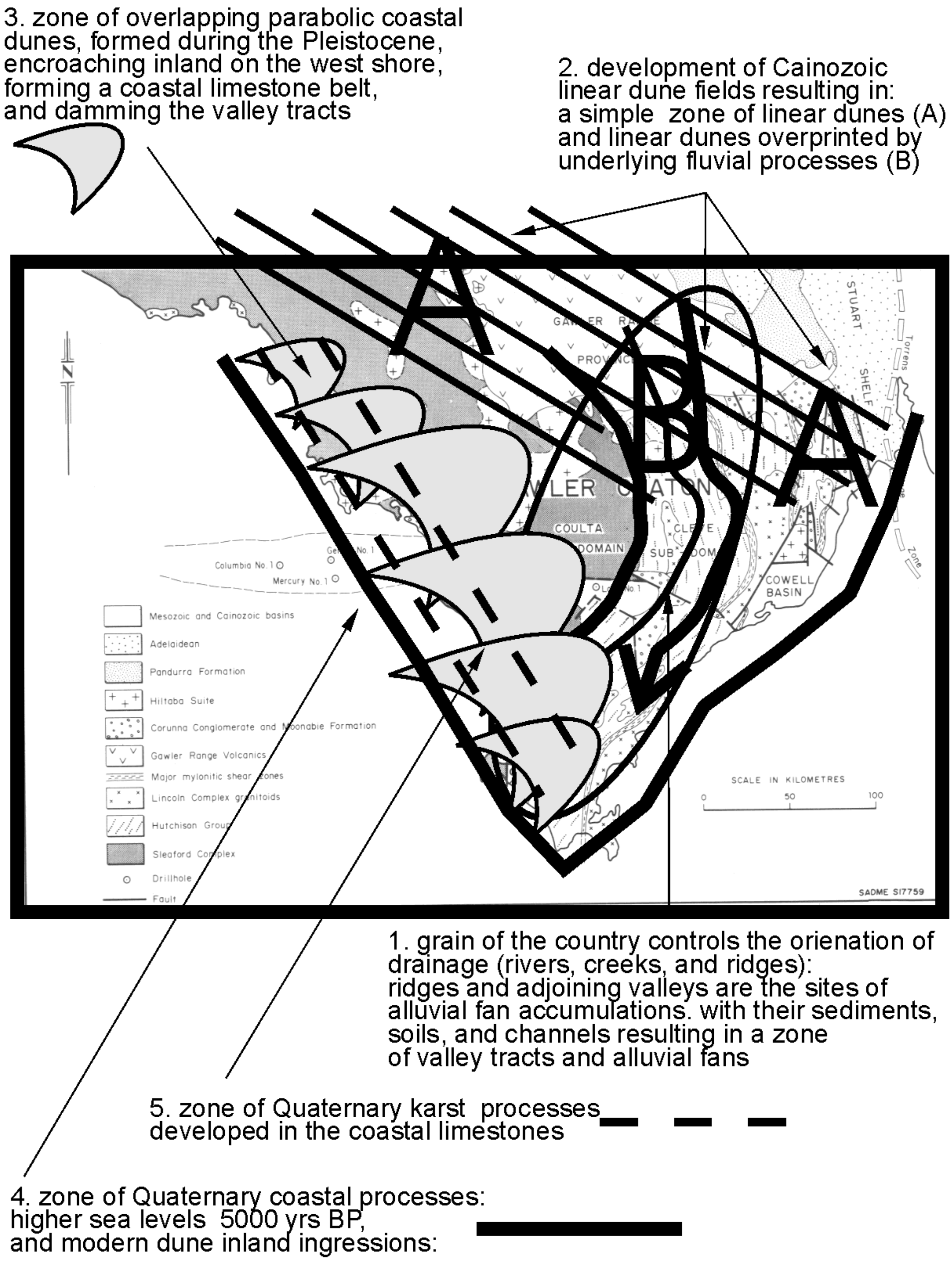


Figure 13: The geological and physiographic systems underpinning the diversity of wetlands on Eyre Peninsula. Long term processes and products that help explain the template for development of the various consanguineous wetland suites – ordered geochronologically.

7.0 Descriptions of wetland types

The approach used by VCSRG in describing wetlands is scalar, and involves starting at the regional scale, working down to the next scale involving consanguineous suites, and ending at the site-specific scale of individual wetlands. In this manner, individual wetlands (site-specific wetlands) can be viewed in context of their consanguineous setting, and the consanguineous suites can be viewed in the context of their regional geological, geomorphic, hydrological and climatic setting.

7.1 Wetland regions

Seven wetland regions have been identified which correspond with the major geomorphic/geologic units in the divisions and/or the contacts between them of Twidale & Campbell (1985), Parker *et al*. (1985), Drexel *et al*. (1995), and Drexel & Priess (1995). They are described below using a modified geologic/geomorphic framework:

1. Lateritic hills underlain by the Archaean to Early Proterozoic complex of gneisses, schists, iron bearing quartzites, and intrusive granitoids, and dissected by freshwater channels
2. Isolated rounded inselbergs and monadnocks of Early to Middle Proterozoic granite with gnammas and rillen
3. Undulating plain underlain by Tertiary alluvial sediments, with chains of large circular basins
4. Alluvial fans underlain by Quaternary alluvial sediments and traversed by channels
5. Linear dune fields, and interdune wetland basins underlain by Quaternary desert clayey sands
6. Coastal Pleistocene (former) parabolic dunes and low undulating plains underlain by Quaternary coastal limestone and calcretised calcareous sand, incorporating karst landscapes and coastal lagoons
7. Coastal Holocene dune barriers underlain by Quaternary coastal unconsolidated calcareous sand with internal deflation and blowout areas

The reader should refer to Figures 13 & 14 while reading the text below.

Table 4, below, is divided into ten sections of which seven correspond to one of the wetland regions listed above and three pertain to contact zones between two or more of these regions, *e.g.*, contact between Archaean to Early Proterozoic bedrock and coastal limestone. Within each section there are given locations where this wetland region occurs, a brief summary of the geology, geomorphic characteristics, and types of wetlands which occur in the region and some examples.

Table 4 Characteristics of wetland regions in terms of geology, geomorphology and wetland types (* denotes those locations that have been selected for baseline monitoring)

Location	Geology	Geomorphology	Wetland types therein	Examples of wetland therein
Archaean to Early Proterozoic bedrock				
Lincoln Uplands Cleve Hills Marble Range North Block South Block Mt Dutton Mt Wedge Barna Hill see p65 for others Miltalie	gneiss, quartzite, schist	low relief dissected lateritic hills with a fault scarp on the east	creeks seasonally flooded plains seasonally waterlogged plains	*Tod River *Yallanda Flat White Flat Koppio *Salt River
Contact between Archaean to Early Proterozoic bedrock and Pleistocene coastal limestone				
Lincoln National Park	contact between metamorphic rocks of Gawler Craton (capped by ferricrete) and coastal limestone	low relief dissected lateritic ridge and limestone swales	lake	*Sleaford Mere
Inselbergs of Early to Middle Proterozoic granite				
Wudinna-Minnipa Koongawa-Waddikee Rocks-Middle Rock	outcrops of granitic rock	isolated rounded hills or inselbergs	seasonally inundated or waterlogged basins (gnammas)	Mt. Wudinna Yarwondutta Rock Uncontitchie Hill *Pildappa Hill Minnipa
Tertiary alluvial sediments				
Cummins	orange-brown quartz sand, sandy clay, clay, rare gravel and laterite nodules red-brown sand and clay soil veneers over calcrete	undulating plain meandering line of circular basins separated by dunes	seasonally inundated basins intermittently inundated basins	Pillana Lagoon Lake Baird *Lake Malata
Contact between Tertiary alluvial sediments and coastal limestone				
Port Lincoln to Wangary	contact between reddy brown sandy clay and limestone	undulating plain	permanently inundated basins seasonally inundated basins creeks	*Lake Greenly *Little Swamp Big Swamp Lake Wangary *Duck Lake
Quaternary alluvial sediments				
Wanilla to Cockaleechie	orange-brown quartz sand, sandy clay, clay, rare gravel and calcrete nodules	alluvial fans	creeks seasonally flooded plains seasonally waterlogged plains	*Wanilla *Merintha Creek
Franklin Harbour to Whyalla	red-brown sand and clay soil veneers over calcrete			*Munyarro Conservation Reserve wetlands

Location	Geology	Geomorphology	Wetland types therein	Examples of wetland therein
Quaternary desert clayey sands				
Tuckey Dune Field	quartz sand or quartz sand overlying massive calcrete or limestone, granite, or alluvium	sand ridge plains with NW to SE trending longitudinal dunes	seasonally inundated basins intermittently inundated basins	Agars lake Kappakoola Swamp *Samphire Flat *Pinthaput Lake Yaninee Lake Warramboo
Quaternary coastal calcretised calcareous sand and limestone				
Coffin Bay Lincoln National Park Peninsula National Park Uley basin Greenacres Coonara Sheringa Bellevue Kilroy	white to cream fine to medium carbonate sand (calcarenite) with calcrete throughout or limestone	coastal parabolic dunes and low undulating plain	lagoons seasonally inundated basins intermittently inundated basins seasonally waterlogged flats intermittently inundated flats	Coffin Bay wetlands *Pillie Lake *Calpatanna wetlands Seagull Lake *Lake Hamilton, Round Lake *Elliston wetlands (Cemetery) Lake Tungketta, Middle Lake and South Lake Bellevue wetlands Poelpena Swamp
Contact between Holocene/Pleistocene coastal unconsolidated dunes and the Pleistocene limestone				
Elliston	white to cream fine to medium carbonate sand and calcarenite or limestone	contact between coastal barrier of modern unconsolidated dunes and the Pleistocene low undulating plain	seasonally inundated basins	*Lake Newland Sheringa Lagoon Yanerbie “birridas”
Holocene/Pleistocene coastal unconsolidated dunes				
Coffin Bay Anxious Bay Spalding Cove	white to cream fine to medium quartz and shelly sand	coastal barrier of modern unconsolidated dunes	intermittently inundated flats	Lake Jessie Newland Barrier Stamford Hill

A summary diagram showing the relationship of the consanguineous wetland suites to the terrain of the Eyre Peninsula (outlined earlier in Figure 13), and typical examples of suites in the geological/physiographic setting is shown in Figure 14.

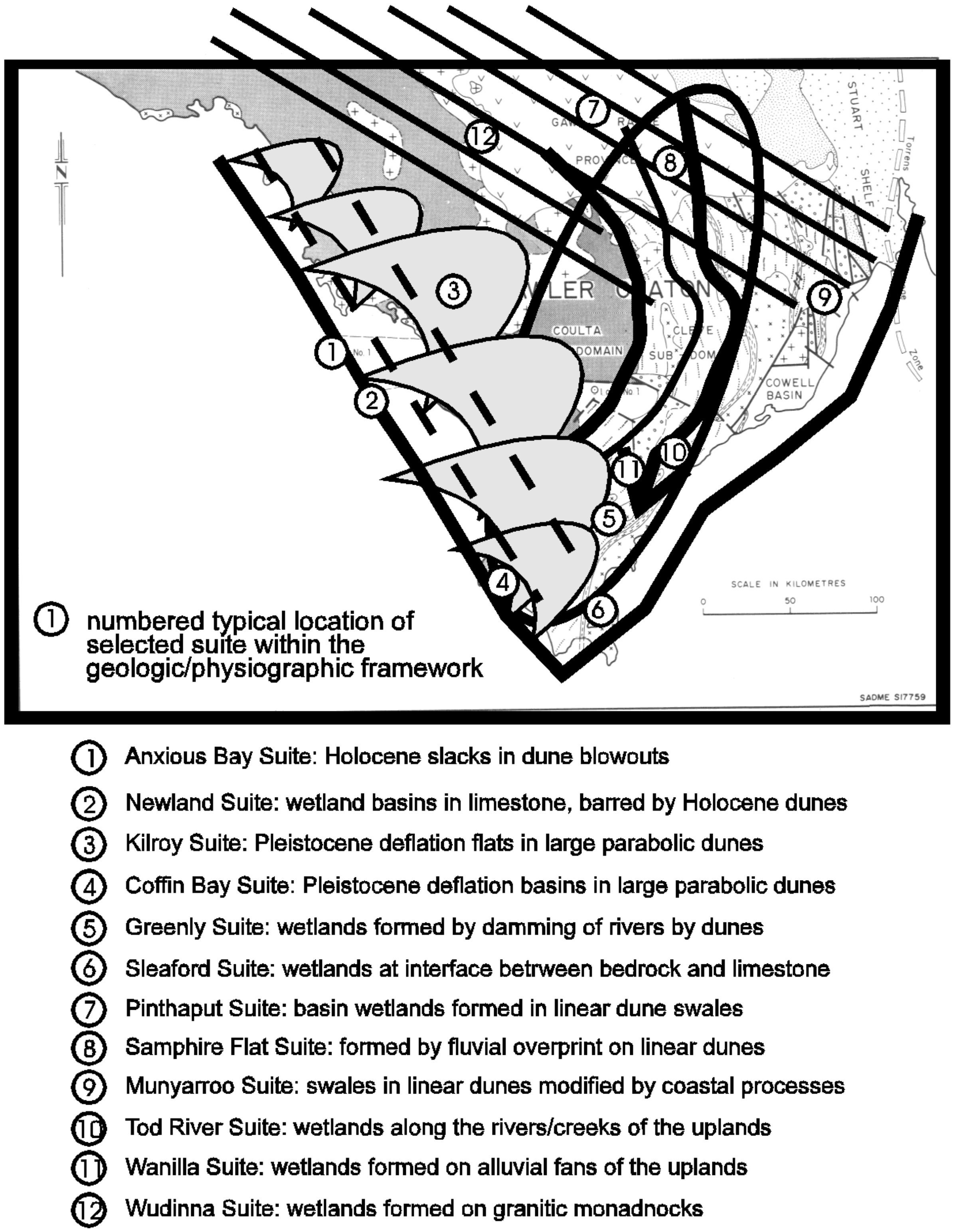


Figure 14: Idealised diagram showing the typical distribution of consanguineous wetland suites and the patterns underpinning the suites within the framework of geology and physiography – not all suites are shown.

As can be seen in Table 4, a wetland region may occur in several geographic localities and therefore it follows that the same wetland suite may be widely distributed geographically, *e.g.*, creeks in the various hilly uplands, Lincoln Uplands, Cleve Hills, Marble Range, North Block, South Block, Mt Dutton, and Mt Wedge. However, a consanguineous suite requires that the water regime, hydrochemistry, and sediment fills in the wetlands be similar and this necessitates that the climatic zone and influencing climatic parameters remain the same. When this is not the case, more than one consanguineous wetland suite in each geologic/geomorphic wetland region may result, *e.g.*, there are 4 in the Quaternary coastal calcretised calcareous sand and limestone wetland region.

7.2 Consanguineous wetland suites of Eyre Peninsula

Twenty wetland suites have been identified in the different wetland regions with various hydrological, hydrochemical, sedimentary and biological attributes. The consanguineous wetland suites are named and described in Table 5 using the geologic/geomorphic wetland regions as the framework. Each description has the following components:

- Consanguineous suite name
- Setting
- Wetland type
- Geometry
- Wetland hydrology
- Stratigraphy
- Descriptions of vegetation communities
- Example wetlands

Each consanguineous suite was determined using the criteria described in Section 4.2, and named after either the wetland which typifies the suite or a geographic location where it occurs. The wetland types were classified according to C A Semeniuk & Semeniuk (1995) as described in Section 3.2.

In terms of site-specific wetlands, the most common wetland types on the Eyre Peninsula, under a regime of seasonal rainfall, are:

1. seasonally inundated basins - sumplands,
2. seasonally waterlogged flats - palusplains, and
3. seasonally inundated channels - creeks.

Lakes are less common. Rivers (permanently inundated channels) are strictly not present. To the north, in drier conditions, playas are possible, but none were encountered in our study.

Wetlands are described below using a combination of scale and established geomorphic terms for plan geometry (round, elongate, linear, anastomosing, sinusoidal). Wetland hydrology is described variably, in terms of recharge and discharge mechanisms, hydroperiod, water levels, and water quality. The hydrology of the wetlands is based only on the period of the study 2005-2006, which is not long enough to determine the full expression of the wetland hydrologically. At least 5 years of monitoring is preferable.

Stratigraphy includes description of sedimentary fill, and where known, basement materials. The basement is the material which underlies the wetland fill and is often similar to the sediments surrounding the wetland. Sedimentary fill generally includes muds, sandy muds and muddy sands. In some cases it includes sands also, *e.g.*, where shell grit has formed a layer, or where sand-sized gypsum crystals have precipitated, or where gypsum crystals have been re-worked and disintegrated into sand-sized grains, or where sheet wash or wind have deposited a layer of quartz sand between the layers of wetland mud. Vegetation communities are described in terms of cover according to Section 3.3, in terms of communities named after dominant species, and finally along transect.

Table 5 Description of wetland suites located within each geologic/geomorphic terrain

* wetlands in which there are staff gauges or piezometers for on-going measurements of water levels, water salinity, stratigraphy, and plant abundance and composition

Consanguineous Suite	Setting geologic/geomorphic terrain	Wetland types therein	Geometry of wetlands	Hydrology	Sediments	Vegetation communities	Examples of wetlands within suite
Koppio	low relief, dissected, lateritic hills and valleys, underlain by bedrock (gneiss, quartzite, and schist)	creeks seasonally flooded plains seasonally waterlogged plains	small scale dendritic channels with narrow well defined adjacent flats; includes point bars, undercut cliffs, and shallow depressions in the floodplain where the channel meanders	recharged by direct precipitation and run-off Freshwater	shale with interbedded sandstone, dolomite and oolitic limestone → terrestrial clay, quartz sand, quartz gravel	sedge: *Baumea juncea* rush: *Juncus kraussii* samphire: *Sarcocornia quinqueflora* open wood: *Eucalyptus camaldulensis*	Tod River *Yallanda Flat White Flat *Koppio
Miltalie	low relief, dissected, lateritic hills and valleys, underlain by gneiss, quartzite, and schist	creeks seasonally flooded plains seasonally waterlogged plains	structurally controlled microscale shallow channels with broad adjacent flats	recharged by direct precipitation and run-off Saline	gneiss → terrestrial clay, quartz sand	rush: *Juncus kraussii* samphire: *Halosarcia pergranulata, H. halocnemoides, Maireana erioclada, Sarcocornia quinqueflora* open shrub: *Melaleuca halmaturorum*	Little Salt Creek *Salt Creek Watchanie Cr. Mernittie Cr Pokalalie Cr
Sleaford	along the contact between the low dissected ridge of lateritised schist, iron & amphibolite metamorphic rocks of the Gawler Craton, capped by limestone, and the adjacent swale underlain by limestone	lake (permanently inundated basin)	megascale, elongate, irregular, shallow basin with relatively straight western shore and indented and protruding eastern shore	recharged by direct precipitation, seepage from western ridge and groundwater Saline	shelly clay and calcareous sand	samphire: *Hemichroa pentandra* closed heath: *Melaleuca halmaturorum, M. brevifolia, M. lanceolata* sedge: *Gahnia trifida*	*Sleaford Mere

Table 5 continued

Consanguineous Suite	Setting geologic/geomorphic terrain	Wetland types therein	Geometry of wetlands	Hydrology	Sediments	Vegetation communities	Examples of wetlands within suite
Wudinna	isolated rounded granitic hills and inselbergs with gnammas and rillen	seasonally inundated or waterlogged basins (gnammas) and channels (rillen)	small scale shallow ovoid basins and U-shaped or V-shaped channels	recharged by rainfall and surface runoff Freshwater		herbs: shrubs: *Melaleuca armillaris*	*Mt Wudinna Yarwondutta Rocks Minnipa Uncontitchie Hill Pildappa Hill
Malata	undulating alluvial plain of valley tract; line of circular basins separated by ridges and lunettes, and underlain by red brown alluvial sandy clay	seasonally inundated basins	megascale to microscale rounded and oblong basins	recharged by rain and groundwater rise Saline	carbonate mud	shrubs: *Melaleuca halmaturorum* samphire: *Halosarcia halocnemoides, H. syncarpa, H. indicans bidens, H. pergranulata, H. flabelliformis Sarcocornia quinqueflora*	*Lake Malata Pillana Lagoon Lake Baird
Greenly	contact between undulating alluvial plain of valley tract, underlain by red brown sandy clay and parabolic dunes, hollows and flats underlain by limestone	permanently and seasonally inundated basins, seasonal creeks and seasonally inundated poorly defined channels	mesoscale sub-rounded basins, small scale shallow creeks, and uncontained drainage lines	recharged by direct rainfall, groundwater rise and influent channel flow Freshwater	peat; terrestrial and carbonate clay	aquatic algae: *Chara* spp. grass: *Sporobolus virginicus* samphire: *Frankenia pauciflora, Halosarcia lepidosperma, H. pergranulata, Sarcocornia quinqueflora* sedge: *Gahnia trifida* shrub: *Melaleuca brevifolia, M. halmaturorum*	*Lake Greenly *Little Swamp Big Swamp Lake Wangary *Duck Lake

Table 5 continued

Consanguineous Suite	**Setting geologic/geomorphic terrain**	**Wetland types therein**	**Geometry of wetlands**	**Hydrology**	**Sediments**	**Vegetation communities**	**Examples of wetlands within suite**
Wanilla	small scale alluvial fans underlain by orange-brown quartz sand, sandy clay, silt, gravel and calcrete nodules	seasonally inundated and waterlogged flats and creeks	microscale meandering shallow channels and narrow flats	recharged by direct rainfall, sheet run-off, and creeks Freshwater	clay, quartz sand, muddy sand, gravelly mud and gravel	shrub: *Melaleuca brevifolia* sedge: *Carex* sp. grass: *Sporobolus virginicus*	*Wanilla *Merintha Creek
Murninnie	large scale merging alluvial and tidal flats underlain by clay soil veneer on red-brown sand over calcrete	seasonally waterlogged and intermittently inundated flat, tidal creeks at coastal margin	megascale flat with cheniers	initially created by marine tidal conditions and later when sealed off from marine processes maintained by groundwater rise	red sands	samphire: *Halosarcia halocnemoides, H. pergranulata, H. pruinosa, Schlerostegia arbuscular, Maireana oppositifolia, Atriplex vesicaria* Low shrub: *Maireana sedifolia*	Moonabie Flat
Pinthaput	sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand or quartz sand overlying alluvium	seasonally inundated basins and intermittently inundated basins	mesoscale to microscale irregular basins	recharged by direct rainfall which is perched on the surface Saline	mud composed of gypsum and terrestrial clay sand composed of quartz, gypsum, and intraclasts of carbonate mud	samphire: *Halosarcia halocnemoides, H. pruinosa, Dysphyma crassifolium, Maireana erioclada* open shrub: *Melaleuca uncinata, M. halmaturorum* low open woodland: *Eucalyptus incrassata*	*Pinthaput

Table 5 continued

Consanguineous Suite	Setting geologic/geomorphic terrain	Wetland types therein	Geometry of wetlands	Hydrology	Sediments	Vegetation communities	Examples of wetlands within suite
Samphire Flat	sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand overlying massive calcrete, limestone, granite, or alluvium	seasonally inundated basins and intermittently inundated basins	megascale to mesoscale irregular basins	recharged by direct rainfall which is perched on the surface Saline	mud composed of gypsum and terrestrial clay sand composed of quartz, gypsum, and intraclasts of carbonate mud	samphire: *Halosarcia halocnemoides, H. pruinosa*, *Dysphyma crassifolium*, *Maireana* spp.	*Samphire Flat Lake Wannamana Lake Yaninee Lake Warramboo
Munyaroo	coastal expression of the sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand or quartz sand overlying massive calcrete, limestone, granite, or alluvium	seasonally waterlogged and inundated basins	microscale linear to ovoid basins	recharged by groundwater rise	red mud and muddy sand laminated calcarenite over wetland sand and calcilutite over red iron stained and crusted sand	samphire: *Carpobrotus rossii*, *Enchyleana tomentosa*, *Maireana oppositfolia*, *Dysphyma crassifolium*, *Frankenia pauciflora*	Munyarroo Conservation Park wetlands
Coffin Bay	bowls of parabolic dunes underlain by limestone	dampland	microscale ovoid basins	saline	carbonate mud and intraclast sand	aquatic algae: *Lamprothamnium papulosum* seagrass: *Ruppia* samphire: *Wilsonia backhousei*, *Sarcocornia quinqueflora* open heath: *Melaleuca halmaturorum, M. brevifolia, M. lanceolata* sedge: *Gahnia trifida*	*Pillie Lake Big Turf Waterhole Little Turf Waterhole Lake Damascus

Table 5 continued

Consanguineous Suite	Setting geologic/geomorphic terrain	Wetland types therein	Geometry of wetlands	Hydrology	Sediments	Vegetation communities	Examples of wetlands within suite
Kilroy	low undulating flat underlain by limestone	intermittently to seasonally inundated flats	mesoscale to macroscale flats	recharged by direct rainfall and perched Saline (brackish?)	thin carbonate mud or calcareous lithoclastic sand over limestone	shrub: *Melaleuca* spp. sedge: *Gahnia* sp. samphires grass	Kilroy Poelpena Swamp 10 km from Bramfield
Gully	karst landscape:- swale between coastal dune ridges underlain by limestone	seasonally inundated channels	short, leptoscale incised channels	recharged directly by rainfall and seepage	limestone	grazed	Wild Dog Gully
Hamilton **Elliston**	karst landscape:-swale between coastal dune ridges underlain by limestone	seasonally inundated basin	megascale linear basin; mesoscale rounded shallow basins	recharged by direct rainfall, springs from limestone aquifer and seepage from western dune ridge; groundwater rise in Elliston wetlands Saline	sandy mud; sand composed of intraclasts; mud composed of organic ooze; carbonate muds	sedge: *Gahnia* sp. shrub: *Melaleuca brevifolia, Melaleuca halmaturorum* samphires: *Sarcocornia quinqueflora Sarcocornia blackiana, Halosarcia pergranulata Suaeda australis, Hemichroa pentandra, Wilsonia humilis* aquatic algae: *Lamprothamnium* sp. seagrass: *Ruppia* sp.	*Lake Hamilton *Round Lake Elliston wetlands Cemetery Swamp *Lake Hamp

Table 5 continued

Consanguineous Suite	Setting geologic/geomorphic terrain	Wetland types therein	Geometry of wetlands	Hydrology	Sediments	Vegetation communities	Examples of wetlands within suite
Calpatanna	karst landscape:- coastal parabolic dunes, bowls and flats underlain by limestone	permanently inundated basins, seasonally inundated basins and flats	mesoscale to macroscale subrounded shallow basins	recharged from direct rainfall, marine tidal waters and upwelling from limestone aquifer Saline (brackish to hypersaline)	limestone and carbonate mud	aquatic algae: *Acetabularia* sp. *Lamprothamnium* sp. seagrass: *Ruppia* spp. samphires: *Halosarcia syncarpa, Sarcocornia quinqueflora, Hemichroa pentandra, Wilsonia humilis*	Calpatanna Lake Un-named flats *Little Seagull Lake Seagull Lake Whirlpool Dolines
Newland	contact between limestone and unconsolidated calcareous sand; karst landscape:-swale between limestone ridge and coastal dune barrier	seasonally inundated basins	elongate linear basin subdivided by arms of low parabolic dunes, spits, ridges, cuspate forelands and pavements into strings of basins	recharged by direct rainfall, springs from limestone aquifer and seepage from western dune ridge Saline (hypersaline) to freshwater	carbonate muddy sand (shells and intraclasts), mud (calcilutite)	aquatic algae: *Chara* sp. seagrass: *Ruppia* sp. samphire: *Halosarcia halocnemoides, H. pergranulata, H. pruinosa, Schlerostegia arbuscular, Maireana oppositifolia, Lawrencia spicata, Wilsonia humilis* sedge: *Gahnia* sp. rush: *Juncus kraussii* shrub: *Melaleuca halmaturorum*	*Lake Newland Sheringa Lagoon

Table 5 continued

Consanguineous Suite	Setting geologic/geomorphic terrain	Wetland types therein	Geometry of wetlands	Hydrology	Sediments	Vegetation communities	Examples of wetlands within suite
Yanerbie	contact between limestone and unconsolidated calcareous sand; parabolic dunes encroachment over pavement	seasonally waterlogged or intermittently inundated basins	microscale to mesoscale rounded shallow basins with internal very low mounds underlain by gypsum sand	recharged by direct rainfall which is perched and seepage from high ridge of mobile dunes Saline	gypsum sand	samphire: *Halosarcia halocnemoides, H. pruinosa, Lawrencia spicata, Wilsonia humilis, Dysphyma crassifolium*	*Yanerbie Hansson
Anxious Bay	blowout within mobile parabolic dune barrier underlain by unconsolidated calcareous sand	seasonally waterlogged basin	microscale elongate basin	recharged by direct rainfall and groundwater rise	humic calcareous sand	sedge: *Isolepis nodosa* samphire: *Sarcocornia quinqueflora* herb: *Samolus repens, Sporobolus virginicus*	*Newland Barrier
Stamford Hill	embayment prograding seaward between headlands	seasonally inundated basin with tidal creek	microscale subrounded shallow basin	recharged by direct rainfall, groundwater rise and inflow from tidal creek	humic calcareous sand	samphire: *Halosarcia pergranulata, H. syncarpa, Suaeda australis, Hemichroa pentandra, Sarcocornia quinqueflora, S. blackiana* scrub: *Melaleuca halmaturorum* shrub: *Melaleuca lanceolata, M. halmaturorum*	Lake Jessie *Stamford Hill Yangie Bay

7.3 Description of consanguineous suites and selected representative sites

Twenty wetland suites and their representative forty sites are described below in terms of setting, wetland type, description, stratigraphy, hydrology, water quality, and vegetation. The location of all the wetland suites is shown in Figure 15. The style of information and data presentation is summarised in Figure 16. The stratigraphic legend for the profiles is shown in Figure 17. The detailed information and data for the 20 suites are presented in Figures 18-46.

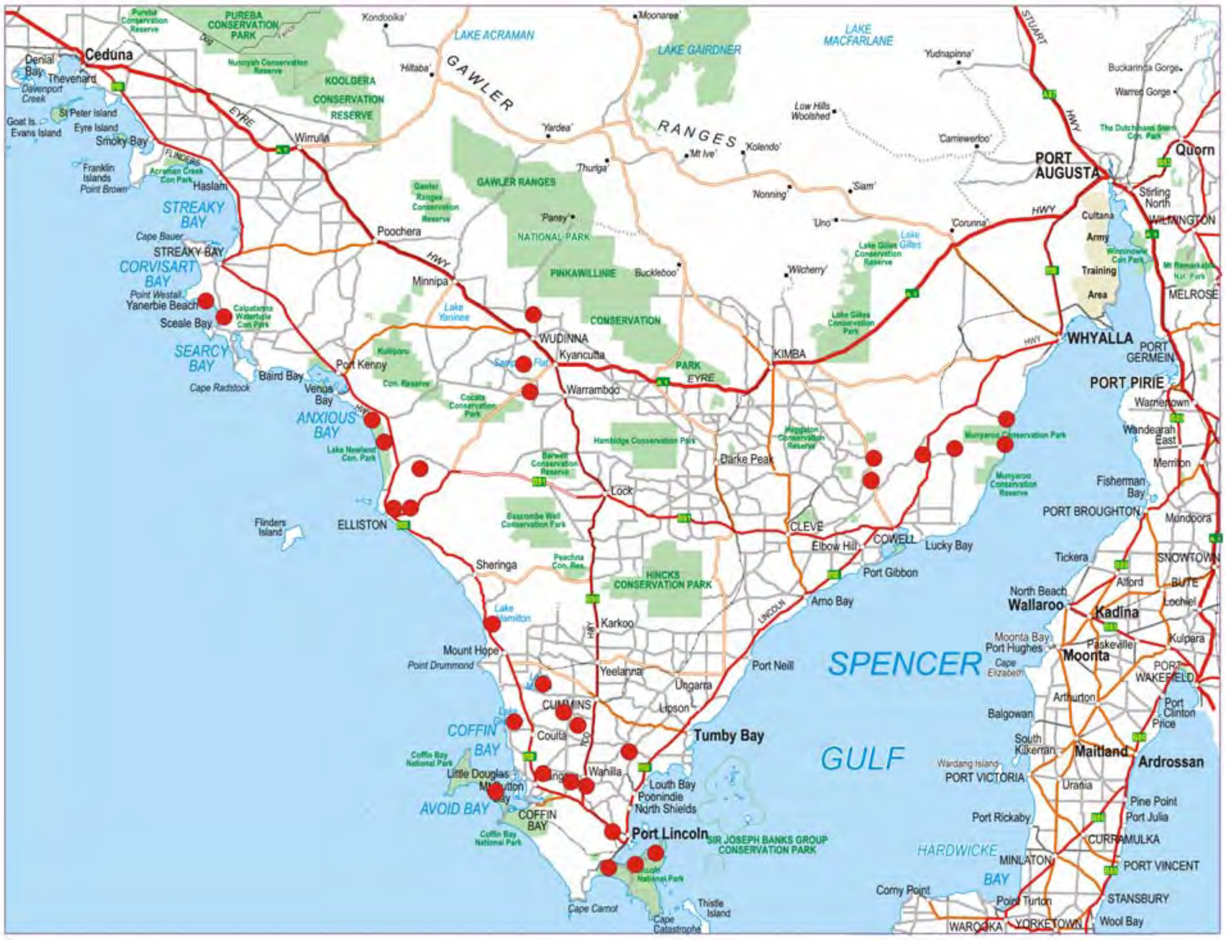


Figure 15: - Distribution of study sites selected as representing each of the consanguineous wetland suites

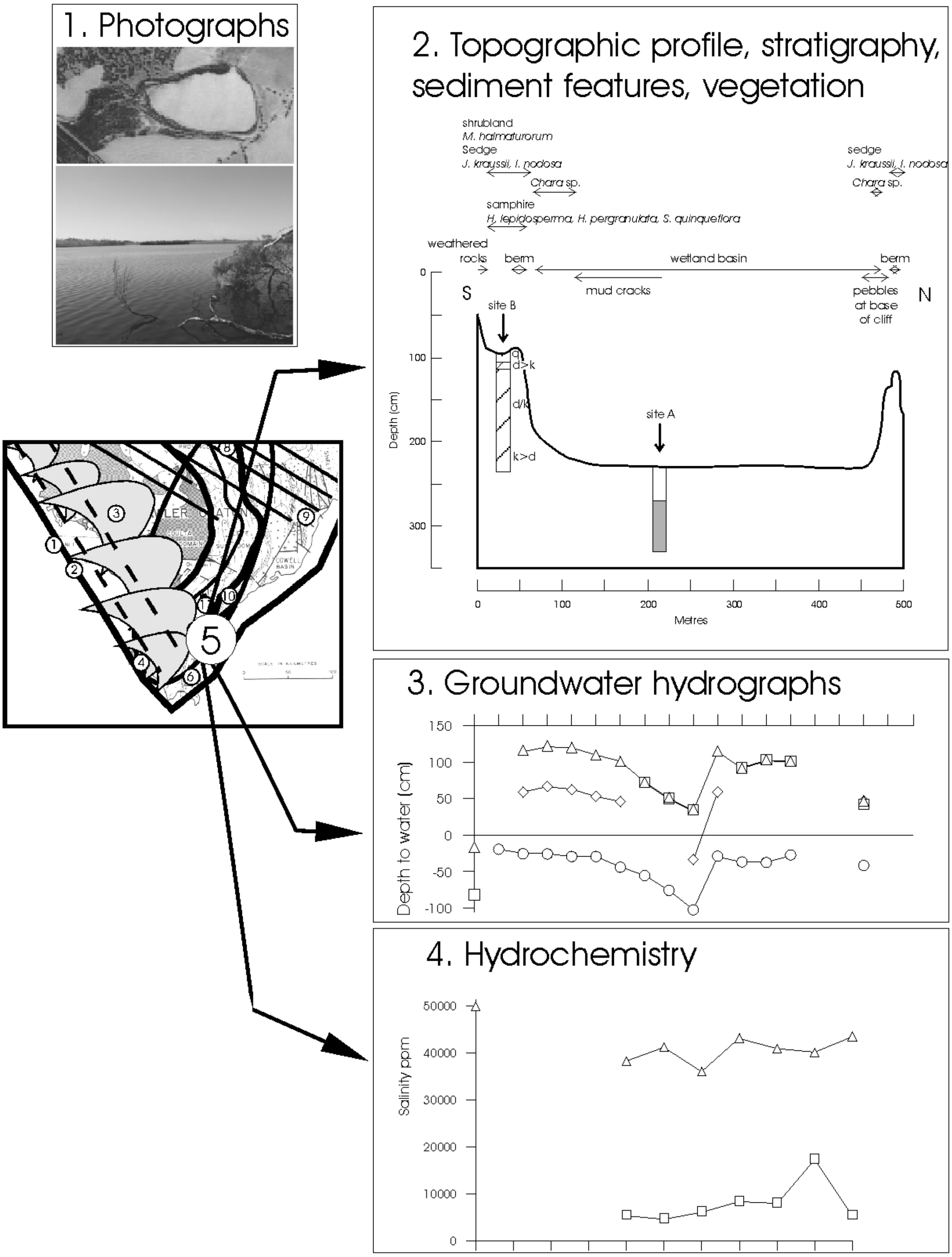


Figure 16: Conceptual diagram showing type and style of information presented for each of the wetlands representing a given consanguineous suite
(not all suites are comprehensively dealt with in this way)

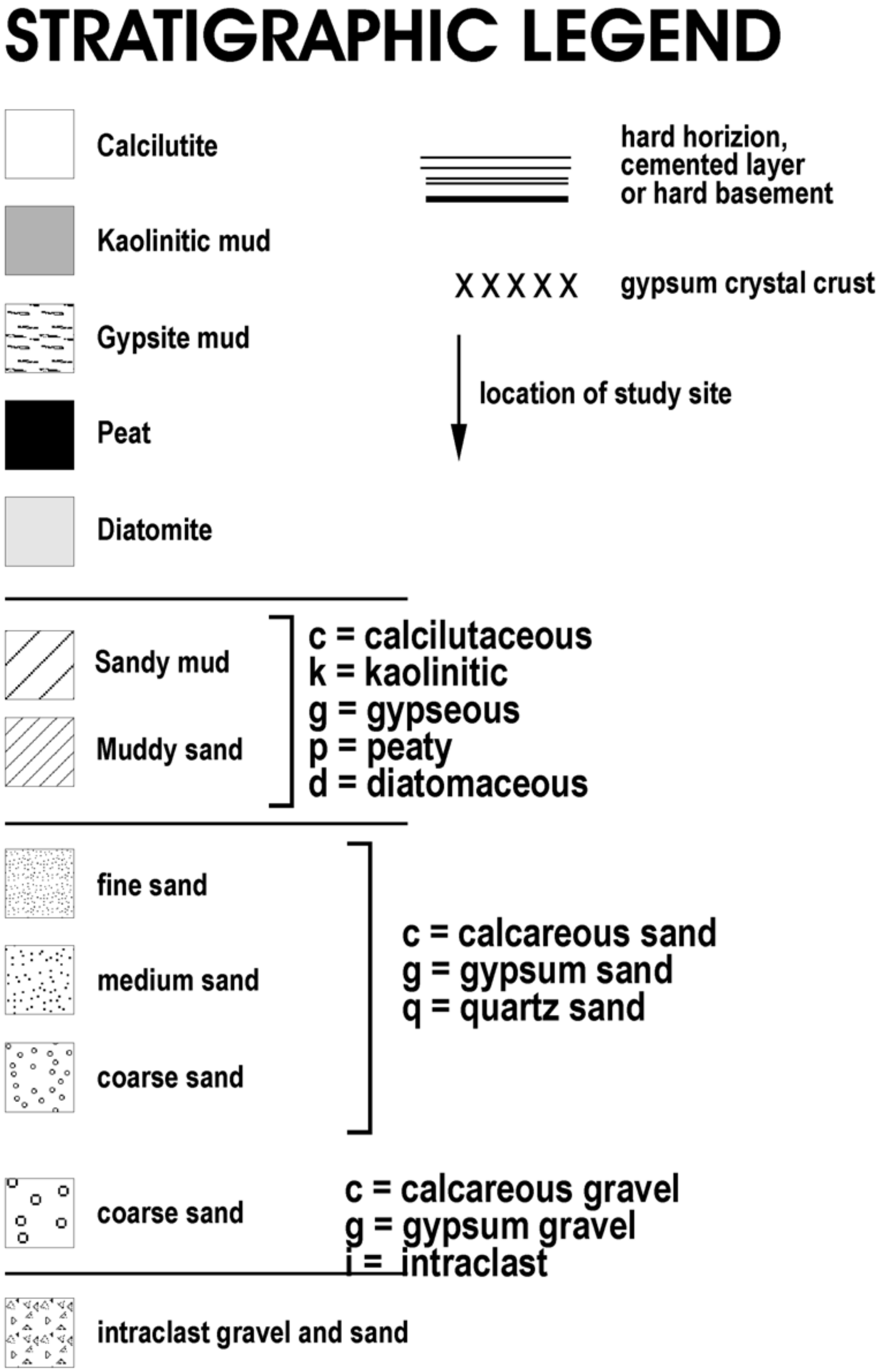


Figure 17: Legend for stratigraphic diagrams (Figures 18-47)

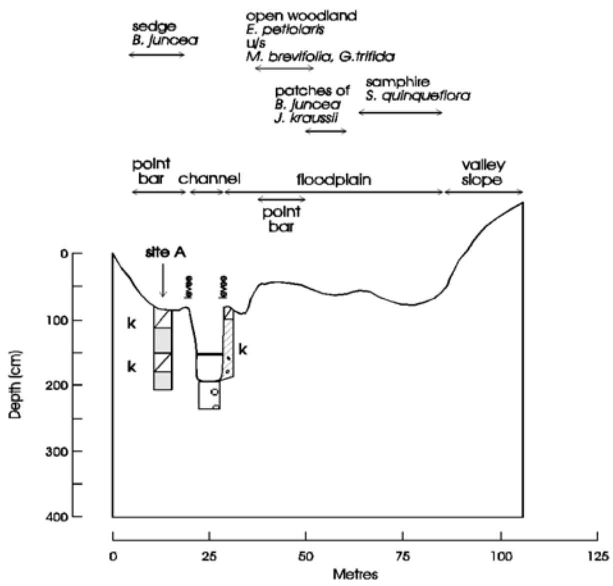
Koppio Suite (Fig. 18)
Setting: This suite is located in the low relief, dissected, lateritic hills and valleys, underlain by bedrock (gneiss, quartzite, and schist).
Wetland types: Creeks, floodplains, palusplains.
Description: Wetlands consist of small scale (5m wide x 1.5 m deep) seasonal, meandering, incised channels with cliffed sides, exhibiting point bar development, small levees, and narrow floodplains with inundation pools.
Stratigraphy: The cliffed sides may be cut into alluvial fans comprising muddy sand or gneissic or schist bedrock, and the channels are clogged with bedloads of gravel and shoals of sand. Floodplains are underlain by kaolin mud and sandy mud.
Hydrology: The wetlands are recharged directly by rainfall and by surface runoff and subsurface seepage. Discharge is via surface flow, discharge to local groundwater and evapo-transpiration. The direction of sub surface seepage depends on the relative water levels in the channel and the surrounding flats. During the period of study, flows were dominantly from the creek to the groundwater aquifer. Groundwater levels fluctuate seasonally from 35-80 cm. Water levels in the channel are generally reduced to a shallow trickle in the dry season but rise approximately 35 cm in winter.
Water quality: The surface and groundwaters at Koppio and Yallanda Flat were predominantly hyposaline (3,000-8,500 mg/L). For three or four weeks water salinity freshened to subhaline (1,000-3,000). Cation concentrations in the waters at the time of sampling were all low (Appendix 3), as were levels of arsenic, lead, copper and phosphorous. The waters fluctuated above neutral, the range being pH 7.8-8.6 with the more alkaline levels being recorded in the summer.
Vegetation: Point bars are vegetated by sparse shrubs of *Melaleuca brevifolia*, *Juncus kraussii* and *Baumea juncea*. Floodplains are vegetated by open woodlands of *Eucalyptus camaldulensis* and understoreys of species of Chenopodiaceae such as *Suaeda australis*, *Sarcocornia quinqueflora* and *Halosarcia* sp.

Seven sites were visited including tributaries of the Tod and White Rivers. Two sites were selected for monitoring: Yallanda Flat GPS 34^o 20.76'S and 135^o 52.64' E; and Tod River at Koppio GPS 34^o 21.55'S and 135^o 52.35' E. At both sites a piezometer was installed for monthly water level readings.

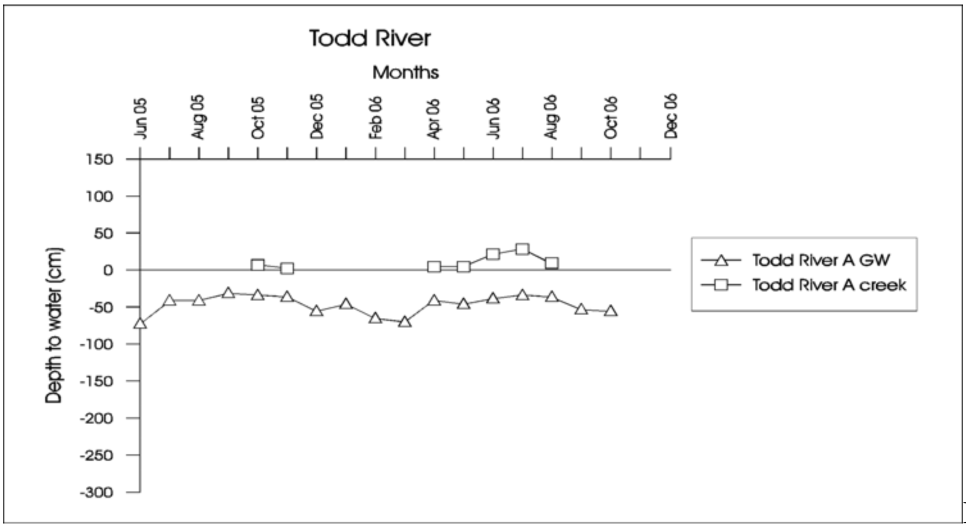
A


B

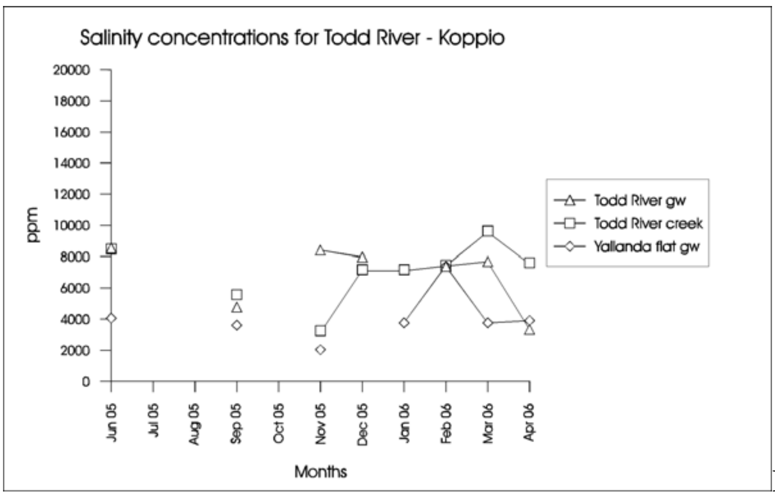
Figure 18: - A: Location of monitoring site on Tod River at Koppio
B: Photo of Tod River site, Koppio



C



D



E

Figure 18: - C: Geomorphology, stratigraphy and vegetation at Tod River site, Koppio
D: Hydrograph of groundwater and surface water at Tod River site Koppio
E: Hydrochemistry at Tod River site Koppio

Miltalie suite (Fig. 19)
Setting: Low relief, dissected, lateritic hills and valleys, underlain by gneiss, quartzite, and schist.
Wetland types: Creeks, floodplains, palusplains.
Description: Structurally controlled, microscale shallow channels with broad adjacent flats.
Stratigraphy: Gneiss, schist outcrop and bedloads of terrestrial clay and quartz/feldspathic sand.
Hydrology: Wetlands are recharged by direct precipitation and run-off. Discharge is via surface flow, discharge to local groundwater and evapo-transpiration. Groundwater levels are generally near the surface in the dry season (-20 cm) but rise approximately 60 cm in winter.
Water Quality: Single samples, taken in April 2006, of the surface and groundwaters at Miltalie sites, were mesosaline (25,000-36,000 mg/L). The salinity values suggest that although salt concentrations would increase over a dry summer and decrease during the winter months, they probably always remain in the mesosaline category. The waters were slightly above neutral, the range being pH 7.8-8.0.
Vegetation: On the floodplains communities are small and patchy (maculiform) and comprise samphires, *Halosarcia pergranulata, H. indicans, H. halocnemoides, Sarcocornia quinqueflora, Mairiana erioclada.* The channel is lined by the rush *Juncus kraussii,* and scattered shrubs of *Melaleuca halmatururoum.* Charophytes occur in quiet shallow pools of the channel.

Four sites were visited. Salt Creek crossing 33^{o} 25.285'S and 137^{o} 00.64' E; Miltalie Creek 33^{o} 31.97'S and 136^{o} 50.51' E; Salt Creek opposite Midgee 33^{o} 27' 6.8"S and 137^{o} 21' 48.1" E;

A


B


C

Figure 19: - A: Location of sites in the Miltalie Suite
B & C: Photos of Salt Creek, Miltalie

Sleaford suite (Figs. 20, 21)
Setting: The contact between the low relief dissected ridge of lateritised metamorphic rocks of the Gawler Craton and the adjacent swale underlain by limestone.
Wetland types: Lake, sumpland
Description: This suite consists of one megascale elongate irregular basin, Sleaford Mere, and one mesoscale round basin, un-named, which is referred to herein as Little Sleaford. Sleaford Mere is permanently inundated and the un-named wetland is seasonally inundated. In the central basin, fossil stromatolites form islands and reefs standing about 50 cm above the present water level. At the margins they form relic beaches, pavements and beach ridges.
Stratigraphy: Both basins are surrounded and underlain by limestone and ferricreted clays and gravel. At Sleaford Mere, the wetland fill comprises waterlogged calcareous ooze and intraclastic calcareous sand and gravel with a surface crust of fossil stromatolites and cemented algal mat. At the un-named sumpland, the wetland fill comprises calcareous mud overlying the basement of orange terrigenous clay and ferricrete, exemplifying the limestone/ironstone contact wherein it lies.
Hydrology: Mechanisms of recharge to Sleaford Mere require further investigation, but include direct precipitation and seepage from adjacent ridges. Groundwater and surface water fluctuations correspond varying approximately 20 cm annually. At the un-named basin water levels fluctuate up to 90 cm and towards the end of winter, groundwater levels are higher than the surface water.
Water quality: The surface water of Sleaford Mere has a consistent pH around 8.2 which is alkaline and typical of limestone aquifers. The groundwater chemistry is variable, at one end closely approximating rainwater and at the other end highly alkaline (pH 6.9-9.4). This suggests that there are a number of sources for groundwater recharge. Near the main basin, the salinity of both surface waters and groundwaters are similar, lying predominantly in the mesosaline range (24,000-29,000 mg/L), but concentrations can be diluted by direct rainfall input. At the lake margins, groundwater is subhaline (1600 mg/L) indicating subsurface seepage from the adjacent ridges of limestone and iron materials. Cation concentrations in the waters at the time of sampling were mostly low with some medium peaks in sodium and magnesium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were also low. At the sumpland, the groundwater chemistry is neutral, (pH 6.9), but the salinity of groundwater perched above the iron cemented layer is hypersaline (70,000 mg/L).
Vegetation: The vegetation cover forms a mosaic of communities and is peripheral (bacataform). The surface crust of fossil stromatolites and cemented algal mat are not vegetated, the upper pavements above mean water level are vegetated by mat plants of *Limonium companionus, Hemichroa pentandra, Schoenus* sp., while the ridges of eroded stromatolites on the margin of the lake support closed heath giving way to shrubland. Closed heath comprises several species of *Melaleuca: M.* h*almaturorum, M. lanceolata, M. cassytha,* and *Gahnia triffida* or *filum, Cryptandra leucopogon, Acrotriche cordufa, Leucopogon parviflorus, Lasiopetalum discolor, Olearia axillaris.* Shrubland is dominated by *Gahnia filum* and *Acacia leiophylla.* At the Little Sleaford sumpland, the vegetation is also peripheral (bacataform). Charaphytes and species of Chenopods colonise the central basin. At the lake margins, where groundwater salinity is probably lowered by subsurface seepage from the adjacent ridges of limestone and iron impregnated and cemented materials, closed heath and then shrubs comprise two species of *Melaleuca, M. brevifolia* and *M. halmaturorum.*

Four sites were visited. Two sites were selected for monitoring: Sleaford Mere GPS 34^{o} 49' 26.5"S and 135^{o} 44' 26.3"E; and Little Sleaford GPS 34^{o} 51' 43.9"S and 135^{o} 43' 16.8" E.

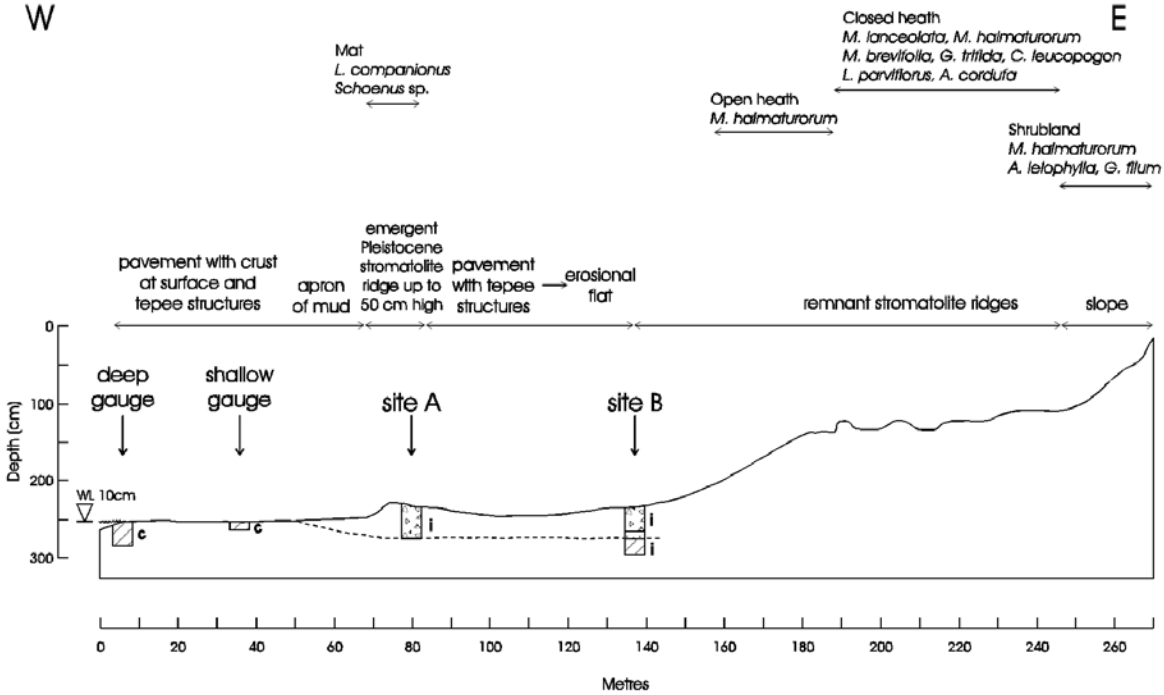
At Sleaford Mere two piezometers and a gauge were installed and at Little Sleaford, two piezometers were installed, for monthly water level readings.

A

B

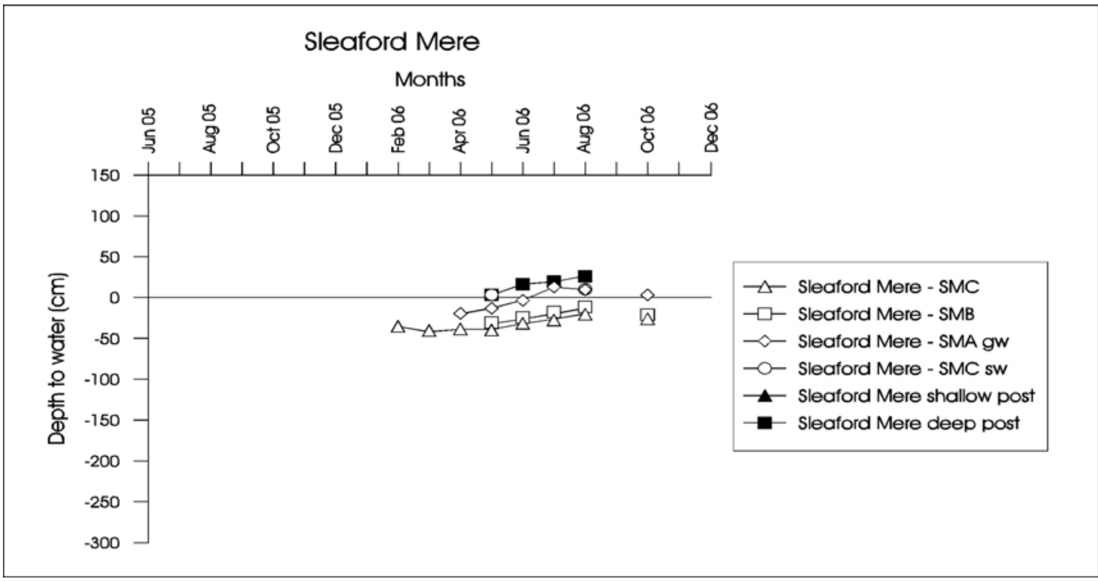
Figure 20: - A: Location of Sleaford Mere
B: Aerial photo of Sleaford Mere and Little Sleaford Mere

C

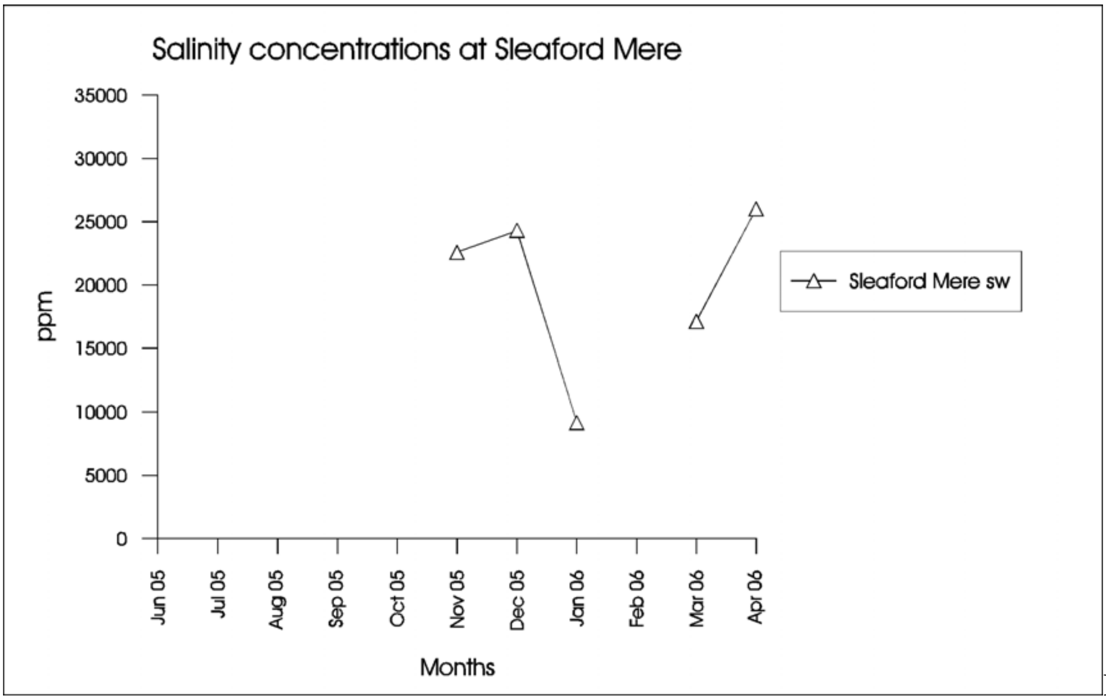


D

Figure 20: - C: Photo of Sleaford Mere site raised (emergent) stromatolite reef along shore
D: Geomorphology, stratigraphy and vegetation at Sleaford Mere site



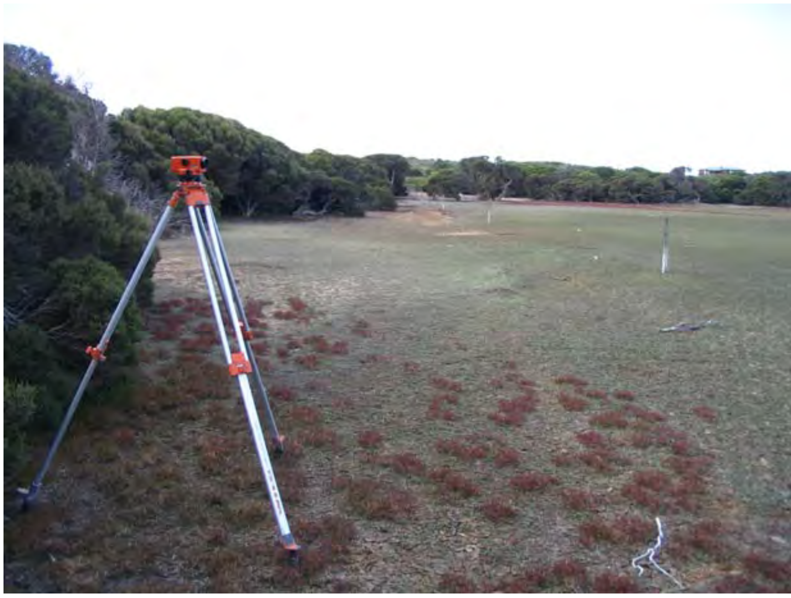
E



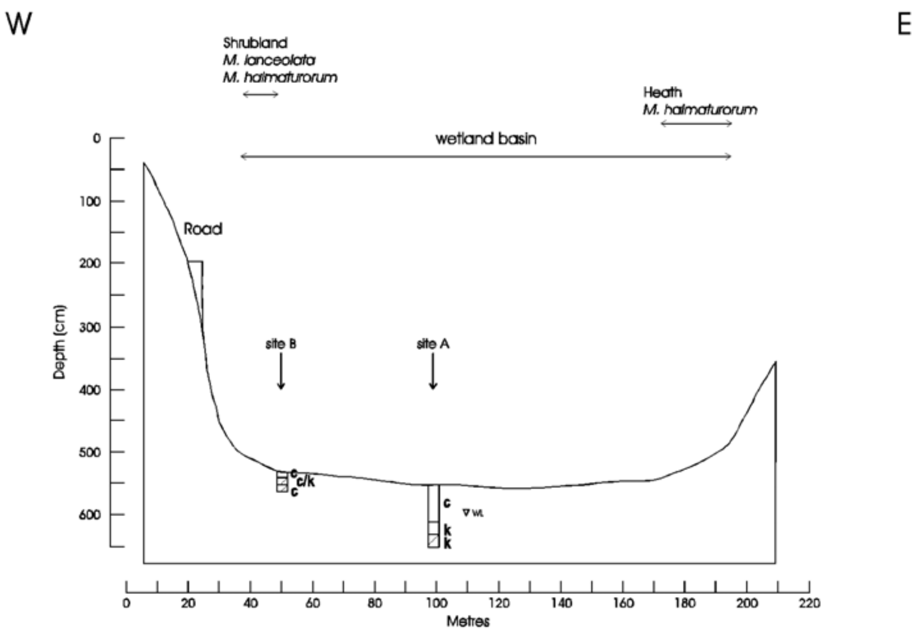
F

Figure 20: - E: Hydrograph of groundwater and surface water at Sleaford Mere site
F: Salinity at Sleaford Mere site

A



B



C

Figure 21: - A: Location of Little Sleaford Mere
B: Photo of Little Sleaford Mere site showing vegetation-ringed basin
C: Geomorphology, stratigraphy and vegetation at Little Sleaford Mere site

Wudinna suite (Fig. 22)
Setting: Isolated rounded granitic hills and inselbergs with gnammas and rillen.
Wetland types: Sumplands, damplands
Description: The gnammas and rillen in the granite monadnocks comprise the wetland types in this suite.
Stratigraphy: The wetland fill comprises organic enriched muddy sand. The basement is granitic rock.
Hydrology: The leptoscale wetlands are recharged directly by rainfall and are freshwater and seasonal. Discharge occurs through seepage and evapo-transpiration.
Water quality: Freshwater.
Vegetation: Plant communities contain herbs and grasses with occasional shrubs of *Melaleuca armillaris.* Locally, small basins are inhabited by *Stypandra glauca* (the Nodding Grass-Lily), a species rated as vulnerable in South Australia and confined to a few granite outcrops on the central Eyre Peninsula.

Locations include: Yarwondutta Rocks, Minnipa Rocks, Uncontitchie Hill, and Pildappa Hill. No sites were selected for monitoring because of the potential risk to declared rare flora.

A

Figure 22: - A: Location of Mt Wudinna

B

C

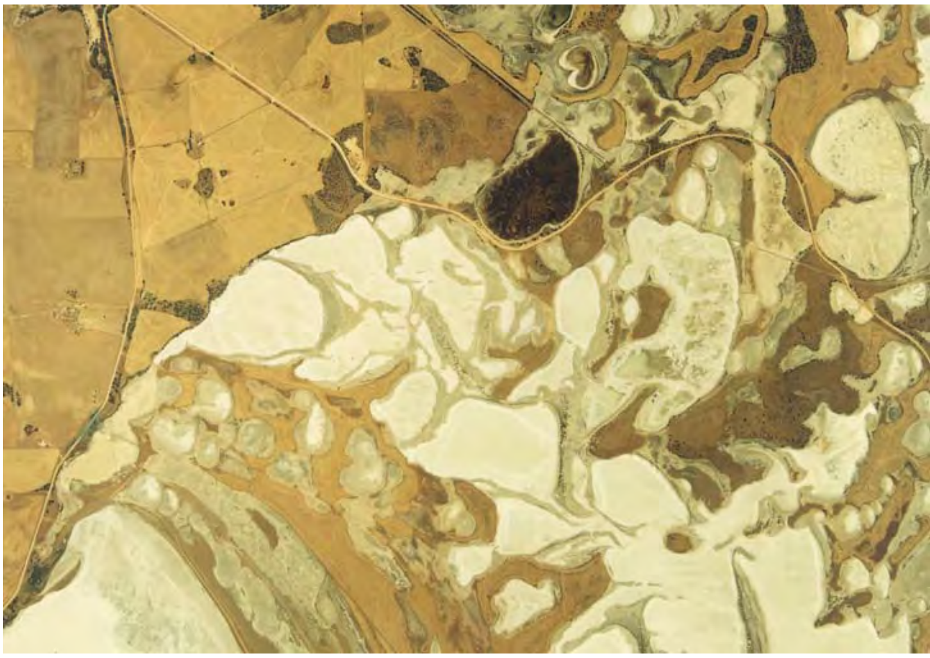
Figure 22: - B & C: Photos of wetlands on Mt Wudinna located on gnammas and rillen.

The Malata suite and Greenly wetland suites are both set in the alluvial valley tract between the bedrock ridges and are both truncated in the south west by the occurrence of limestone. However, wetlands in this setting, have been separated into two suites because progressive aridity northwards and inland has influenced the outcome of the consanguineous criteria relating to stratigraphy and hydrology. In regard to Lake Malata, less winter runoff has resulted in the replacement of inflowing channels by large scale surface water basins with adequate fetch, wave development and wind transport to construct circumferential ridges, series of ridges, or semi-circular ridges (lunettes) thus altering the wetland types and their geometry. Less rainfall has also resulted in increasing salinity of surface and ground waters, and as a consequence, the development of a different chemical precipitation environment within the sedimentary body.

Malata suite (Figs. 23, 24, 25)
Setting: Undulating alluvial plain of valley tract; line of circular basins separated by ridges and lunettes, and underlain by red brown alluvial sandy clay.
Wetland types: Sumplands, damplands
Description: This suite consists of one megascale rounded basin, Lake Malata, and multiple microscale to mesoscale sub-rounded to ellipsoid basins, which are un-named. Many of these basins, including Lake Malata are seasonally inundated. Lake Malata complex has a complex history of wet and dry conditions but is presently a seasonal groundwater discharge area.
Stratigraphy: The Malata wetland system is surrounded and underlain by alluvial clays, silts, sands and gravel. In the central basins, and at the margins there are ridges and lunettes respectively underlain by gypsum silt and sand. At Lake Malata, the wetland fill comprises calcareous mud, sand (gypsum, quartz), and muddy sand (gypsum, clay mineral, quartz) with layers of shell fragments.
Hydrology: Hydrographs of groundwater levels do not exhibit seasonality. Groundwater levels directly fluctuate in response to separate rainfall events, but when no rain falls, levels remain steady. There appear to be separate groundwater aquifers, the shallower one receiving a continual slow discharge from the surface and the deeper one being recharged by lateral flow. Shallower groundwater levels fluctuate around 70 cm and deeper groundwater levels around 125 cm annually.
Water Quality: The water salinity of both surface and groundwaters, is hypersaline (44,000-266,000 mg/L). The exception is the groundwater on the western margin of Lake Malata itself which is slightly less saline than seawater (28,000-35,000 mg/L). Cation concentrations in Lake Malata exhibit high concentrations of sodium, potassium and magnesium (Appendix 3), indicating that it acts as a closed system. Levels of arsenic, lead, copper and phosphorous were low. The surface and groundwaters fluctuated around neutral, the range being pH 6.9-7.6. Exceptions were the groundwater flowing from the western side into Lake Malata which had a slightly higher mean of pH 7.9 and the groundwater at the edge of the Lake which had a lower mean of pH 6.7 with the more acidic levels being recorded in spring. Again, these results suggest different sources of recharge to the lake.
Vegetation: The centre of many of the basins is unvegetated but the margins, where steep, exhibit patches of heath and low shrubs: *Melaleuca brevifolia, Halosarcia syncarpa, Lawrencia spicata* and *Threlkeldia diffusa*. Margins which are wider and less steep exhibit mosaics of samphires (bacataform), *Halosarcia halocnemoides, Halosarcia indicans bidens, Halosarcia syncarpa, Halosarcia pruinosa, Halosarcia pergranulata,* and *Sarcocornia quinqueflora.* The gypsum ridges are vegetated by open low shrub communities *Halosarcia pruinosa, Frankenia pauciflora, Mairiana oppositifolia* and *L. spicata* and the declared rare flora *Halosarcia flabelliformis* forms pure and mixed stands in one of the smaller basins.

Four sites were visited. Three sites were selected for monitoring: Sites 1 and 2 GPS 34^{o} 09.41'S and 135^{o} 31.99'E; and Lake Malata itself, GPS 34^{o} 11.13'S and 135^{o} 29.11'E. Four piezometers were installed at sites 1 and 2, and at Lake Malata, two piezometers were installed, for monthly water level readings.

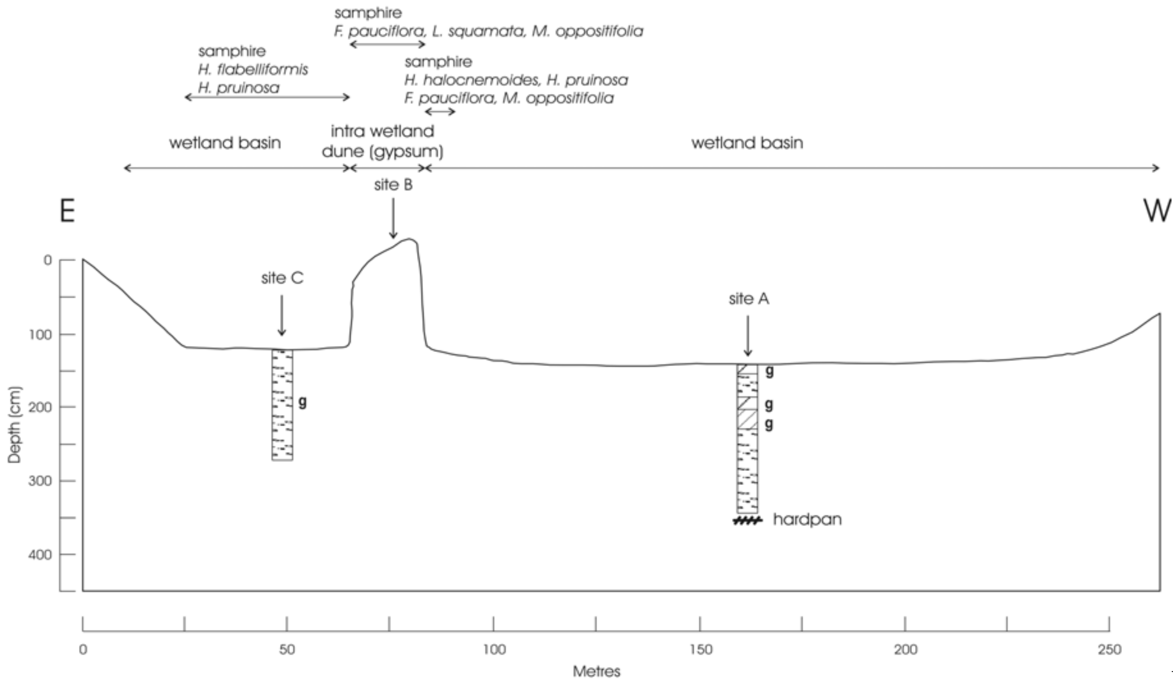
A



B

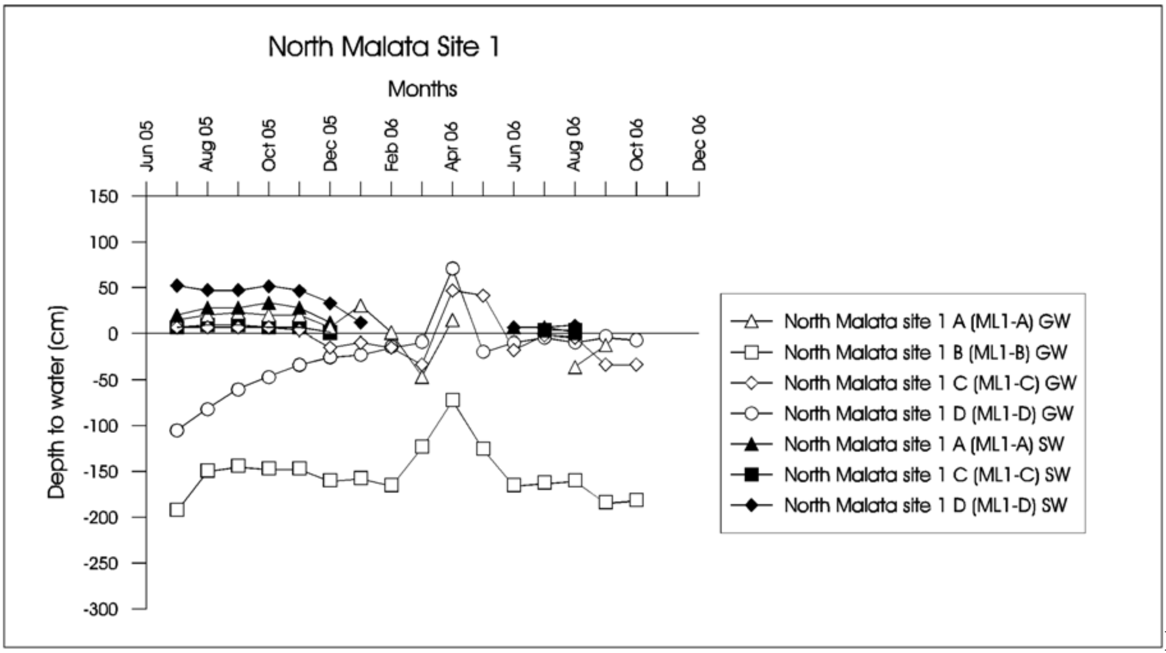
Figure 23: - A: Location of Malata sites 1A, B, C, D
B: Aerial photo of Malata sites 1A, B, C

C

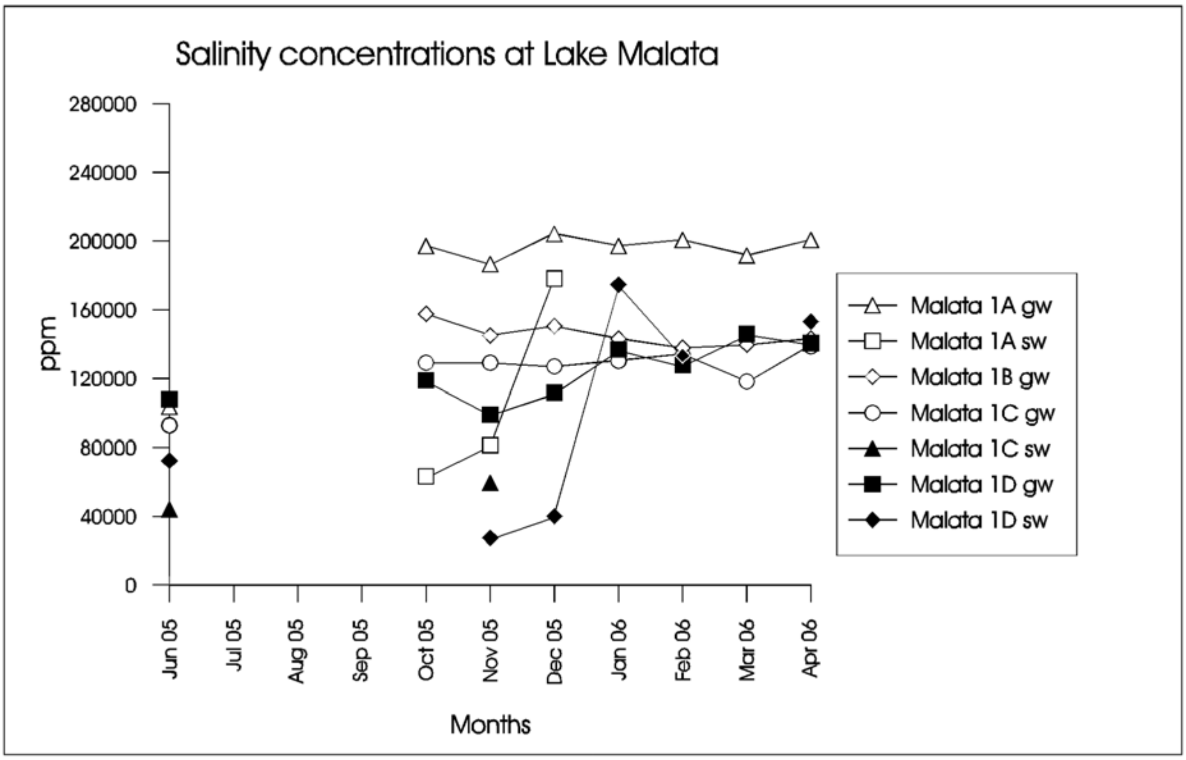


D

Figure 23: - C: Photo of Malata sites 1A, B, C
D: Geomorphology, stratigraphy and vegetation at Malata sites 1A, B, C

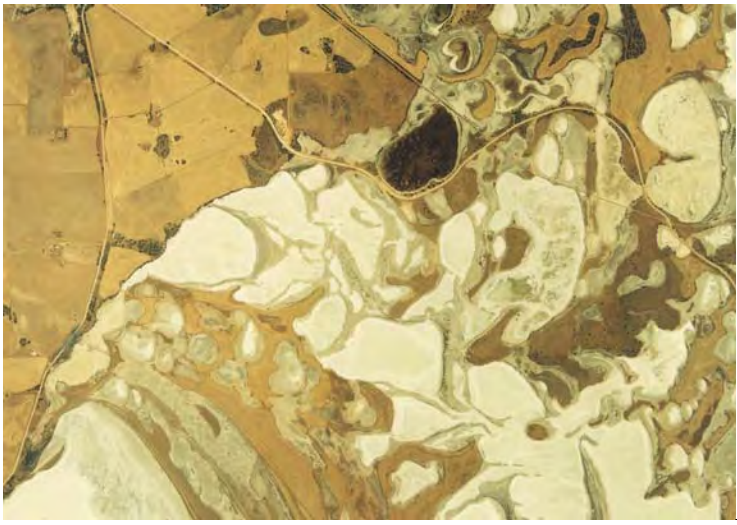


E



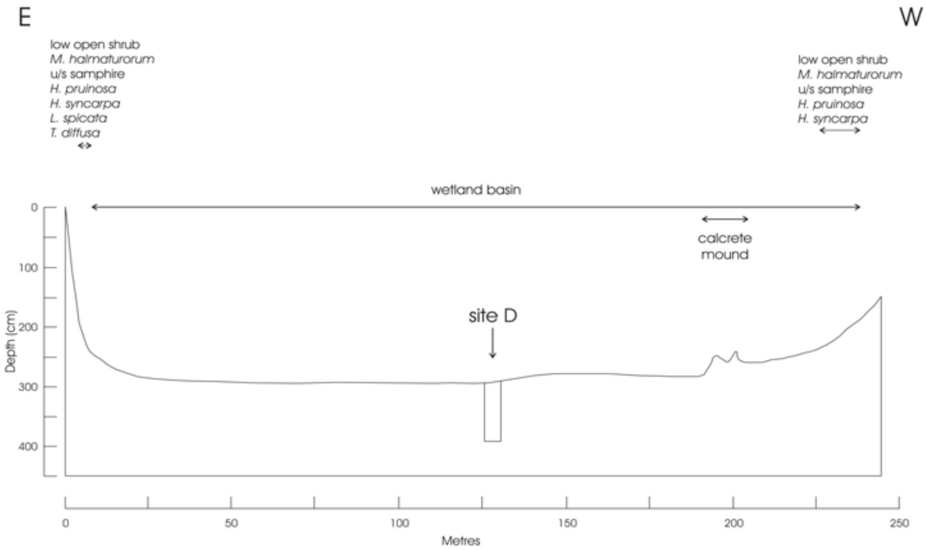
F

Figure 23: - E: Hydrograph of groundwater and surface water at Malata sites 1A, B, C
F: Water salinity at Malata sites



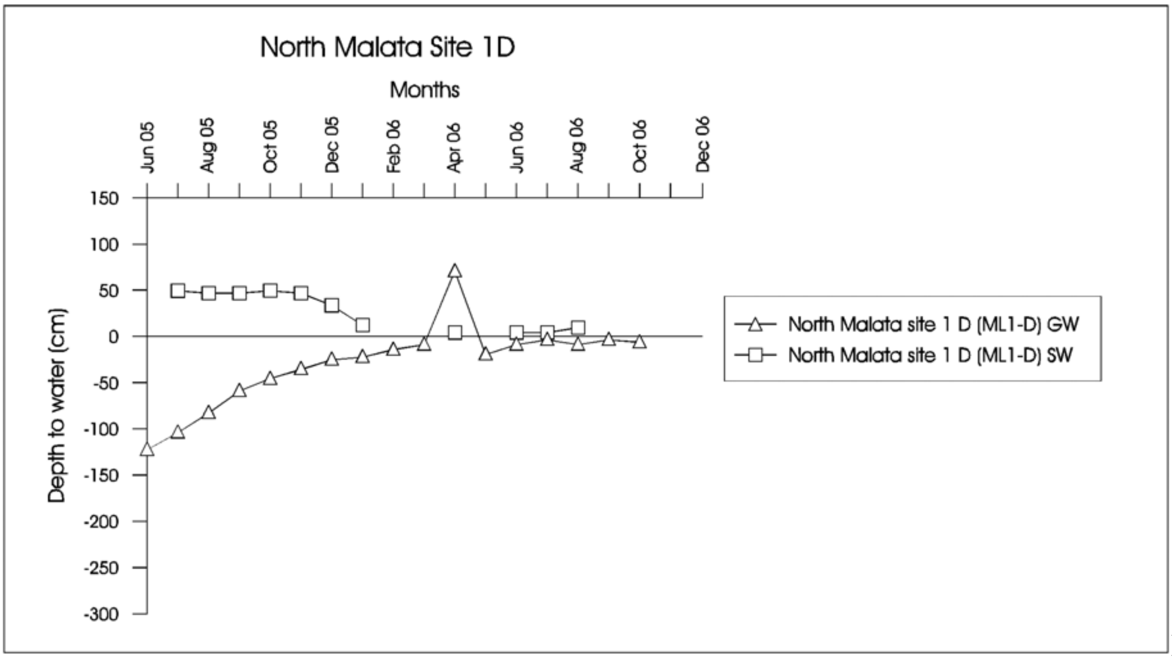
A

B

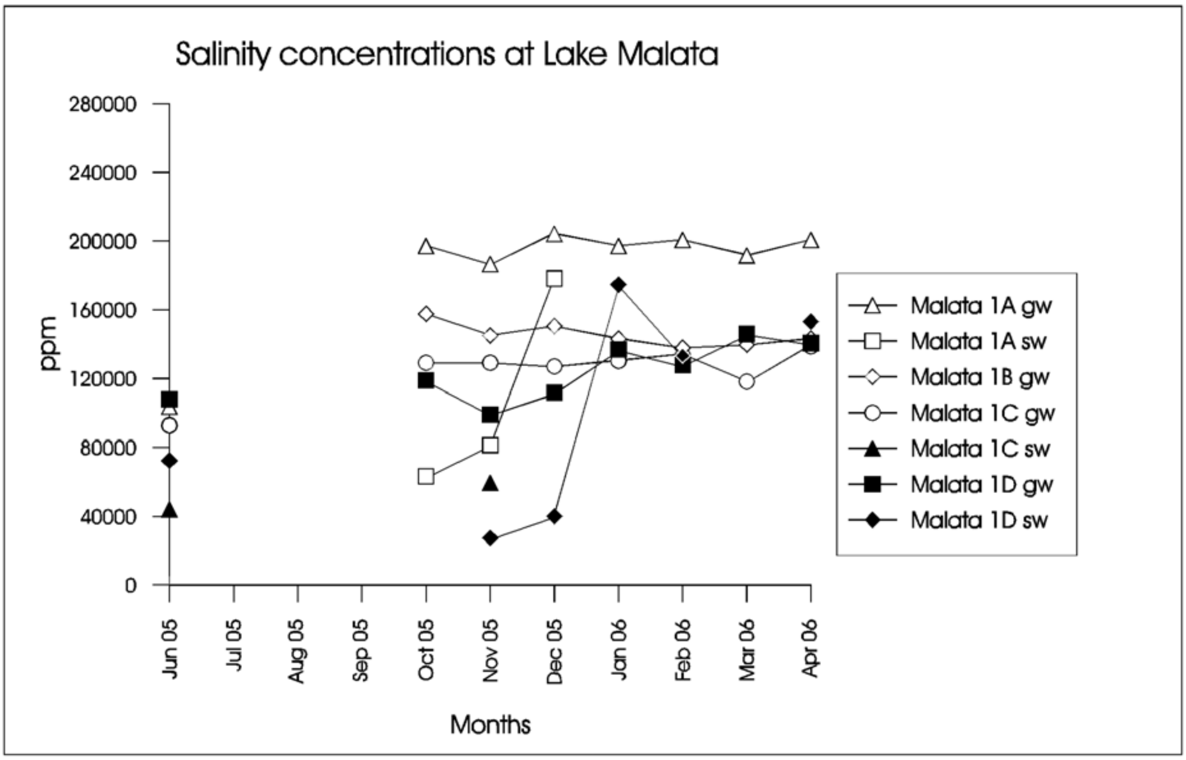


C

Figure 24: - A: Aerial photo of Malata site 1D
B: Photo of Malata site 1D showing steep shore
C: Geomorphology, stratigraphy and vegetation at Lake Malata site 1D



D



E

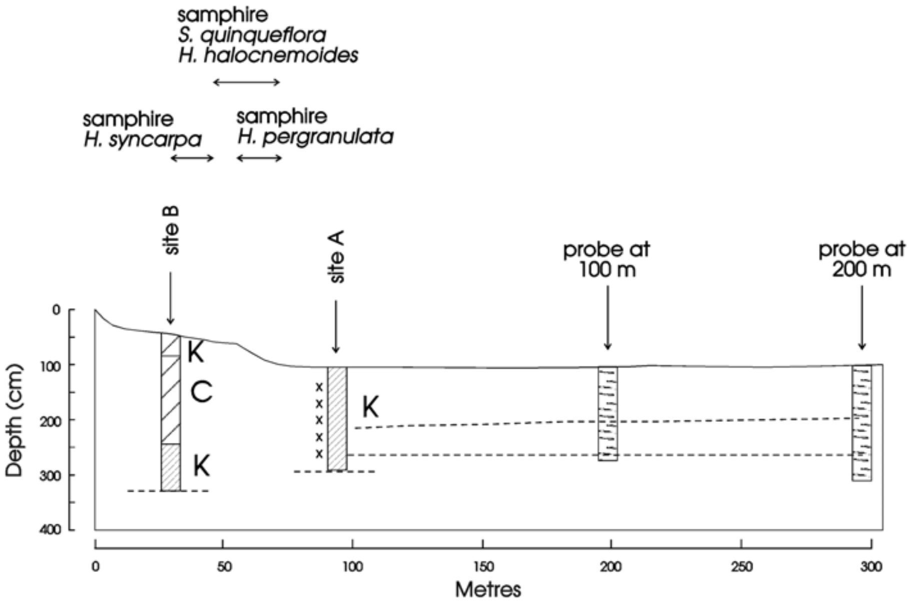
Figure 24: - D: Hydrograph of groundwater and surface water at Lake Malata site 1D
E: Water salinity at Lake Malata site 1D

A

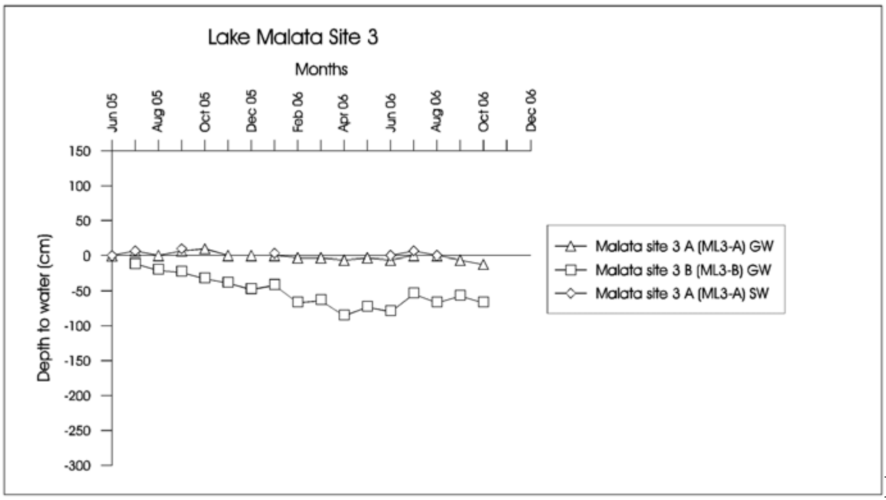
B

C

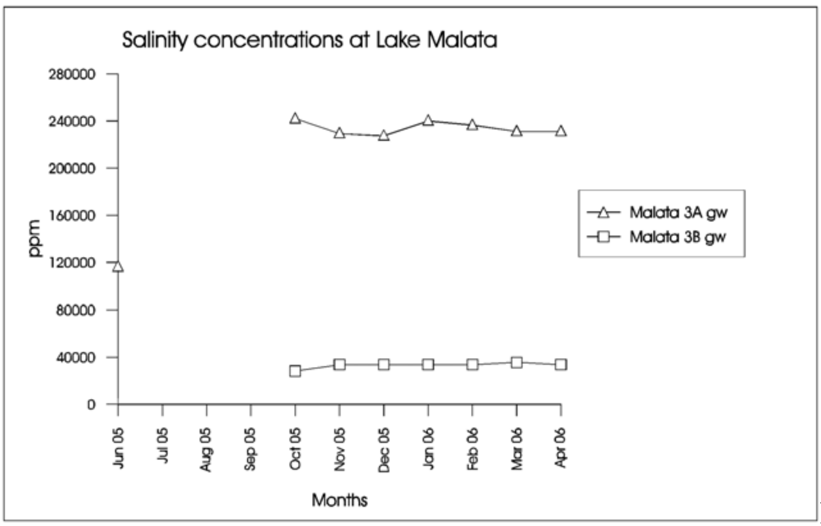
Figure 25: - A: Location of monitoring site on Lake Malata 3
B: Aerial photo of Lake Malata 3
C: Photo of Lake Malata



D



E



F

Figure 25: - D: Geomorphology, stratigraphy and vegetation at Lake Malata site 3
E: Hydrograph of groundwater and surface water at Lake Malata site 3
F: Water salinity at Lake Malata site 3

Greenly suite (Figs. 26, 27, 28)
Setting: These wetland systems lie in valley tracts and are partly surrounded and underlain by alluvial clays, silts, sands and gravel, but at the southern end of each wetland system lies the contact with the limestone in which the southern part of the basin and southern channels are embedded.
Wetland types: Sumplands.
Description: This suite consists of megascale to mesoscale ovoid to semi-circular basins, and small scale connecting, inflowing or outflowing channels. These wetlands are seasonally inundated, but Lake Wangary has become permanently inundated by damming the head of the southern exit channel.
Hydrology: Recharge occurs via direct precipitation and inflow, and short-term perching occurs after the first rains, while discharge is much slower. As a result, water levels fluctuate 70 - 100 cm annually. In Little Swamp, groundwater eventually rises to merge with the ponded surface water, but in Lake Greenly the length of the rain season and the volume of input are insufficient for the groundwater table to rise and intersect the basin surface, thus maintaining the separate water bodies throughout the year. Water movement in both basins is generally downward.
Stratigraphy: The wetland fills change slightly in composition and stratigraphy as the climatic setting changes from humid with adequate rainfall to more arid, however calcareous mud is present at all sites. At Little Swamp, the calcareous mud and intraclasts, which predominate the fill, are overlain by peat and overlie basal sediments composed of a mix of kaolin clay, carbonate mud and quartz sand. At Duck Lake, the wetland fill comprises a mix of calcareous and kaolinitic mud, and at Lake Greenly, it comprises solely calcareous mud. Sponge spicules, *Chara* oogonia, foraminifera, diatoms, ostracods, gastropod and bi-valve shells, pellets and other skeletal material occur throughout the sedimentary profiles.
Water Quality: The water salinity of surface waters is generally hyposaline (2,700-17,000 mg/L) while groundwaters range from hyposaline to hypersaline (8,000-170,000 mg/L). These wetlands exhibit the greatest variability in salt content, peaks occurring at the onset of rain (June 2005). Cation concentrations reflect the same patterns with low to high levels of sodium, potassium and magnesium (Appendix 1). Levels of arsenic, lead, copper and phosphorous were low. The surface and groundwaters fluctuated around neutral, the range being pH 6.9-7.8. Little Swamp exhibited more alkaline waters (up to p H 9.1). Little Swamp has several sources of water recharge, groundwater rise, inflowing streams carrying water from flash floods, and direct rainfall. It is probable that the waters from these three sources do not mix until late winter when the resulting salinity becomes a mixture of three independent water bodies.
Vegetation: The centres of many of the basins are unvegetated but the margins, where narrow and more sloping, exhibit open shrublands of *Melaleuca halmaturorum,* with open ground cover of *Halosarcia lepidosperma, Halosarcia pergranulata*, *Sarcocornia quinqueflora* and *Hemichroa pentandra*. Margins which are wider and less sloping, exhibit zones within the samphire communities. Beginning at the upland edge, samphire communities were dominated by *Halosarcia syncarpa,* then *Halosarcia pergranulata,* and then *Sarcocornia quinqueflora (*Fig. 20D). Of the flats bordering the channels, the seasonally inundated part is maculiform, vegetated by low shrubland of *Halosarcia lepidosperma*, *Halosarcia pergranulata* and *Melaleuca halmaturorum* and the seasonally waterlogged zone is latiform, vegetated by *Gahnia trifida* with scattered shrubs of *Melaleuca halmaturorum*. Aquatics included species of *Chara*.

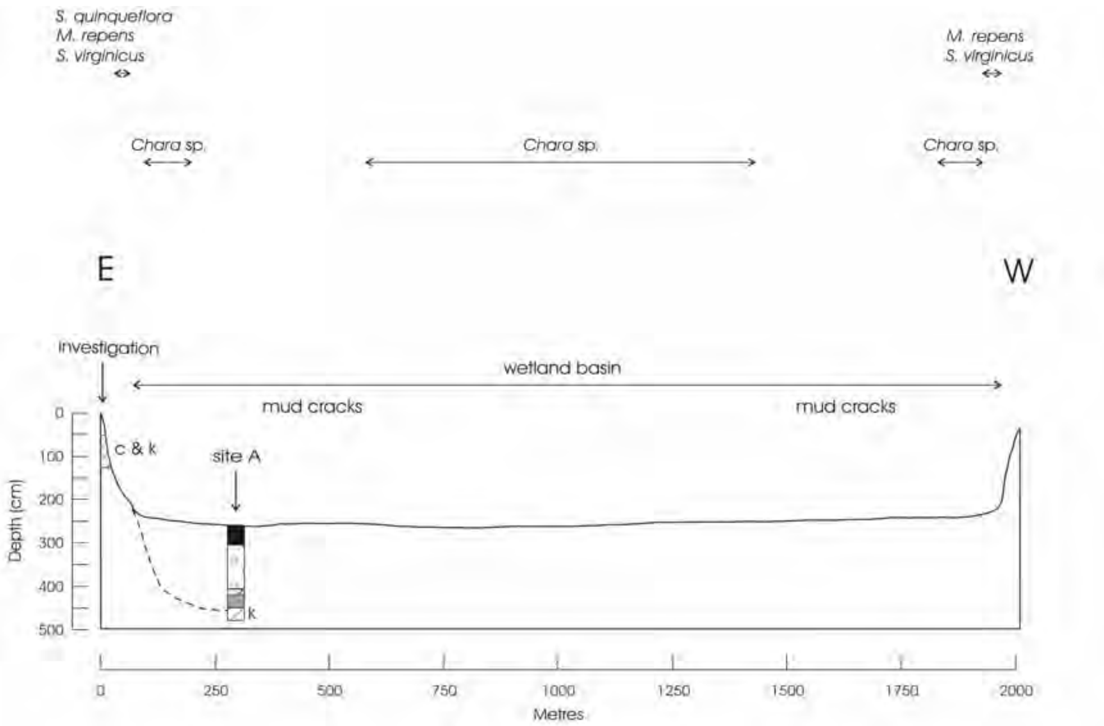
9 sites were visited, including Lake Greenly, Little Swamp, Big Swamp, Lake Wangary, Duck Lake, Pillara Lagoon, Lake Baird and un-named wetlands. Three sites were selected for monitoring: Little Swamp, GPS 34^{o} 41.50’S and 135^{o} 48.19’E, Duck Lake GPS 34^{o} 31.03’S and 135^{o} 30.35’E; and Lake Greenly GPS 34^{o} 19.32’S and 135^{o} 26.79’E. Two piezometers were installed at Little Swamp one deep and one shallow and a surface water gauge, two piezometers were installed at Duck Lake and two surface water gauges, and at Lake Greenly, in addition to the 3 piezometers installed by Flinders University, a deeper piezometer was installed at the margin of the lake, for monthly water level readings.

A

B

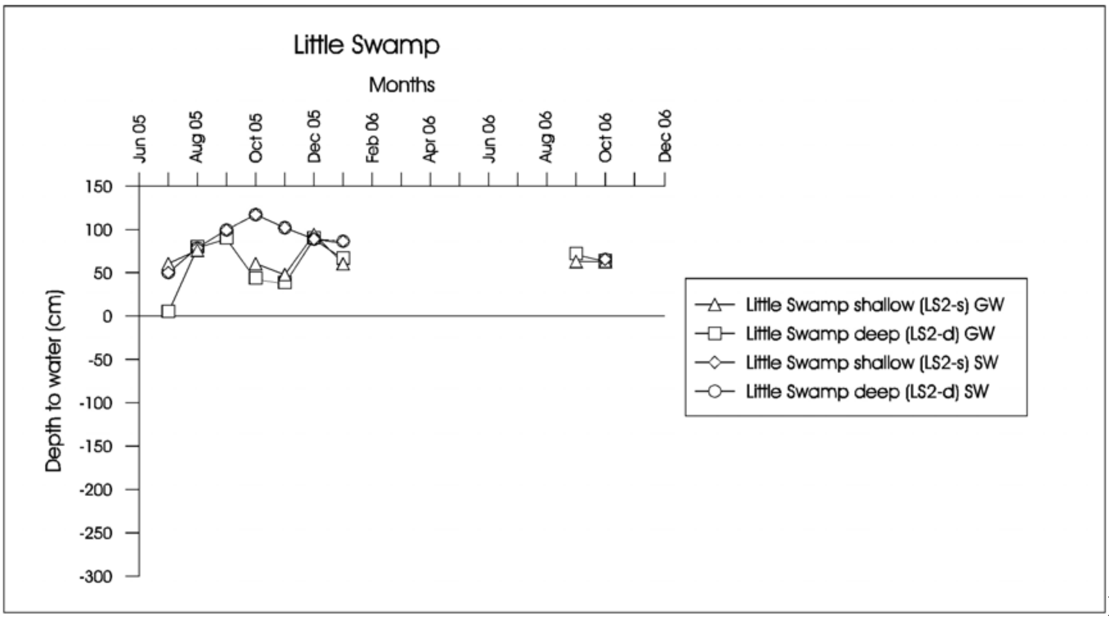
Figure 26: - A: Location of Little Swamp
B: Aerial Photo of Little Swamp


C

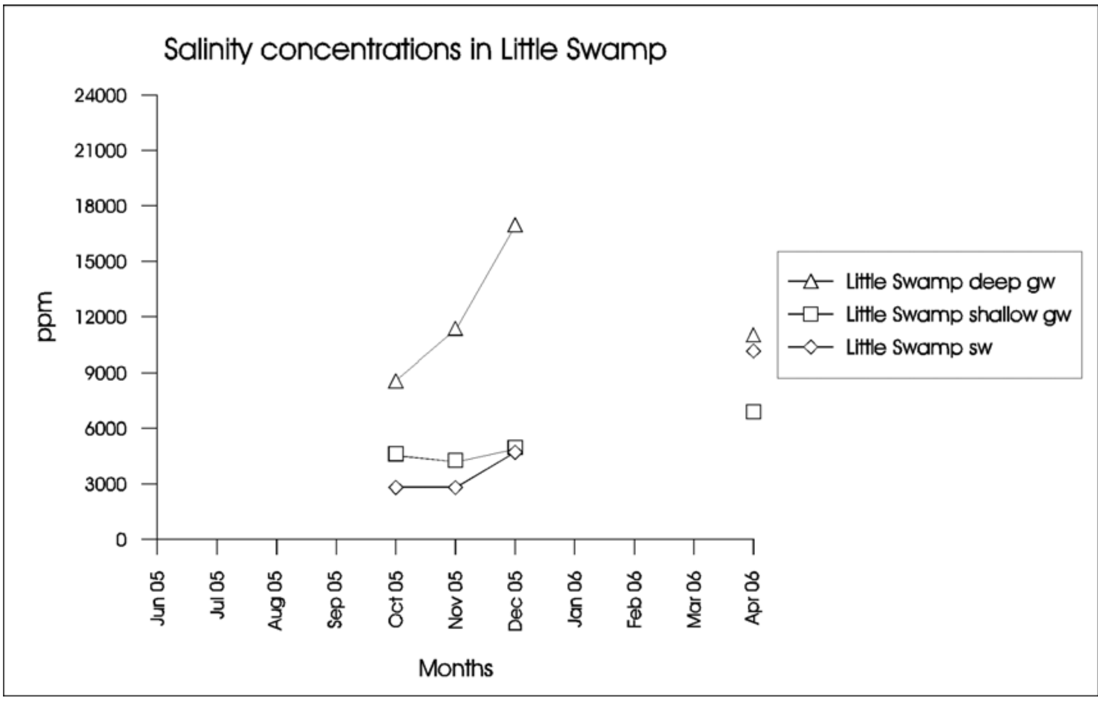


D

Figure 26: - C: Photo of site at Little Swamp at low water in summer
D: Geomorphology, stratigraphy and vegetation at Little Swamp



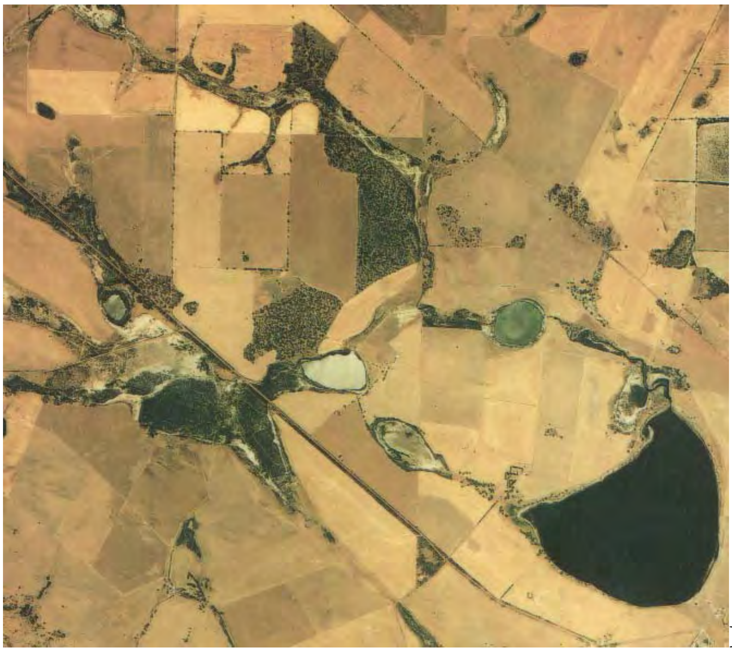
E



F

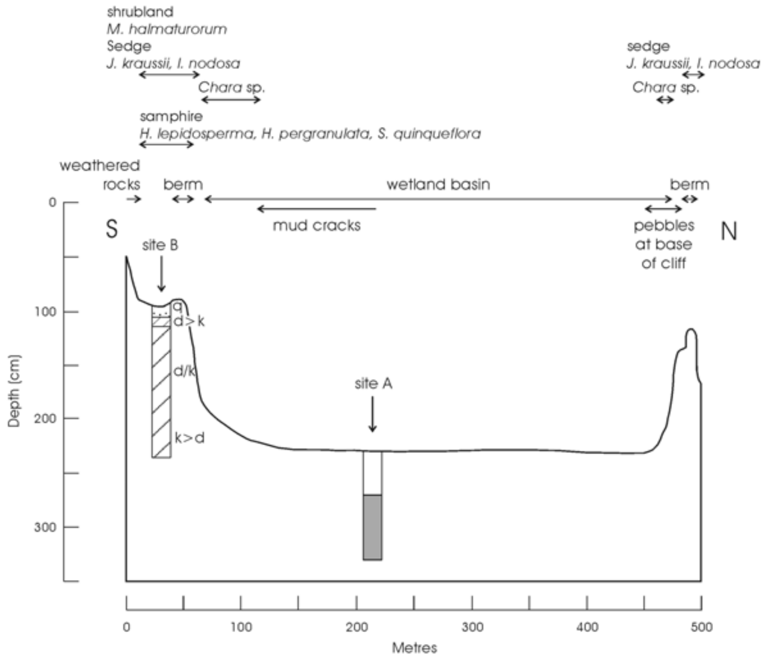
Figure 26 - E: Hydrograph of groundwater and surface water at Little Swamp
F: Water salinity at Little Swamp

A

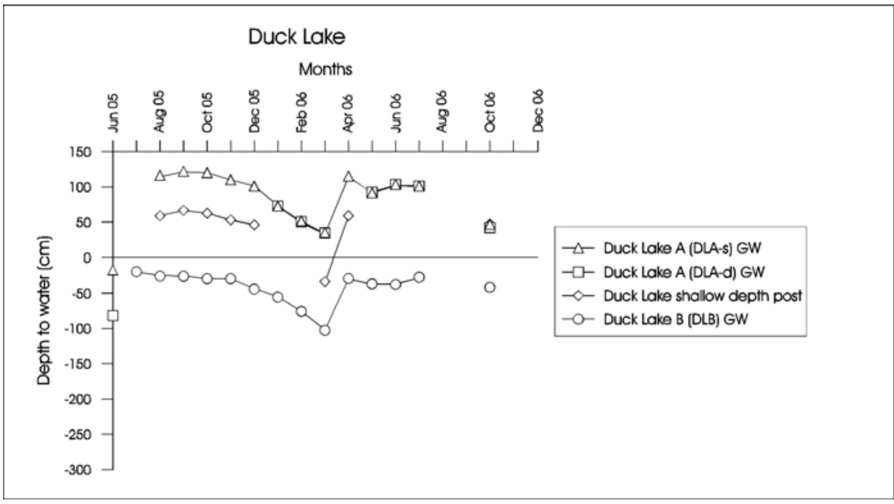

B


C

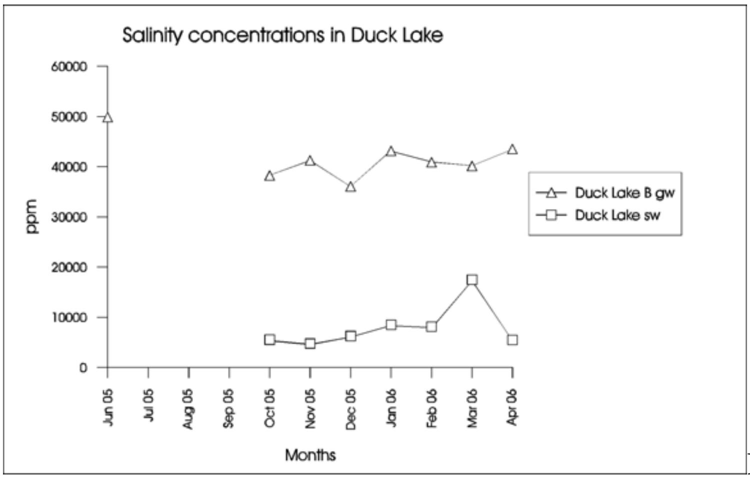
Figure 27: - A: Location of Duck Lake
B: Aerial Photo of Duck Lake
C: Photo from shore of Duck Lake at high water



D



E



F

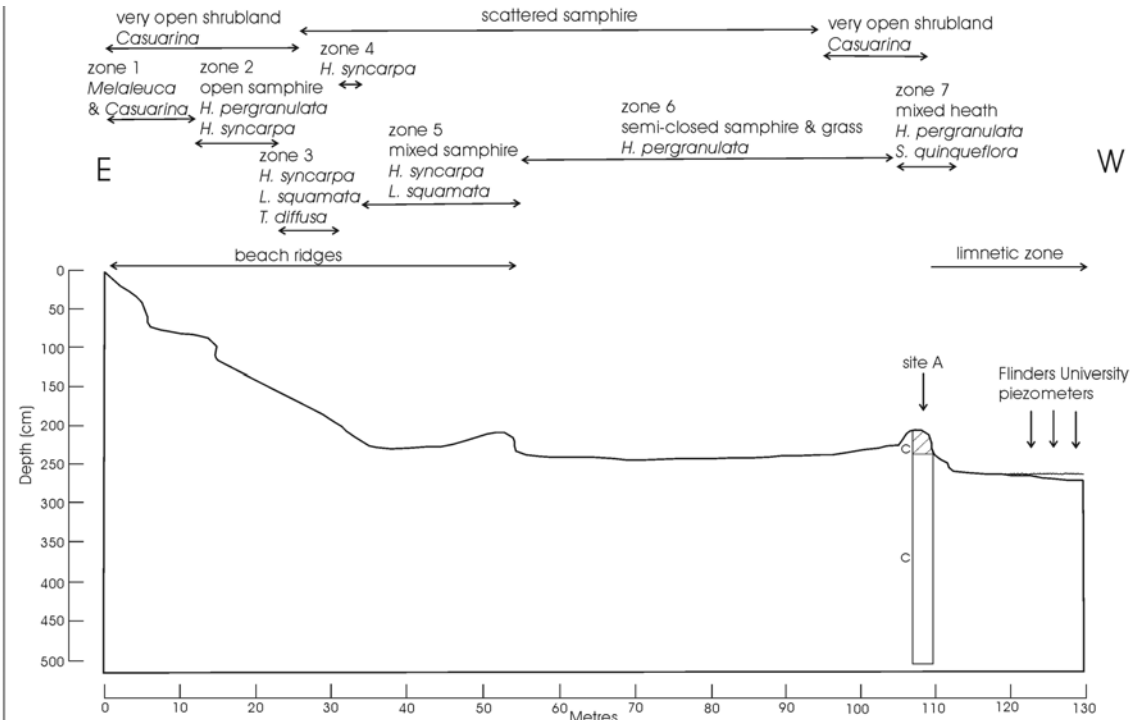
Figure 27: - D: Geomorphology, stratigraphy and vegetation at Duck Lake
E: Hydrograph of groundwater and surface water at Duck Lake
F: Water salinity at Duck Lake

A


B

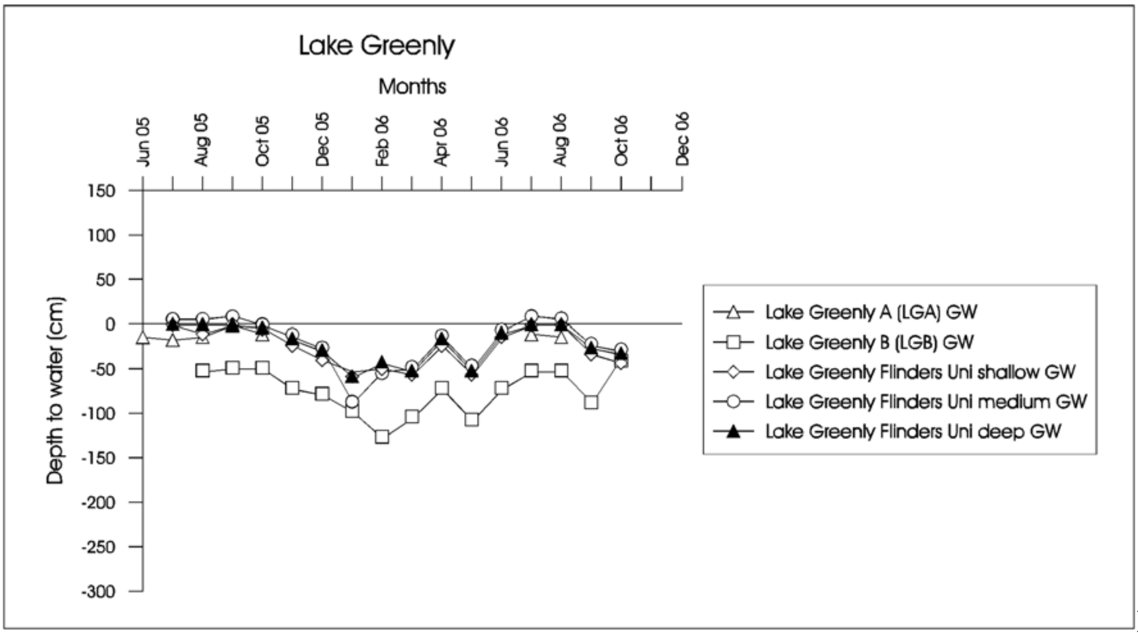
Figure 28: - A: Location of Lake Greenly
B: Aerial Photo of Lake Greenly

C



D

Figure 28: - C: Photo from eastern shore of Lake Greenly to across the basin
D: Geomorphology, stratigraphy and vegetation at Lake Greenly



E

Figure 28: - E: Hydrograph of groundwater and surface water at Lake Greenly

Wanilla suite (Fig. 29)
Setting: Small scale alluvial fans underlain by orange-brown quartz sand, sandy clay, silt, gravel and calcrete nodules.
Wetland types: Creeks, palusplains
Description: This suite consists of short microscale channels which descend from the Lincoln Hills, traverse the alluvial fans at the base, and thereafter become waterlogged flats. These wetlands are seasonally inundated or seasonally waterlogged.
Hydrology: The creeks are shallow (20 cm) and have flow periods of approximately 5 months, recharged by direct rainfall and runoff from Lincoln Hills. In the wetter season, rainwater infiltrates and waterlogs the top 50 cm of sediment under the adjacent flats. Under current conditions, water from the creek discharges to the groundwater under the adjacent flats.
Stratigraphy: Wetlands are underlain by alluvial clay mineral muddy sands, quartz silt, and ferricrete, and gravel composed of quartz, veined calcrete, feldspar and nodular weathered shale. Phytoliths are present in the surface layers of the sedimentary profile. The basement is feldspathic and lithoclastic very coarse sand and gravel.
Water Quality: The water salinity of all waters was generally hyposaline (2,800-18,000 mg/L), groundwater being slightly higher than surface water. Cation concentrations were low (Appendix 1), as were levels of arsenic, lead, copper and phosphorous. The surface and groundwaters fluctuated around slightly alkaline (pH 8.4), the range being pH 7.6-8.8.
Vegetation: The riparian vegetation and waterlogged plains support open shrublands of *Melaleuca brevifolia* sometimes with an understorey of sedge *Carex* sp. and grass *Sporobolus virginicus*.

Three sites were visited. Two sites were selected for monitoring: Merintha Creek, GPS 34^{o} 34 1.2"S and 135^{o} 36' 39.9"E, and Wanilla GPS 34^{o} 33.04'S and 135^{o} 39.59'E. One piezometer was installed at Merintha Creek on the flat, and one piezometer on the flat and a surface water gauge near the creek were installed at Wanilla for monthly water level readings.

A

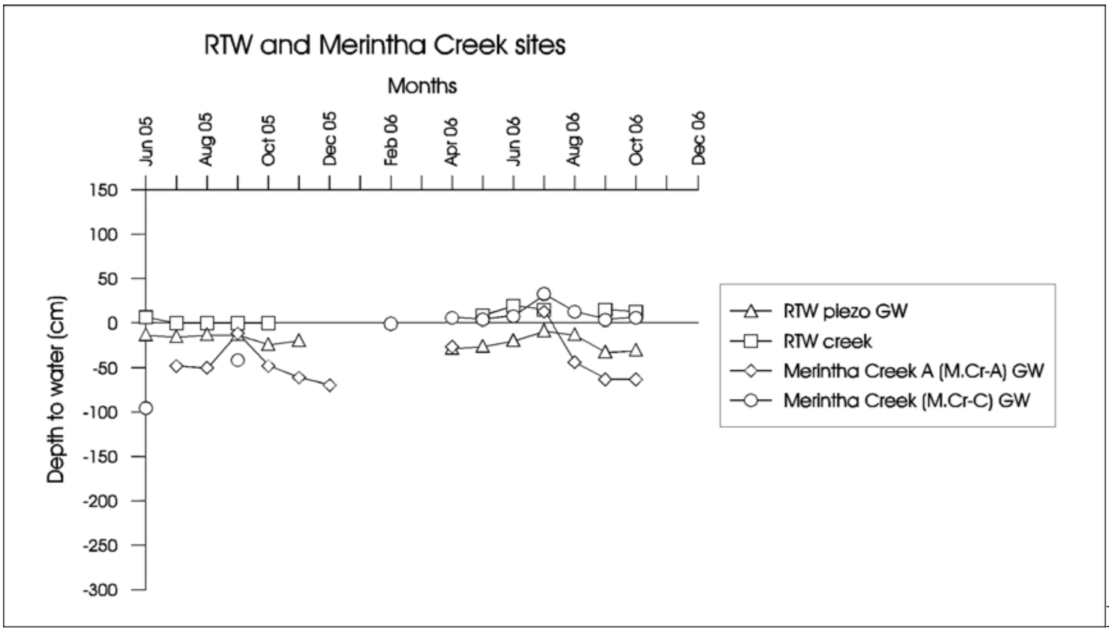
Figure 29: - A: Location of Wanilla and Merintha Creek


B

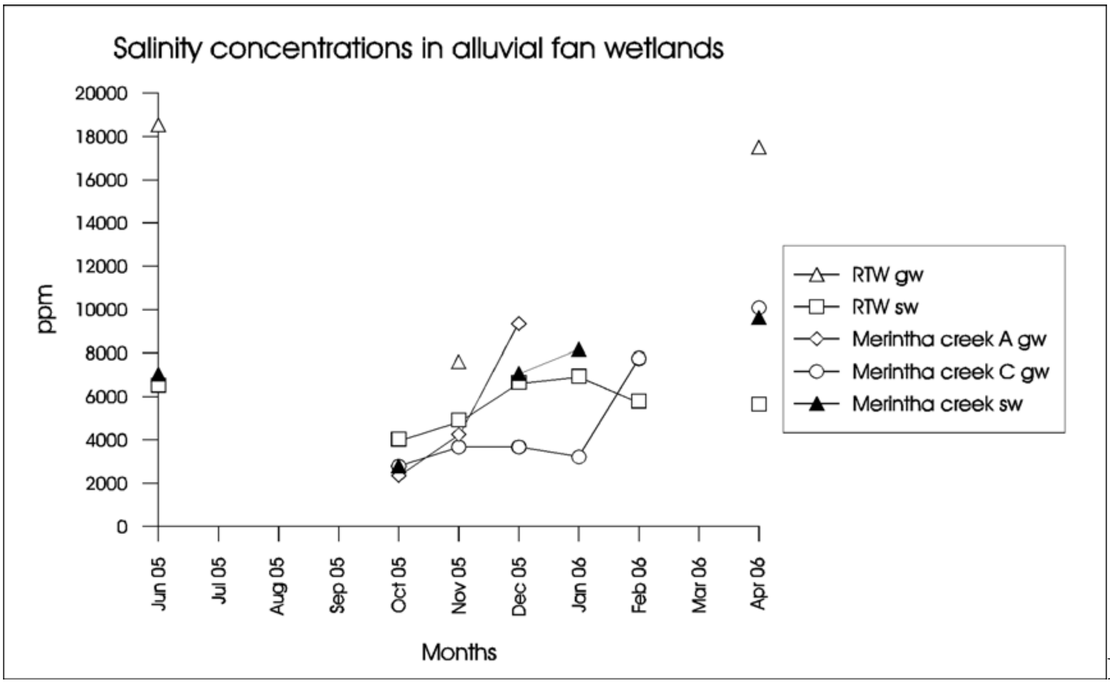

C


D

Figure 29: - B: Aerial Photo of Wanilla and Merintha Creek
C: Photo of site at Merintha
D: Photo of site at Wanilla



E



F

Figure 29: - E: Hydrograph of groundwater and surface water at Wanilla and Merintha Creek
F: Water salinity at Wanilla and Merintha Creek

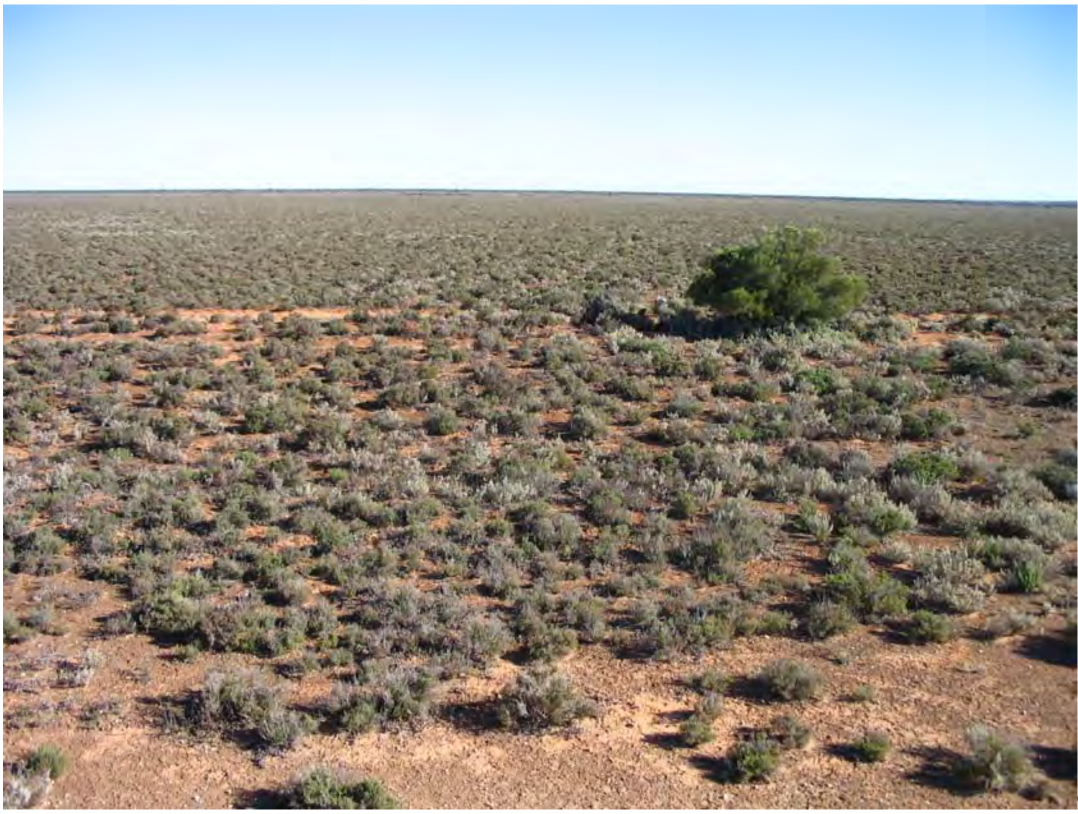
Murninnie suite (Fig. 30)
Setting: Large scale merging alluvial and tidal flats underlain by clay soil veneer on red-brown sand over calcrete.
Wetland types: Palusplain, creeks
Description: This suite contains a megascale flat with cheniers on the surface, a tidal creek and pools at the coastal edge and leptoscale creeks inland.
Hydrology: The portion of the flat nearest the coast is recharged by tidal marine waters; inland the flat is hydrologically recharged by groundwater rise and discharged by creeks and evapo-transpiration.
Stratigraphy: On the tidal flat the wetland fill is brown calcareous mud with some kaolinitic mud and quartz silt. Further inland this becomes red kaolinitic muddy sand. The basement material is quartz sand.
Water Quality: No data
Vegetation: A tidal flat with maculiform low samphire shrub vegetation, *Halosarcia halocnemoides, Halosarcia pruinosa, Halosarcia pergranulata, Frankenia pauciflora, Schlerostegia arbuscular, Maireana oppositifolia,* grades into palusplain with diverse low samphire shrubland of *Schlerostegia disarticulata, Atriplex vesicaria, H. pruinosa, Hemichroa diandra, Maireana appressa, Minuria cunninghami,* which gives way inland to a low open shrubland of Bluebush (*Maireana sedifolia*).

Three sites were visited. No sites were set up for monitoring, on the advice that at the time community support in this area was unknown.

A

Figure 30: - A: Location of Murninnie

B



C

Figure 30: - B & C: Photos of Murninnie wetland showing samphire-vegetated surface

Pinthaput suite (Figs. 31, 32)
Setting: Sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand or quartz sand overlying alluvium.
Wetland types: Sumplands.
Description: This suite consists of mesoscale to microscale linear basins aligned with the northwest to southeast orientation of the linear dune and swale field in which they lie.
Hydrology: There appears to be very little annual fluctuation (15 cm) in the water table due either to recharge or discharge. The water table lies close (< 25 cm) to the ground surface waterlogging the shallow sediments, and during the wet season, it rises to the surface. Rain infiltrating the near surface sediments at the basin margins discharges to the central basin. Perching of surface or near surface water occurs during the wetter months.
Stratigraphy: The wetland fills predominantly are filled with sandy muds and muddy sands. Kaolinitic mud occurs throughout the profile but the sands are variable in composition. Quartz may occur alone or variably mixed with gypsum or carbonate mud intraclasts in various proportions. Sometimes, gypsum fine sand or gypsum mud constitute the surface layers. The basement material is quartz sand.
Water Quality: The water salinity of all waters was hypersaline (41,000-270,000 mg/L), the upper level indicating gypsum precipitating conditions. Cation concentrations were high (Appendix 3), especially sodium and magnesium, but levels of arsenic, lead, copper and phosphorous were low. Waters were acidic with a mean of pH 4.5 ranging from pH 3.5-7.1, suggesting current dissolution of gypsum crystals.
Vegetation: At the contact between the wetland and adjacent calcretised sand dune, a narrow band of open shrubland may occur *Eucalyptus* sp. (*e.g.*, *Eucalyptus incrissatta*), *Melaleuca uncinata* and *Melaleuca halmaturorum* with an understorey of *Maireana brevifolia*, and locally (*e.g.*, Site 2), *Allocasuarina helmsii*. On the flatter parts of the wetlands, such as a vegetated periphery or across the basin, low samphire shrubland dominates: *Halosarcia pruinosa*, *Hemichroa diandra*, *Lawrencia spicata*, *Disphyma crassifolium*, *Maireana erioclada*, *Maireana brevifolia*, *Osteocarpum salsaginosum*, and *Nitraria billardierei*.

Three sites were visited including un-named wetlands. Two sites were selected for monitoring: Simpson Rd, GPS 33^o 6.72’S and 135^o 25.49’E and Cocata Hill Rd GPS 33^o 14.24’S and. 135^o 26.24’E One piezometer was installed at Simpson Rd, and three (one deep and one shallow in the centre and one at the margin) piezometers were installed at Cocata Hill Rd for monthly water level readings.

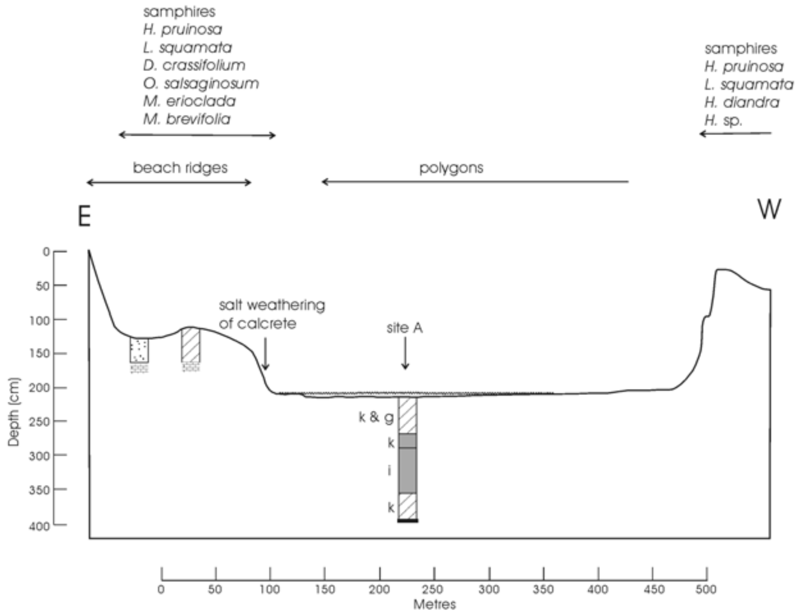
A

Figure 31: - A: Location of Pinthaput sites 1 and 2

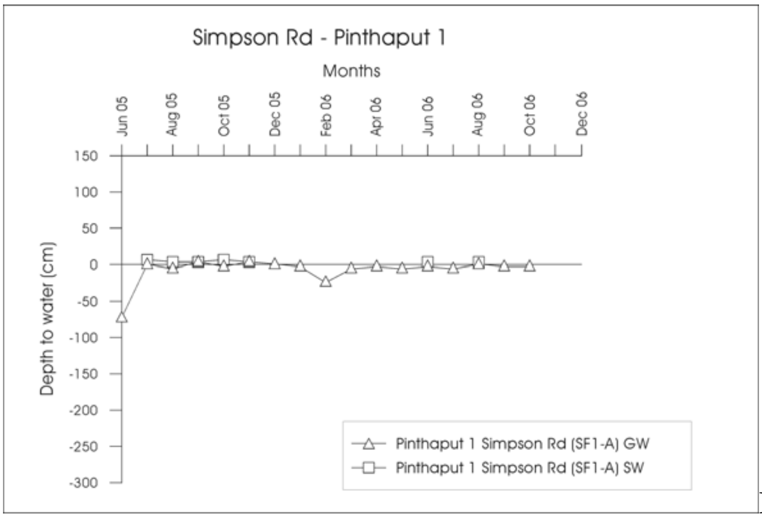
B

C

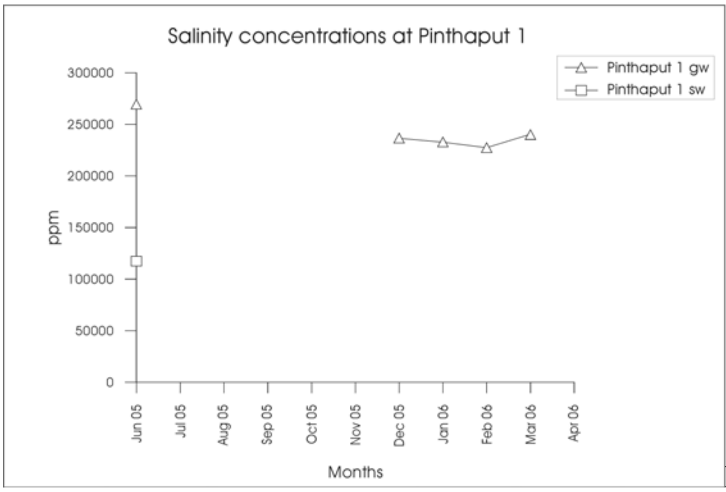
Figure 31: - B: Aerial Photo of Pinthaput site 1
C: Photo of site at Pinthaput site 1 showing steep shore with peripheral vegetation



D



E



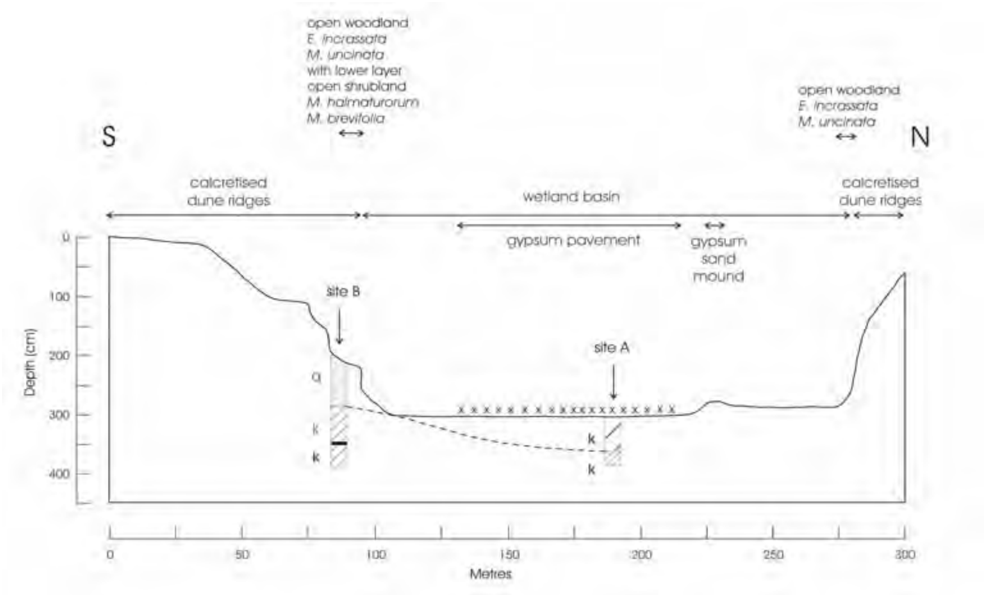
F

Figure 31: - D: Geomorphology, stratigraphy and vegetation at Pinthaput site 1
E: Hydrograph of groundwater and surface water at Pinthaput site 1
F: Water salinity at Samphire Flat and Pinthaput sites

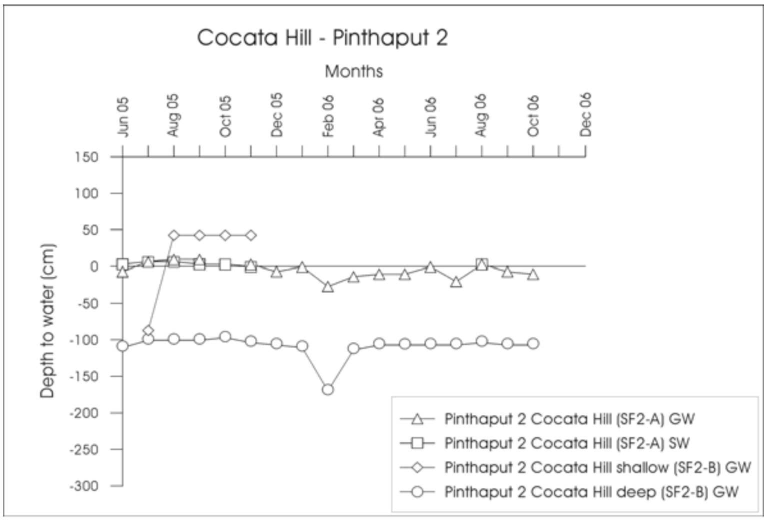

B


C

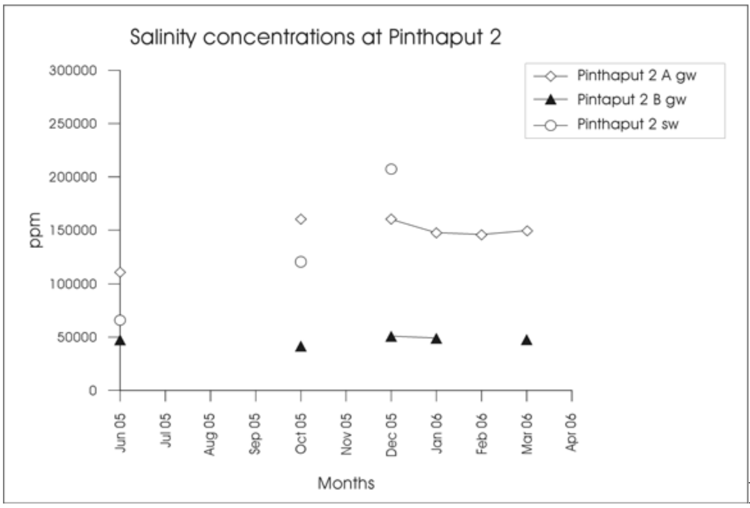
Figure 32: - B: Aerial Photo of Pinthaput site 2
C: Photo of site at Pinthaput site 2 showing steep shore with peripheral vegetation



D



E



F

Figure 32: - D: Geomorphology, stratigraphy and vegetation at Pinthaput site 2
E: Hydrograph of groundwater and surface water at Pinthaput site 2
F: Water salinity at Pinthaput site 2

Samphire Flat suite (Fig. 33)
Setting: Sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand or quartz sand overlying massive calcrete, limestone, granite, or alluvium.
Wetland types: Palusplain or barlkarra.
Description: This suite consists of megascale to mesoscale flats with peripheral fingers and irregularities aligned with the northwest to southeast orientation of the linear dune and swale field in which it lies. The wetland surface is undulating, due to many small scale features: low parallel ridges, scours from surface water flows and wind deflation, hollows where surface water collects intermittently, sand shadow mounds trapped behind plants, and low dunes.
Hydrology: There appears to be very little annual fluctuation (15 cm) in the water table due either to recharge or discharge. Perching of surface or near surface water occurs during the wetter months. In Samphire Flat itself, waterlogging is probably intermittent, groundwater being contained between semi-confining layers of calcrete, gypsum crystals and gypsum sands (-100 cm, -250 cm). Seasonal inundation (< 20 cm) occurs where and when there is perching of surface water.
Stratigraphy: The wetland fills predominantly are filled with sandy muds and muddy sands. Kaolinitic mud occurs throughout the profile but the sands are variable in composition. Quartz may occur alone or variably mixed with gypsum or carbonate mud intraclasts in various proportions. Sometimes, gypsum fine sand or gypsum mud constitute the surface layers. Calcrete layers (massive and nodular) are also present throughout the wetland profile and adjacent dunes. This sedimentary sequence seems to indicate a record of wetter and drier phases throughout the history of the wetlands, the quartz, carbonate mud intraclasts and gypsum sand forming during drier periods and the crystalline gypsum, gypseous mud and clay mineral mud accumulating during inundation. Salt crystals also occur in the surface layers. The basement material is quartz sand.
Water Quality: The water salinity of all waters was hypersaline (41,000-270,000 mg/L), the upper level indicating gypsum precipitating conditions. Cation concentrations were high (Appendix 1), especially sodium and magnesium, but levels of arsenic, lead, copper and phosphorous were low. Waters were acidic with a mean of pH 4.5 ranging from pH 3.5-7.1, suggesting current dissolution of gypsum crystals.
Vegetation: Low samphire shrubland dominates: *Halosarcia pruinosa, Hemichroa diandra, Lawrencia spicata, Disphyma crassifolium, Maireana erioclada,* and *Maireana brevifolia*.

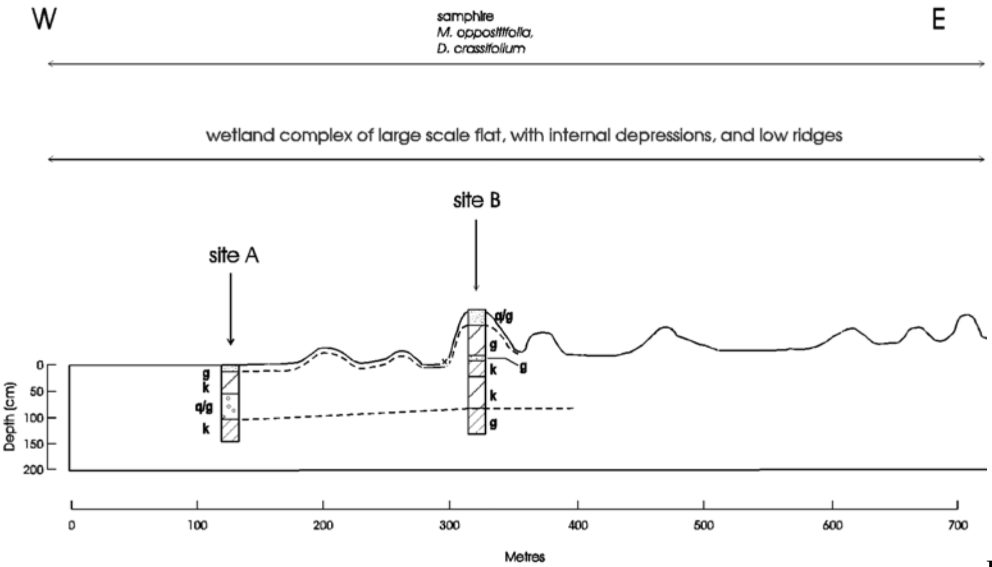
One site was visited and selected for monitoring: Samphire Flat GPS 33^{o} 10.52'S and 135^{o} 28.41'E. Two piezometers were installed at Samphire Flat for monthly water level readings.

Figure 33: - A: Location of Samphire Flat site 3

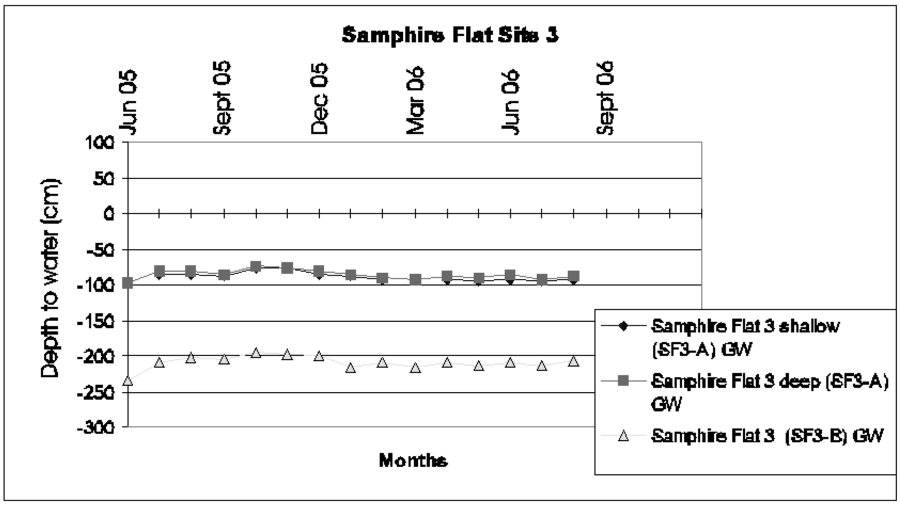
B

C

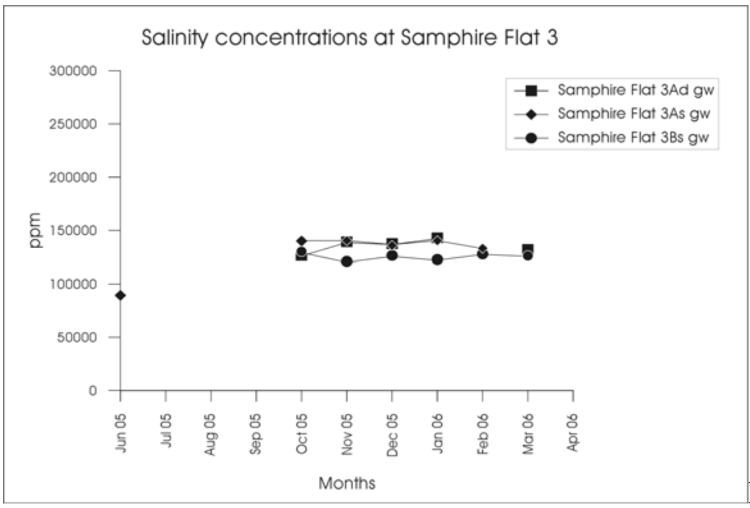
Figure 33: - B: Aerial Photo of Samphire Flat site 3
C: Photo of site at Samphire Flat site 3, showing samphire vegetated surface



D



E



F

Figure 33: - D: Geomorphology, stratigraphy and vegetation at Samphire Flat site 3
E: Hydrograph of groundwater and surface water at Samphire Flat site 3
F: Water salinity at Samphire Flat site 3

Munyaroo suite (Fig. 34)
Setting: Coastal expression of the sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand or quartz sand overlying massive calcrete, limestone, granite, or alluvium .
Wetland types: Sumplands, damplands
Description: This suite contains microscale linear ovoid wetlands in the inter dune depressions of the linear dune field at the coast. These wetlands are seasonally waterlogged and may occasionally be inundated. Wetlands initially have been scoured out by marine processes and then the breach has been healed by the construction of shore parallel ridges. The regional water table is quite close to the surface at this location and probably maintains waterlogged conditions for most of the year.
Stratigraphy: The wetland fills have a layer of calcareous mud at the surface which overlies red dune sand or cream re-worked sand. Calcrete layers are also present throughout the wetland profile and adjacent dunes.
Water Quality: No data
Vegetation: Low samphire shrubland.

4 un-named wetland sites were visited. No sites were selected for monitoring because of the difficulty of access.

A

Figure 34: - A: Location of Munyaroo


B

Figure 34: - B: Aerial Photo of Munyaroo wetlands

In the limestone belt which covers the southern and western parts of Eyre Peninsula, there are two settings in which wetland formation takes place and two distinct processes. The first setting is that in which coastal parabolic dunes are constructed. In such settings, parabolic dune construction has continued since the Pleistocene and distinct layers of cemented to unconsolidated cross bedded calcareous sands testify to numerous phases of dune construction. Parabolic dunes formed by southwesterly wave and wind agents acting upon supplies of sands eroded from the coast are re-worked into dune ridges or isolated parabolic dunes which encroach inland leaving long trailing arms. In the wind deflated bowls of such parabolic dunes, wetlands form at the water table or perched on the limestone pavement which marks a much older water table position.

The second setting is that in which karst processes are active in the ridges, swales and flats of the coastal limestone belt. Linear chains of sink holes, canyons, caves, weathered pavements and wetland basins occur between Streaky Bay and Drummond Point. Limestone dissolution is a major process of wetland formation, and in many cases, hydrological maintenance, through the formation of conduits connecting inland wetlands to the marine environment.

As a result of these two different settings, two broad wetland suites have been identified: Coffin Bay suite in the parabolic dune setting, and Hamilton suite in the karst landscape. However, there may be a case for further subdivision based on the following factors: the different ages of the wetlands, the climatic gradient from south to north with respect to rainfall, and the occurrence of a coastal barrier adjacent to the wetland which may have influenced sedimentological, hydrological and hydrochemical characteristics of the wetland. In younger wetlands, there has been insufficient time for individual wetland basins to coalesce into one continuous basin, *e.g.*, Lake Newland, and for the calcareous sand barrier which separates this wetland from the coast to become completely solidified. In the first instance, the geometry of the younger wetland will alter, the wetland fill and the hydrochemistry throughout the basins may become less heterogeneous with time. In the second instance, pathways of water flow through an unconsolidated barrier are likely to be more akin to sheet flow and less like the established conduit flow from specific points into the wetland, which typifies limestone ridges, thus effecting the hydrology overall. All of these factors are important in applying criteria for wetland consanguinity and may over time result in a distinct suite called the Lake Newland suite.

The rainfall gradient is important in that it affects the water regime of the wetlands and also the geochemistry and hydrochemistry, which, in this setting, is likely to precipitate gypsum. The occurrence of gypsum in the northern wetlands may be sufficient to further effect local water flows, storage capacity, and surface and groundwater chemistry, and through these mechanisms create new assemblages of plants and biota. In addition, karst weathering of gypsum, in contrast to limestone, may be a new and more rapid process of wetland formation. These factors may influence the categorisation of wetlands into a new suite called the Calpatanna suite.

What follows is a preliminary subdivision of suites which may be altered with additional information on the relevant wetland sites.

Coffin Bay suite (Fig. 34)
Setting: Bowls of parabolic dunes underlain by limestone.
Wetland types: Sumplands.
Description: This suite consists of microscale elongate linear to irregular basins. These wetlands are seasonally inundated. The wetland surface is covered by a thin veneer of clasts and low beach ridges and strandlines are also composed of this material which has been eroded from the relic polygons and stromatolites.
Hydrology: Recharge appears to be via direct rainfall and groundwater recharge. Average annual water level fluctuations are 50 cm. Water flow in the basin is downward.
Stratigraphy: The sedimentary fill above the limestone is composed of calcareous sandy mud overlying calcareous intraclast sand. Ostracod and bivalve shells occur throughout.
Water Quality: The salinity concentrations in the groundwaters at Pillie Lake indicate that there are two distinct aquifers; the shallow one containing water which is dominantly mesosaline (30,000-40,000 mg/L) and the deeper one containing water which is hyposaline (5,000-16,000 mg/L). For three or four weeks annually, water salinity in the shallow aquifer is diluted by rainfall. Cation concentrations in the waters at the time of sampling were all low (Appendix), as were levels of arsenic, lead, copper and phosphorous. The water in the deeper aquifer is more alkaline (mean pH 8.3) than in the shallow aquifer (mean pH 7.7).
Vegetation: Macrophyte communities are peripheral and zoned (zoniform), the inner zone comprising *Wilsonia backhousei* and *Sarcocornia quinqueflora* and the outer zone comprising open heath of *Melaleuca brevifolia* and *Gahnia trifida.* The aquatics comprise species of *Chara.*

Six sites were visited. One site was selected for monitoring: Pillie Lake, GPS 34^o 49’ 16.4”S and 135^o 51’ 25.0”E. Two piezometers were installed, one deep and one shallow, for monthly water level readings.

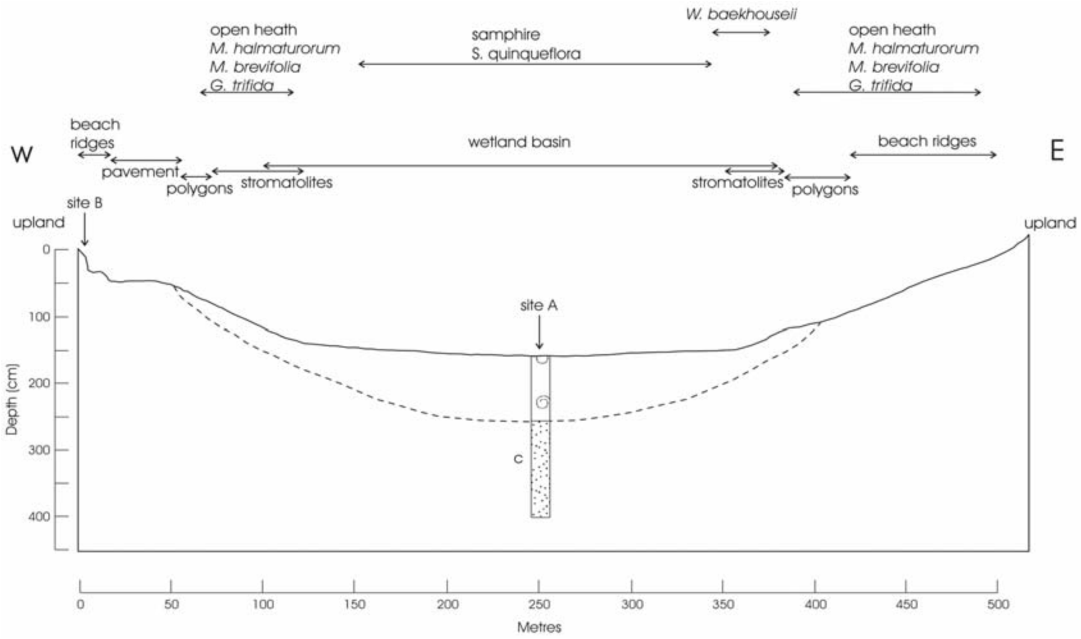
A

Figure 34: - A: Location of Pillie Lake

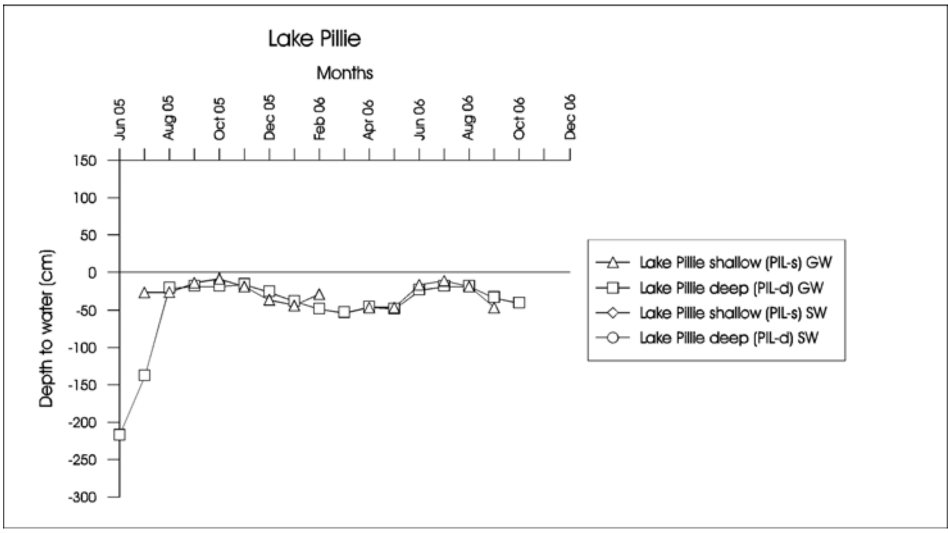

B

C

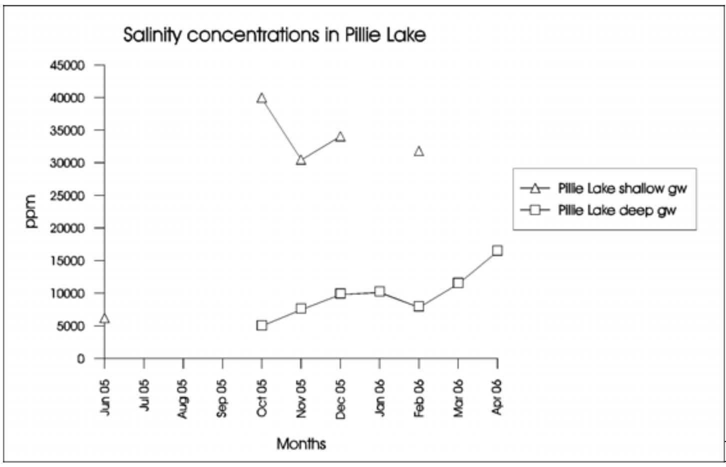
Figure 34: - B: Aerial Photo of Pillie Lake
C: Photo of site at Pillie Lake showing low gradient shore and, in the middle ground, the ring of peripheral vegetation



D



E



F

Figure 34: - D: Geomorphology, stratigraphy and vegetation at Lake Pillie
E: Hydrograph of groundwater and surface water at Lake Pillie
F: Water salinity at Lake Pillie

Subdivision of the Coffin Bay suite

Kilroy suite (Fig. 35)
Setting: Low undulating flat set amidst limestone hills and underlain by limestone.
Wetland types: Palusplain, barlkarra
Description: This suite consists of an undulating megascale flat which may have been an extensive area of blowouts. The wetland is intermittently inundated now with areas that are seasonally waterlogged but it may once have been more regularly flooded. Recharge appears to be via direct rainfall and groundwater recharge.
Stratigraphy: The wetland surface is covered by a thin veneer of calcareous sandy mud (40 cm) and calcareous intraclast sand. Some surface areas are enriched by organic matter (0-15 cm). Diatomite may be present.
Water Quality: No data
Vegetation: Plant communities ranged from pure stands of *Melaleuca* sp. to *Melaleuca* open shrubland and scrub with an understorey of *Gahnia* to low open samphire shrubland.

Three sites were visited. No sites were selected for monitoring given the difficulty of access and the owner's intention to clear much of the endemic assemblages.

A


B

Figure 35: - A: Location of Kilroy Suite
B: Photo of Kilroy wetland

C

Figure 35: - C: Photo of Brampton wetland

Hamilton suite (Figs. 36, 37, 38)
Setting: These wetland systems occur in a karst landscape, in depressions between the successive limestone ridges, former bowls of parabolic dunes, or infilled sink holes, and are surrounded and underlain by limestone.
Wetland types: Sumplands.
Description: This suite consists of mesoscale to microscale ovoid basins and a megascale elongate linear basin. These wetlands are seasonally inundated.
Hydrology: In Lake Hamilton, recharge appears to be via several pathways. Direct precipitation is in many places perched (over shallow limestone, cemented calcarenite or calcilutite), although in other areas this may eventually infiltrate to the water table. Fresh water from the eastern and western limestone ridges discharges into the lake. On the western ridge such seepage lines have been mapped while on the eastern side springs are evident. Vents occur on the western side of the lake which appear to be the outlet for marine waters, and tidal channels transport this water from the western edge to the central basin.

In the Elliston wetlands, recharge appears to be via direct rainfall and infiltration to the shallow water table. Period of inundation is short, water being discharged via seepage through the limestone and evaporation.

Stratigraphy: The wetland fills in Lake Hamilton and Round Lake have an indurated crust at the surface underlain by calcareous intraclast sand over the main body of calcareous mud which sits on a limestone basement. The depth to limestone and therefore the thickness of the calcareous mud varies from site to site. Calcareous mud has cemented in some areas and occurs as a gelatinous waterlogged mud in others. Algal mats form on the surface, while emergent stromatolite heads form beach ridges and pavements. Ostracod and gastropod shells occur in surface layers.

The Elliston wetlands are underlain by relatively thick (2-3 m) white calcareous mud with calcrete sometimes at the surface, and sometimes in the subsurface, capping layered Pleistocene cemented calcareous mud. Mud composed of diatoms occurs at about 1 m from the surface in Lake Hamp. The sedimentary fill is underlain by limestone.

Water Quality: The salinity concentrations in Lake Hamilton and Round Lake varied both temporally and spatially. Within a single sampling period (April 2006), salinity concentrations in the groundwater varied from hyposaline to hypersaline (4,800-72,000 mg/L). Data collected from some of the same sites in September 2005 and January 2006 showed that salinity concentrations were just as volatile over seasons (Appendix 1). The surface water salinity was sampled at a number of sites: the vent, in the tidal creek and in the main lake body on the western and eastern sides. Measures of surface water were in the vent 32,000 mg/L, in the channel 28,000 mg/L, in the western part of the lake 27,000 mg/L, and in the eastern part of the lake 19,800 mg/L respectively, mostly in the mesosaline category but clearly demonstrating different sources. Water salinity in the shallow surface aquifer is diluted by rainfall and concentrated by evapo-transpiration. Cation concentrations in the waters at the time of sampling were low to medium with the greatest contribution from sodium and the least from potassium and calcium (Appendix 1). Levels of arsenic, lead, copper and phosphorous were low. Spatial variability in pH was also evident, the most alkaline waters coming from the vent (pH 8.2) and the more neutral waters at the lake surface (pH 6.9).

The salinity concentrations in the groundwaters at Lake Hamp (Elliston) were hypersaline (96,000-105,000 mg/L). Cation concentrations in the waters at the time of sampling were all medium (Appendix). Levels of arsenic, lead, copper and phosphorous were low. The groundwater was acidic (mean pH 6.7) which in the carbonate mud aquifer is unusual. It may be assumed that the carbonate mud is acting as a buffer, and that the inflowing waters are initially more acidic. The potential source of such acidic waters is probably the leachate from the rubbish dump.

Vegetation: Plant communities in Lake Hamilton are diverse and vary with substrate type and water chemistry. On intraclast sand, the community comprises shrubland of *Melaleuca brevifolia* and *Olearia axillaris* with an understorey of *Gahnia trifida, Isolepis nodosa*, and *Sarcocornia quinqueflora*. In waterlogged areas this is replaced with pure stands of *Gahnia trifida*. On calcareous mud, the plant communities tend to be low samphire shrublands comprising *Sarcocornia quinqueflora, Sarcocornia blackiana*, *Suaeda australis, Halosarcia halocnemoides, Halosarcia pruinosa,* with *Wilsonia humilis, Hemichroa pentandra, Frankenia pauciflora,* and *Samolus repens.* On beachridges and on shoreline stromatolitic pavements, *Suaeda australis* and *Sarcocornia quinqueflora* form open low shrublands. Around freshwater seepages and springs, *Juncus kraussii* and *Gahnia trifida* occur. Two of the dominant aquatic plants occurring are the charaphyte *Lamprothamnium* sp. and the seagrass *Ruppia* sp.

Plant communities at Lake Hamp are peripheral and zoned (zoniform), the inner zones comprising *Halosarcia pergranulata* with scattered *Sarcocornia blackiana,* then *Wilsonia humilis* and the outer zones comprising open heath of *Melaleuca halmaturorum* with an understorey of *Halosarcia pruinosa, and open shrubland of Melaleuca halmaturorum, Olearia axillaris, Leucopogon parviflorus,* and *Exocarpus syrticola.* The aquatics comprise species of *Chara.*

Sixteen sites were visited. Three sites were selected for monitoring: Round Lake, GPS 33^{o} 56’ 24.4”S and 135^{o} 16’ 40.8”E, Lake Hamilton east GPS 33^{o} 57’ 11.9”S and 135^{o} 16’ 49.2”E, and Lake Hamp, GPS 33^{o} 38’ 0.5”S and 134^{o} 53’ 41.0”E. Three piezometers and a surface water gauge were installed at Round Lake, a surface water gauge and two piezometers, one deep and one shallow, were installed at Lake Hamilton east, and two piezometers were installed at Lake Hamp, for monthly water level readings.

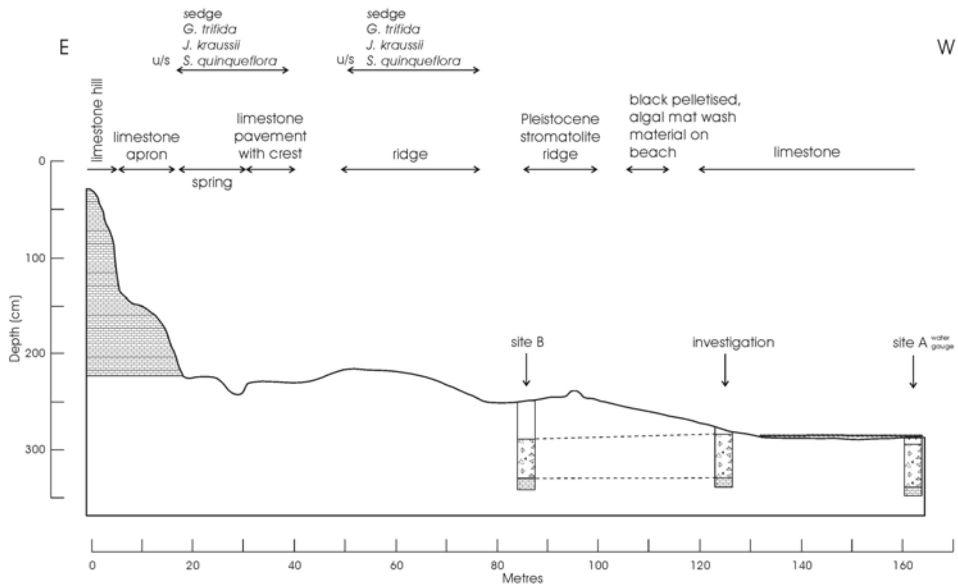
Figure 36: - A: Location of Lake Hamilton

B

Figure 36: - B: Aerial Photo of Lake Hamilton


C

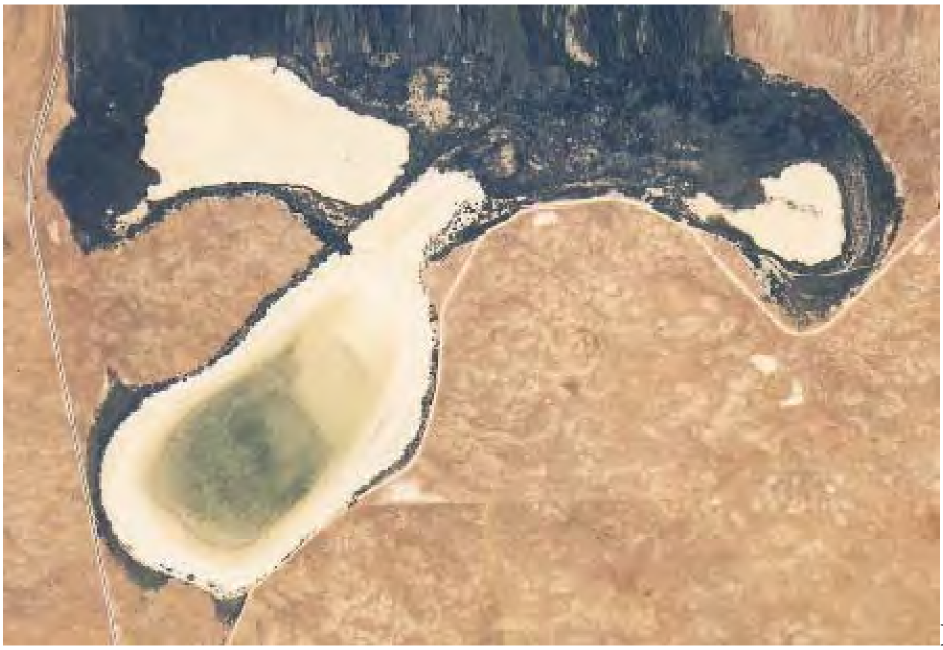

D



E

Figure 36: - C: Photo of site at Lake Hamilton west (view across limestone and across lake)
D: Photo of site at Lake Hamilton east
E: Geomorphology, stratigraphy and vegetation at Lake Hamilton

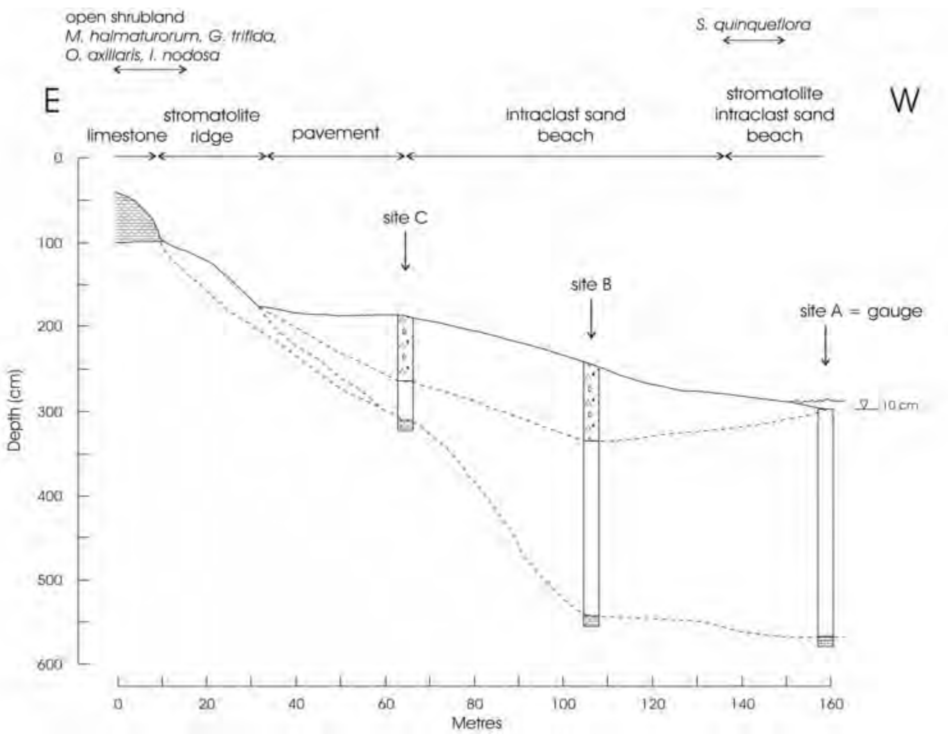
A



B

Figure 37: - A: Location of Round Lake
B: Aerial Photo of Round Lake

C



D

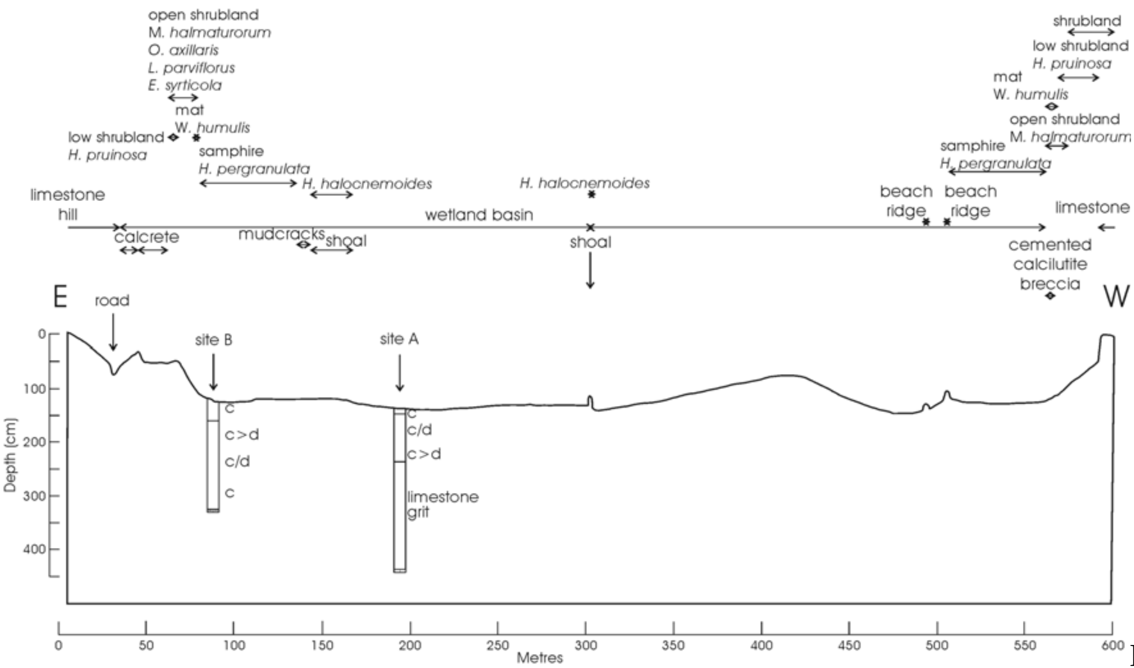
Figure 37: - C: Photo of Round Lake across the basin from the stromatolite zone
D: Geomorphology, stratigraphy and vegetation at Round Lake

A

B

Figure 38: - A: Location of Elliston wetlands
B: Aerial Photo of Lake Hamp and Cemetery Lake

C



D

Figure 38: - C: Photo of Lake Hamp across the dried basin floor (end of summer)
D: Geomorphology, stratigraphy and vegetation at Lake Hamp

Subdivision of the Hamilton suite
Gully suite (Fig. 39)
Setting: karst landscape:-swale between coastal dune ridges underlain by limestone
Wetland types: Wadi
Description: This suite consists of microscale incised dendritic channels in steep gullies in the midst of limestone hills. The channels are seasonally to intermittently inundated for very short periods. Recharge appears to be via direct rainfall, local run-off and minor seepage with rapid infiltration to the water table.
Stratigraphy: basement limestone
Water Quality: No data
Vegetation: Plants have been grazed.

One site was visited: Wild Dog Gully. No sites were selected for monitoring, GPS 33^{o} 44' 14.9"S and 135^{o} 03' 55.1"E.

A


B

Figure 39: - A: Location of Wild Dog Gully
B: Photo of Wild Dog Gully

Subdivision of the Hamilton suite

Calpatanna suite (Fig. 40)

Setting: Karst terrain of red sandy mud underlain by Pleistocene laminated limestone and calcrete.

Wetland types: Lakes, sumplands

Description: This suite consists of a macroscale to microscale oblong to irregular basins. Some of the wetlands are former dolines and others are cavities around vents in the underlying marine shelly limestone. Wetland margins exhibit erosion features such as cliffs (0.5-1.0 m) and infilling with sand from dissolution of limestone. Wetlands are permanently and seasonally inundated.

Hydrology: Recharge mechanisms include terrestrial and marine processes. Terrestrial processes include freshwater groundwater seepage from the coastal dune barrier and direct rainfall. The occurrence of marine organisms within the wetlands supports the conclusion that basins are also recharged by marine waters through conduits and vents in the limestone.

Stratigraphy: Calcareous mud and shelly intraclast sands and gravel are the dominant wetland fills with occasional gypsum crystal layers.

Water Quality: Surface water salinity ranged from mesosaline (marine) to hypersaline (34,000-60,000 mg/L). Cation concentrations in the waters at the time of sampling were all medium, the composition suggesting seawater input (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. pH varied from slightly below neutral to alkaline (pH6.9-8.1), suggesting that there may be a number of sources and pathways for recharge of the wetlands, *e.g.*, marine conduits, freshwater seepage, groundwater and direct rainfall.

Vegetation: Plant communities are narrow, peripheral and zoned, the inner zones comprising *Halosarcia syncarpa*, *Sarcocornia quinqueflora*, *Hemichroa diandra*, then *Wilsonia humilis*, *Lawrencia spicata* and the outer zone comprising open heath of *Melaleuca lanceolata.* The aquatics comprise species of *Chara*, *Acetabularia*, and *Ruppia.* Sea anemones, macro invertebrates, and marine gastropods are present.

Six sites were visited. Three sites were selected for monitoring: Little Seagull Lake, GPS 32^{o} 57' 58 6"S and 134^{o} 12' 34.1"E, the Doline, GPS 32^{o} 56' 53 6"S and 134^{o} 12' 59.6"E, and Paddy's Vent GPS 32^{o} 56' 51.9"S and 134^{o} 13' 4.5"E. A water gauge was installed in Little Seagull Lake and in Paddy's Vent for monthly water level readings.

A

Figure 40: - A: Location of Calpatanna wetlands


B


C

Figure 40: - B: Aerial Photo of Calpatanna wetlands
C: Photo of Little Seagull Lake

D

E

Figure 40: - D: Gauge at Paddy's Vent
E: Paddy's Vent

Subdivision of the Hamilton suite

Newland suite (Figs. 41, 42, 43)

Setting: The wetland complex is situated in a karst landscape behind a dune barrier which encroaches upon the wetlands.

Wetland types: Lake, sumplands, damplands.

Description: This suite consists of a megascale linear complex of megascale to microscale, ovoid and irregular basins. These wetlands range from being permanently or seasonally inundated, to seasonally waterlogged. Basins are separated by limestone hills and pavements, and underlain by buried cliffs consistent with karst terrain. Sink holes are evident on the islands within the basins and along the basin margins themselves, some infilled with calcareous mud. Overprinting the karst geometry are modern wave built beachridges, cuspate forelands, beaches and sand shoals which encroach into the basins and subdivide them. Plants quickly colonise these shoals once they reach a minimum height above water level.

Hydrology: Some of the basins are groundwater recharged and others perch rain at the surface, particularly where the limestone is within the top 30 cm. On the eastern side, springs in the limestone aquifer occur at the margins, *e.g.*, Weepra Spring and LNS-S1. Discharge is predominantly due to evapo-transpiration and downward leakage.

Stratigraphy: The wetland calcareous mud fill ranges in depth but always overlies marine shelly limestone. In the northern part the wetland fill comprises fine to coarse intraclast sands and shelly calcareous mud. In the central part, wetland fill comprises fine sands and deeper basins are underlain by shelly, intraclastic calcareous mud. In the southern part, wetland fill comprises shelly, intraclastic, and quartz, sand and gravel. Throughout layers of shell grit (gastropods and pelecypods) or grainstone intraclasts occur.

Water Quality: The surface and groundwaters at most sites in the complex were hypersaline (38,000 mg/L to 118,000 mg/L) but can be higher (gypsum precipitating at 285,000mg/L). Where groundwater is confined in the limestone aquifer, the salinities were much lower, *i.e.*, hyposaline (5,100-7,000 mg/L) and in some areas, were close to freshwater (900-1,450 mg/L). Springs are fed from the limestone aquifer containing hyposaline water. Cation concentrations in the waters at the time of sampling were variable and showed no obvious pattern other than their concentration in the surface water, as a result of dissolution of salt precipitate residues on the wetland surface from the previous dry season. At other sites there were relatively low values of calcium and magnesium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. The chemistry of the waters fluctuated around neutral (pH 6.9 to 7.4). The spring waters exhibited slightly higher alkalinity around pH 8-8.3.

Vegetation: Plant assemblages vary according to habitat. There are 1) waterlogged basin assemblages, 2) peripheral assemblages around permanently and seasonally inundated basins, 3) assemblages on waterlogged flats underlain by calcareous mud 4) beach ridge assemblages, 5) limestone pavement assemblages, 6) limestone hill assemblages, 7) gypsum dune assemblages, and 8) assemblages associated with springs. Waterlogged basin assemblages comprise *Wilsonia humilis, Hemichroa pentandra.* Peripheral assemblages comprise scrub and heaths of *Melaleuca halmaturorum*, with clumps of *Juncus kraussii* or heath of *Halosarcia pruinosa* or low samphire shrublands of *Sarcocornia quinqueflora* and *Suaeda australis, Schlerostegia arbuscular.* Calcareous mud flat assemblages comprise *Melaleuca halmaturorum* and *Gahnia trifida.* Beach ridge assemblages comprise *Melaleuca halmaturorum, Halosarcia pruinosa, Halosarcia halocnemoides, Gahnia trifida.* Limestone pavement assemblages comprise *Meariana oppositifolia, Halosarcia pruinosa, Halosarcia pergranulata, Frankenia pauciflora, Lawrencia spicata, Samolus repens, Dodonea sp.*. Limestone hills assemblages comprise *Pittosporum angustifolium* amongst others. Gypsum dune assemblages comprise low heaths of *Halosarcia pruinosa, H. halocnemoides, Olearia axillaris, Melaleuca halmaturorum, Olearia axillaris, Leucopogon parviflorus, Exocarpus syrticola*, *Maireana oppositifolia*, and *Frankenia pauciflora*. Spring assemblages comprise *Cyperus sp.*, *Juncus kraussii, Isolepis nodosa, Baumea juncea* and *Sarcocornia quinqueflora*.

Ten sites were visited in the Newland complex itself and numerous sites along the coast road to un-named wetlands, sinkholes, and coastal shoreline cliffs and outcrops. Three sites were selected for monitoring: Middle Lake Newland Y and Z, GPS 33^{o} 24' 13.2"S and 134^{o} 51' 51.1"E; and south Lake Newland GPS 33^{o} 28' 15.8"S and 134^{o} 53' 16.0"E. One piezometer was installed at Y, one piezometer in the well, one piezometer and two surface water gauges at Z; one gauge was installed at the margin of the lake at south Newland for monthly water level readings. No piezometers were installed at north Lake Newland because of the danger of sink holes.

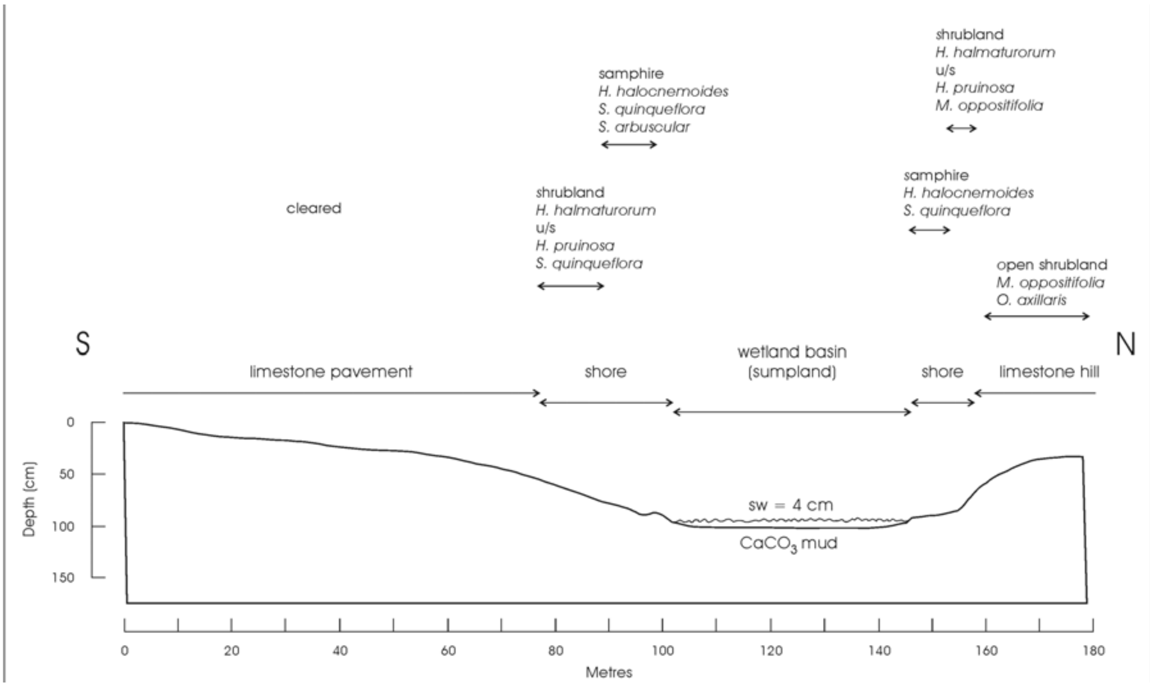
A

Figure 41: - A: Location of Lake Newland

B

Figure 41: - B: Aerial Photo of Lake Newland

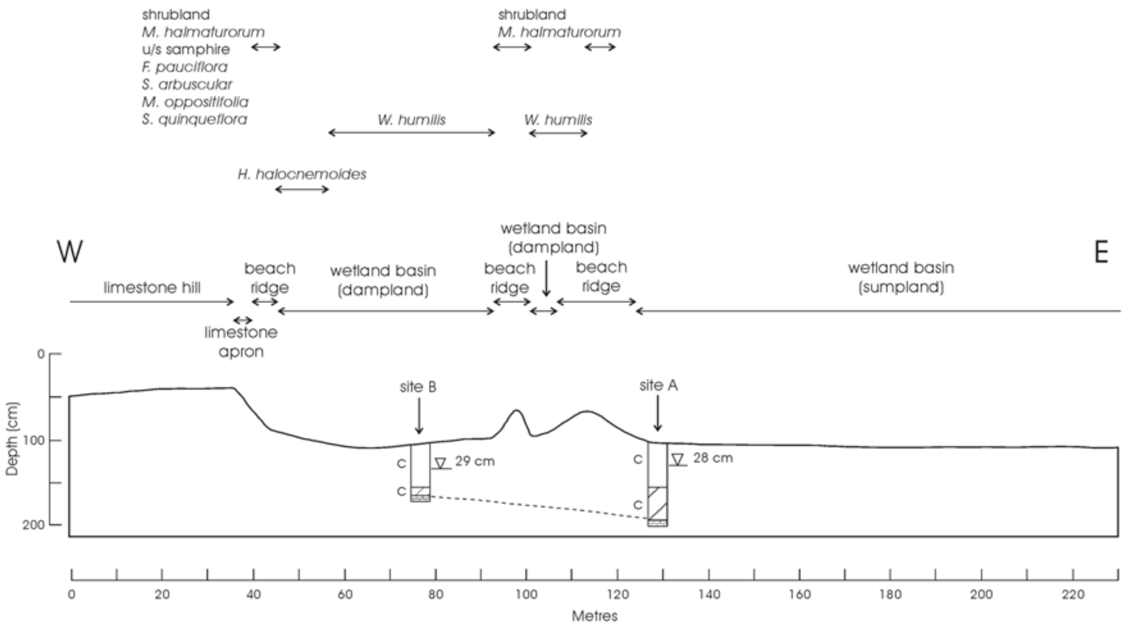
C



D

Figure 41: - C: Photo of Lake Newland MLNY
D: Geomorphology, stratigraphy and vegetation at MLNY

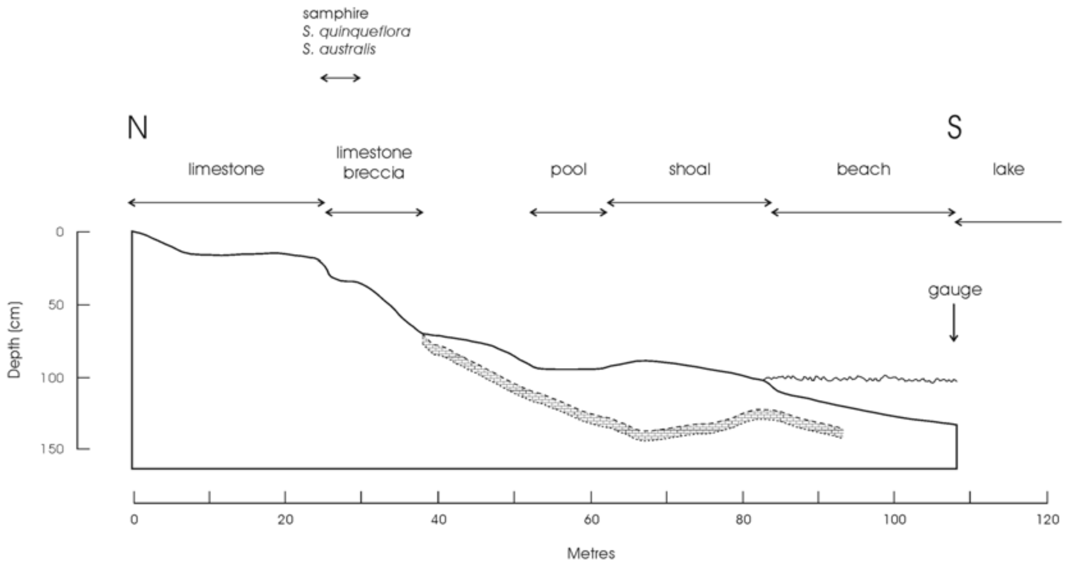
A



B

Figure 42: - A: Photo of Lake Newland MLNZ
B: Geomorphology, stratigraphy and vegetation at MLNZ

A



B

Figure 43: - A: Photo of Lake Newland south across the low gradient limestone pavement shore
B: Geomorphology, stratigraphy and vegetation at Lake Newland south

Yanerbie suite (Fig. 44)
Setting: Contact between limestone flat and leading edge of a parabolic dune complex underlain by unconsolidated calcareous sand.
Wetland types: Sumplands.
Description: This suite consists of microscale rounded basins, with a series of internal low beachridges and swales. Wetlands are seasonally waterlogged.
Hydrology: Recharge occurs through a seasonal rise in the regional water table, and discharge via evapo-transpiration.
Stratigraphy: Wetland fill comprises surface layers of fine gypsum and shelly sand overlying calcareous mud overlying layers of coarse and fine gypsum and calcareous sands.
Water Quality: The groundwater was hypersaline (112,000 mg/L) but can be higher (gypsum precipitating). The chemistry of the waters was around neutral (pH 6.9).
Vegetation: Plant communities vary between the ridges, swales and central basin. The ridge assemblage comprises low open samphire shrubland of *Halosarcia halocnemoides*, with *Frankenia pauciflora*, *Disphyma crassifolium*, *Lawrencia spicata* and *Wilsonia humilis.* The swale and central basin assemblage comprises low open samphire shrubland of *Halosarcia pruinosa.*

Two sites were visited. One site was selected for monitoring: GPS 32^{o} 54' 6 6"S and 134^{o} 9' 40"E, and a piezometer was installed for monthly water level readings.

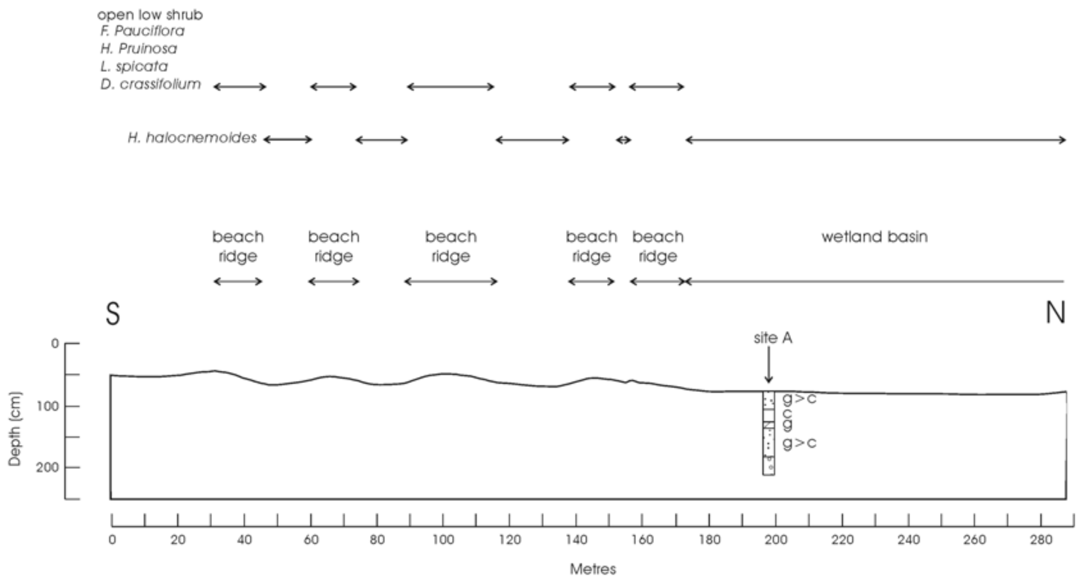
A

Figure 44: - A: Location of Yanerbie wetlands

B

C

Figure 44: - B: Aerial Photo of Yanerbie and Hansson
C: Photo of Yanerbie showing samphire vegetated surface



D

Figure 44: - D: Geomorphology, stratigraphy and vegetation at Yanerbie wetland

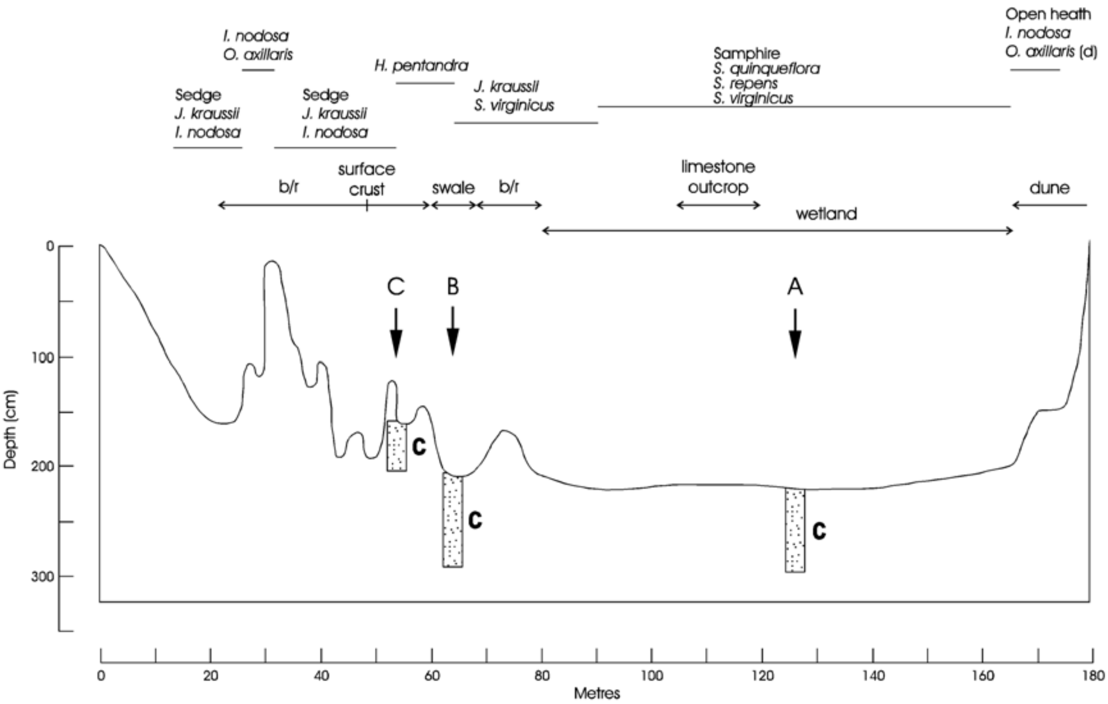
Anxious Bay suite (Fig. 45)
Setting: Blowouts within mobile dune coastal barrier underlain by Pleistocene limestone and calcrete.
Wetland types: Sumplands.
Description: This suite consists of a microscale rounded basins. The wetlands occur in wind deflated hollows within the dunes, and there are low mounds within the basins where sand has been deposited by wind or sheet wash, and conical hill residuals where the surrounding area has been eroded. Wetlands are seasonally inundated.
Hydrology: Wetlands are recharged by seasonal groundwater rise but the water table is always near the surface (< 1 m).
Stratigraphy: Cream dune shelly calcareous/quartz sand underlies the wetlands with slight humic development at the surface. The basement is limestone.
Water Quality: The groundwater was fresh to hyposaline (900-4,000mg/L). The chemistry of the waters fluctuated from near neutral to alkaline (pH 7.2-8.3).
Vegetation: At the margins, plant communities comprised open heath and scattered sedgelands of *Isolepis nodosa* and *Juncus kraussii*, with emergent *Olearia axillaris*, all colonising species of coastal wet hollows. The central basin was colonised by a low mat of *Sarcocornia quinqueflora*, *Sporobolus virginicus and Samolus repens.*

Four sites were visited. One site was selected for monitoring: GPS 33^{o} 20’ 0 4”S and 134^{o} 48’ 26.5”E, and two piezometers were installed for monthly water level readings.


A

Figure 45: - A: Location of Anxious Bay wetlands

B



C

Figure 45: - B: Photo of wetland in the Anxious Bay wetlands of the Newland Barrier
C: Geomorphology, stratigraphy and vegetation at wetland in Newland Barrier

Stamford Hill suite (Fig. 46)
Setting: Embayment prograding seaward between headlands.
Wetland types: Sumplands.
Description: This suite consists of microscale ovoid basins behind a coastal dune barrier. The wetlands are the result of coastal deposition. Sedimentary infilling of small bays occurs by marine processes. Eventually, a barrier forms at the seaward edge which reaches above mean sea level. Sand is subsequently deposited on this barrier by aeolian processes which heightens and widens the barrier over time thus disconnecting the marine wetland from its source. Terrestrial wetland processes then commence. The wetlands are seasonally inundated.
Hydrology: Wetlands are recharged by seasonal groundwater rise.
Stratigraphy: The surface is hummocky, covered by gypseous crusty mini-mounds. Under the veneer of algal gypseous crust, there is cream/brown calcilutite and mottled calcareous muddy sand and limestone. Under dense vegetation cover, a thin layer of organic matter enriched calcilutite forms.
Water Quality: Groundwater salinity was hypersaline (92,000 mg/L). Cation concentrations in the waters at the time of sampling exhibited elevated levels of potassium and medium concentrations of sodium, calcium and magnesium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. pH was near neutral at pH 7.4. Evaporation during the summer depletes water in the capillary zone and at high salinities, gypsum precipitates at the surface overprinting the calcilutite.
Vegetation: At the margins, plant communities comprised shrubland of *Melaleuca lanceolata*, *Melaleuca halmaturorum* and then closed scrub of *M. halmaturorum*. In the basins were low samphire shrublands of *Sarcocornia quinqueflora*, *Sarcocornia blackiana*, *Halosarcia pergranulata*, *Halosarcia syncarpa*, *Schlerostegia arbuscular*, *Frankenia pauciflora*, *Suaeda australis*, *Hemichroa pentandra*, herbs *Samolus repens* and *Atriplex palludosa* and minor clumps of *Austostipa* and *Juncus kraussii*.

Three sites were visited: Stanford Hill, Lake Jessie and Yangie Bay. One site was selected for monitoring: GPS 33^o 20' 0 4"S and 134^o 48' 26.5"E, and two piezometers were installed for monthly water level readings.

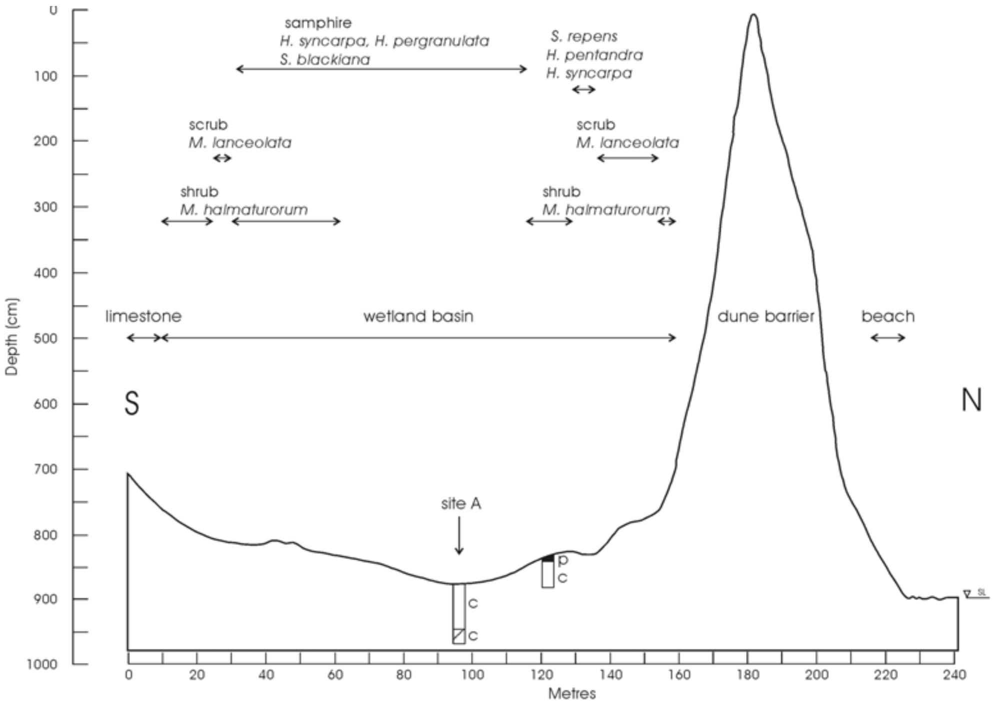
A

Figure 46: - A: Location of Stamford Hill wetland

B

C

Figure 46: - B: Aerial Photo of Stamford Hill wetland
C: Photo of Stamford Hill wetland



D

Figure 46: - D: Geomorphology, stratigraphy and vegetation at Stamford Hill wetland

8.0 Vegetation

8.1 General vegetation on Eyre Peninsula

National Land and Water Resources in their audit of Australian vegetation types produced a map titled "National Vegetation Information System" (2001) in which they identified two major vegetation groups on Eyre Peninsula: the Mallee Woodlands and Shrublands, and the Eucalypt Woodlands. The Mallee Woodlands and Shrublands comprise trees which are multi-branched and less than 6 m in height. The dominant genus comprising these woodlands and shrublands is *Eucalyptus*; co-dominants include *Melaleuca, Acacia,* and *Hakea*. The Eucalypt Woodlands are described as a transitional ecotone between forests and hummock grasslands and shrublands, comprising a series of communities dominated by box and ironbark types of Eucalypts. This vegetation has been extensively cleared. Both of these vegetation groups are species rich and contain many endemic species. These vegetation groups colonise the upland areas around the wetlands.

8.2 Wetland vegetation

Wetland vegetation predominantly comprises low samphire shrubland and open shrubland. The low samphire shrubland comprises species of Chenopodiaceae and the open shrubland comprises species of *Melaleuca*. Sedge and grassland communities are uncommon, as are woodland and forest communities. These formations are often associated with freshwater, although in the Eyre Peninsula the water salinity pattern is markedly poikilohaline (crosses salinity classes). Even freshwater wetlands become hyposaline in the dry season.

Halosarcia pruinosa is the most widely distributed Chenopod and *H. lepidosperma* is the most restricted in this survey (Table 6). *H. pruinosa* commonly occurs on carbonate mud, while *H. pergranulata* tends to occur where there is iron present in the sediments but these preliminary observations would have to be tested in a specific experimental programme. No pattern of fidelity, *i.e*., where two or more species consistently occur together, was evident in the samphire species, but an association between *Melaleuca halmaturorum* and *Gahnia trifida* is suggested by Table 6.

Regionally there is very little evidence in this study to show that climatic factors influence wetland plant distribution. Some general observations can be made in that two species of Halosarcia (*H. halocnemoides, H. pruinosa*) show a skewed distribution towards areas with rainfall <450 mm/yr (Table 7). *Melaleuca halmaturorum* and *Gahnia trifida* both show a tendency to occur in areas with rainfall > 300 mm/yr. However, it should be noted that many of the wetlands on Eyre Peninsula display a diversity of wetland habitats from fresh water to hypersaline, and this variability, rather than climatic factors, is more likely to be the major influence on wetland plant distribution and luxuriance. Within the wetlands themselves, further observations have been made with respect to geomorphology and sediment type, the former directly influencing the period of waterlogging and the latter determining water availability through porosity.

Table 6 Pattern of species distribution south to north of Eyre Peninsula

Suite	***M. brevi***	***M. halma***	***M. lance***	***H. haloc***	***H. pruin***	***H. syncarp***	***H. perg***	***H. lepid***	***S. arbus***	***S. virg***	***J. kraus***	***G. trifid***
Sleaford		x	x									x
Stamford Hill		x	x			x	x					x
Pillie		x										x
Greenly		x				x	x	x				x
Wanilla		x										
Koppio											x	
Malata				x	x	x	x					
Kilroy Munyaroo		x										x
Murninie				x	x		x		x			
Pinthaput		x			x							
Samphire					x							
Miltalie		x		x			x				x	
Hamilton		x			x							x
Elliston		x			x		x					x
Newland		x		x	x				x		x	x
Anxious Bay				x						x	x	
Calpatanna			x		x	x						
Yanerbie				x	x							

Table 7 Pattern of species distribution with respect to mean annual rainfall isohyets from high to low.

Suite	***M. brevif***	***M. halmat***	***M. lanceol***	***H. haloc***	***H. pruinos***	***H. syncarp***	***H. pergran***	***H. lepidos***	***S. arbusc***	***S. virginic***	***J. kraussi***	***G. trifida***
Sleaford		x	x									x
Pillie		x										x
Stamford Hill		x	x			x	x					x
Greenly		x				x	x	x				x
Wanilla		x										
Koppio											x	
Malata				x	x	x	x					
Hamilton		x			x							x
Elliston		x			x		x					x
Newland		x		x	x				x		x	x
Anxious Bay				x						x	x	
Calpatanna			x		x	x						
Yanerbie				x	x							
Kilroy		x										x
Pinthaput		x			x							
Samphire					x							
Miltalie Munyaroo		x		x			x				x	
Murninie				x	x		x		x			

8.3 Interpretation of the relationship between hydrological parameters, sediment types and plant assemblages within wetlands

From the literature it can be seen that samphires sometimes form zones around a wetland basin, or are distributed along gradients with respect to depth to water (Datsun 2002). Datsun has observed that in Western Australia samphire species are quite fragile and susceptible to any hydrological (drainage, hydroperiod, salt load) or sedimentological change (composition) in their habitat. Datsun (2002) presents a general stylised profile showing preferred zones of samphire species based upon her field observations, which is similar to patterns of distribution found around the wetlands of Eyre Peninsula and described below.

Some observations of plant distributions are described below but it should be noted that these are limited to the dataset and the time period of the study and have not been tested.

In terms of tolerance to waterlogging, some species tend to prefer relatively higher ground (*Halosarcia halocnemoides*, 20-30 cm beachridge) and better drained substrates (*H. indicans*, and *Schlerostegia arbuscular* on gypsum or quartz sand). *Wilsonia humilis* appears to prefer seasonal waterlogging to inundation. In contrast, *Sarcocornia quinqueflora* occurs closest to water's edge in lakes and sumplands, and *Halosarcia flabelliformis* can withstand seasonal inundation.

In terms of hydrochemistry, the following aspects are discussed below: water salinity, cation concentrations, heavy metal and nutrient concentrations and acidity/alkalinity. The salinity fields of the wetlands can be described in two ways : in terms of concentrations and in terms of stability. In terms of concentrations there are three categories of wetlands:

- hyposaline (Koppio, Greenly, Wanilla, Coffin Bay, and Anxious Bay suites),
- mesosaline (Miltalie and Sleaford suites), and
- hypersaline (Malata, Pinthaput, Samphire Flat, Lake Hamilton, Lake Newland, Elliston, Calpatanna, Yanerbie, and Stamford Hill suites).

No clear regional plant distribution patterns emerge with respect to salinity, the most important reason being that the main species of samphire belong to the Chenopodiaceae, and members of this family display a marked tolerance to salinity conditions, their only requirement being freshwater input to initiate reproduction (English *et al*. 2002, Datsun 2002, Wilson 1980). In addition, individual species have developed many methods for withstanding unfavourable conditions. Examples include: species hybridisation, physiological adaptations of size and stem density, dormancy, and genetic modifications. However, samphires <u>are</u> selective with regard to microstratigraphy within the wetland itself and some of these patterns may relate to salinity tolerance. Other observations are that *Gahnia trifida* occurs on waterlogged flats with fresh to hyposaline water, *e.g*., Round Lake, Lake Hamilton, Lake Greenly, Duck Lake, and *Melaleuca halmaturorum* occurs along seepage zones for fresh to hyposaline water, *e.g*., Cocata Hill, Sleaford Mere, Lake Malata site 2, and Lake Newland.

In terms of water salinity and its stability, most of the wetlands are stasohaline, that is remaining within the same salinity category in spite of changes in concentration. The wetlands which traverse several categories of salinity are described by the term poikilohaline and the most common range is from hyposaline (as a result of dilution by rainfall) to hypersaline (as a result of concentration by evapo-transpiration). Wetland suites which are poikilohaline are Sleaford Mere, Little Sleaford and Duck Lake. In Sleaford Mere, the vegetation is located on the margins where salinity is lower and more consistent. In the central basin of Little Sleaford, plant communities respond with an open structure and relatively short life spans, maturing over one or two seasons.

In terms of cation concentrations, calcium appears to be the limiting factor. Low concentrations throughout the region could mean that plants are quick to take up any calcium in the water. This hypothesis would need to be tested. In some wetlands (Lake Baird, Lake Pillara, Cocata Hill Rd Samphire Flat, Malata, Greenly and Stanford Hill), the concentrations of potassium are high. This could be associated with several factors: the absence of plants, the input of fertilisers or the presence of *Halosarcia syncarpa* and *H. pergranulata*. It is beyond the scope of this study to resolve this pattern. In some wetlands, (Greenly, Malata, Lake Baird, and Cocata Hill Rd) there are high concentrations of magnesium in the water. This may be associated with several factors: sediment type, geomorphology of the basins and hydrological processes. It is unlikely to be related to plant occurrence. Testing of groundwaters, for nutrients and heavy metal contamination, revealed that the sites which were sampled are within normal parameters showing that these constituents were either absent or below detectable limits.

With respect to acidity/alkalinity patterns, there are clear patterns of plant distribution. In sites with slightly higher alkalinity, suggesting that the water source is from limestone aquifers, the plant assemblages comprise sedges and shrubland of *Juncus kraussii, Gahnia trifida, Cyperus laevigatus, Triglochin striatum, Melaleuca halmaturorum,* and *M. lanceolata*. pH does not seem to be a factor in the distribution of Chenopodiaceae (Datsun 2002).

In terms of plant distributions with respect to geochemistry, there appears to be preference by some plants for sediments containing iron as opposed to sediments containing carbonate, *e.g.*, *Melaleuca brevifolia* on iron rich alluvial sediments at Wanilla and Merintha Creek and on laterised sand at Little Sleaford, and *Melaleuca halmaturorum* on carbonate mud at Lake Pillie, Stamford Hill, Elliston, Lake Newland, and Calpatanna.

8.4 Flora and fauna communities in response to cyclic rainfall

It is evident from the stratigraphic sequences that the majority of wetlands have passed through various cycles of wetness and aridity, and higher-than-present water levels. Carbonate and gypseous mud fills, algal oozes and mats, and relic stromatolites standing above current high water levels, all testify to former phases of aquatic conditions, while intraclasts, eroded pavements and sand sheets point to periods of aridity and denudation. Some of these extremes, *e.g.*, stranded relic stromatolites, may be due to higher-than-present water levels, concomitant with higher-than-present earlier Holocene sealevels, but some of these extremes also appear to be an intrinsic part of the normal conditions for these wetlands, *e.g.*, cementation and breccia pavements developed on the present prevailing wetland floors. It is likely that any wetland basin will experience periods during which there will be a higher than average frequency of inundation or waterlogging followed by periods during which there will be a lower than average frequency of inundation or waterlogging. Consequently, fauna and flora will adapt to these conditions and population dynamics and composition will alter correspondingly.

In this context, in the case of plant assemblages, there will be a time lag between changing hydrological conditions and biological response, *i.e.*, changes in composition and areal extent of wetland vegetation. In addition, there will be some species that will survive inhospitable conditions for varying lengths of time and other species that will succumb very quickly, bringing about their demise and disappearance in any particular basin. In the case of invertebrate fauna whose adaptive mechanisms are quite rapid, it follows that several faunal assemblages may be necessary to typify a basin, *e.g.*, assemblages corresponding to prolonged, seasonal, and intermittent inundation. Disappearance of invertebrate fauna will require the investigator to determine whether the cause is a deleterious change in wetland habitat or a normal cyclic climatic phase of predominant aridity.

9.0 Assessment of wetlands

Below are briefly described the values of the different consanguineous suites. These have been included, not as a comprehensive inventory of wetland values, but as a guideline to management. A full survey of wetland values is beyond the scope of this study and needs to be undertaken independently using a tested and nationally recognised evaluation system.

The values of wetlands, as determined from the literature, and from field visits, are described below for wetlands which were visited over the period of this study (June 2005-December 2006). They include values pertaining to ecology, culture, recreation and tourism, education and research, and geoheritage with an emphasis on geomorphic and hydrologic features. It is expected that when future biological surveys are undertaken that other values will be added to this preliminary list, *e.g.*, habitats for declared rare flora and fauna, representative or unusual plant communities, representative faunal populations, migratory fauna, restricted endemic fauna, drought refuges.

9.1 Key values of wetlands

The wetlands were examined with respect to the following values: ecological, cultural, recreational, tourist, educational, research and geoheritage. The values are described with respect to wetland site and consanguineous suite.

Koppio Suite

Tod River at Koppio, GPS 34^{o} 21.55’S and 135^{o} 52.35’ E. This site has a high degree of naturalness and ecological and aesthetic value. It displays the typical small scale seasonal, freshwater, meandering, incised channel with cliffed sides, point bar development, small levee, and narrow floodplain with inundation pools. The range of fluvial habitats has resulted in a number of small but diverse plant communities which include *Melaleuca brevifolia* shrubs, *Juncus kraussii* rush, *Baumea juncea* sedge, *Eucalyptus camaldulensisis* woodland, and samphires. As a result of disturbance to geomorphic habitat types, change in hydrochemistry or removal of vegetation, this range of plant communities has disappeared from many other sites. The water is clear and free from the turbidity which often occurs in valley areas cleared of vegetation.

The main channel, tributaries and reservoir of the Tod River provide an important drought refuge for waterbirds (Musk Duck, Pacific Black Duck, Grey Teal),and aquatic habitat for invertebrate fauna such as yabbies. Freshwater fish include *Galaxidae* sp. (de Jong & Stanton 1995)

This site needs to be managed to preserve its ecological functions, naturalness and plant diversity.

Miltalie suite
Miltalie Brook GPS 33^{o} 28' 53.6"S and 136^{o} 48' 56.4"E. This site has a high degree of naturalness as well as important ecologic, recreation and aesthetic values. In an area where many other locations have disturbed geomorphology, hydrochemistry and/or vegetation, this site stands out. It encompasses an undisturbed channel thalweg and margins, with point bars, mid stream shoals and intact banks. Riparian vegetation gradually merges into upland assemblages.

This site needs to be managed to preserve its naturalness, geomorphic integrity, water quality, transitional ecological zones, and aesthetics.

Sleaford suite
Sleaford Mere GPS 34^{o} 49' 26.5"S and 135^{o} 44' 26.3"E. This site has a high degree of naturalness and uniqueness as well as important geoheritage and biological values. The hydrological regime appears to be natural. Groundwater abstraction is not evident and hydrographs show a seasonal response to rainfall and groundwater fluctuations. At the lake margins there is subsurface seepage from the adjacent ridges. The hydrochemistry also appears unaltered, in that surface water has pH around 8.2 which is typical of limestone aquifers, and the groundwater chemistry is neutral, approximating rainwater (pH 6.9-7.1).

Geoheritage values include its setting, origin, hydrological maintenance and periodicity, and stromatolite development. Sleaford Mere is located along the contact of the lateritised metamorphic rocks of the Gawler Craton (schist, iron, amphibolite) and the limestone and is one of only two wetlands to occur in this setting. The origin of Sleaford Mere and its continuing hydrological functioning are still not fully resolved, but there are indicators that the wetland is under both marine (tidal) and terrestrial influences. This type of wetland maintenance is uncommon. In the central basin of Sleaford Mere, algal mats are currently forming and at various times and in various places are undergoing cementation, growth and destruction. Also in the central basin, fossil stromatolites form islands and reefs standing about 50 cm above the present water level. At the margins they form relic beaches, pavements and beach ridges.

Biologically, the terrestrial populations of Southern Bush Rats, the breeding populations of Chestnut Teal and the aquatic population of skates are important and unusual occurrences (Robinson & Heard 1985).

This site needs to be managed to preserve its naturalness, geoheritage values, scientific information, its uniqueness as an example of a wetland of this type and setting, its water quality, biological values and aesthetics.

Wudinna suite
This site has a high degree of naturalness as well as important geoheritage, biological and recreational values. The gnammas and rillen are recharged by rainfall which discharges through seepage and evapotranspiration. The wetlands themselves are restricted to the granite monadnocks in the region of Wudinna and exhibit various stages of development from hollows in the bedrock surface to deeper cavities with established soil profiles which

are seasonally waterlogged. The wetland plant communities contain herbs and grasses with occasional shrubs of *Melaleuca armillaris* which is rare throughout both the Eyre Peninsula region and the state of South Australia, and species of aquatic plants restricted in habitat distribution (*Limosella granitica*) (Day *et al.* 2004).

The sites are popular for picnicking, walking and photography.

This site needs to be managed to preserve its naturalness, geoheritage values, scientific information, its example of a wetland of this type and setting, its water quality, declared rare flora, recreation values and aesthetics.

Malata suite

Sites 1 and 2 GPS 34^{o} 09.41'S and 135^{o} 31.99'E; and Lake Malata itself, GPS 34^{o} 11.13'S and 135^{o} 29.11'E. The Malata suite has important geoheritage, cultural and biological values. The Malata wetland system is a dammed drainage channel within a valley tract. Geomorphological features include: basins, islands, spits, lunettes, irregular sub-parabolic dunes, beach ridges, and beaches. Smaller basins are evidence of processes of deflation and groundwater discharge. Although situated in an alluvial environment, Lake Malata fill is dominated by relatively mud free gypseous sediments, a feature made more interesting by the fact that its neighbour Lake Greenly is filled with carbonate mud (calcite and dolomite). Strandline features contain a rich record of major climatic change which extends back into the Pleistocene (approximately 320,000 years) with evidence of 4 major phases of lunette deposition, and sediments associated with alternate wet (aquatic sediments) and dry conditions (desiccation, calcrete and soil horizons) (Dutkiewicz *et al.* 2002).

An undisturbed Aboriginal campsite comprising stone grinding plate and scraping tools is present in one of the foredunes.

Although the vegetation associations have been altered overall through grazing and clearing, the declared rare flora *Halosarcia flabelliformis* forms pure and mixed stands in at least one of the smaller basins.

This site needs to be managed to preserve its naturalness, scientific and cultural values, its example of a wetland of this type and setting, its water quality, declared rare flora, and aesthetics.

Greenly suite

Lake Greenly GPS 34^{o} 19.32'S and 135^{o} 26.79'E. This site has a medium to high degree of naturalness as well as important geomorphic, sedimentary and biological values. Local hydrological mechanisms appear to be unaltered as do regional areas immediately to the northeast in the Malata system and between the two wetlands, although the latter may be at risk with continued mining of the Malata wetlands. Re-vegetation is required in a number of shoreline areas. Geomorphological features include: the basin, basement cliffs, lunettes, beach ridges, and beaches, lateral marginal seepage spring zones and surface drainage channels. Although these wetland systems lie in valley tracts underlain by alluvial sediments, the southern end of each wetland system is in embedded in limestone. There is a rich assemblage of biotic grains throughout the profile, which suggests that a variety of organisms inhabit this environment, *e.g.*, sponge spicules, *Chara* oogonia, forams, diatoms, ostracods, gastropod and bi-valve shells, pellets and other skeletal material.

The plant assemblages at the margins are quite diverse, and zoned with respect to distance from the shore and slope, where they are relatively uniform, and with respect to water availability and sediment chemistry, where there is beachridge/swale topography. Assemblages include: 1) *Melaleuca* 2) low shrubs of *Halosarcia halocnemoides* and *Threlkeldia diffusa,* and 3) low shrubs of *Halosarcia halocnemoides, H. indicans bidens, Sarcocornia quinqueflora,* and *Frankenia pauciflora* 4) low shrubs of *H. halocnemoides* and *Lawrencia spicata* and 5) sedge *Gahnia trifida* with scattered shrubs of *Melaleuca brevifolia*. Well developed assemblages of *Gahnia trifida* and *Gahnia filum* at Lake Greenly and Duck Lake are significant not only in themselves as uncommon communities but also because they support the declared rare butterfly *Hesperilla flavescens* during crucial growth stages.

This site needs to be managed to preserve its naturalness, geomorphic integrity, hydrological links with Lake Malata and its connection to the coastal limestone, water flow paths, scientific values, and plant assemblage zonation and diversity.

Wanilla suite

Merintha Creek, GPS 34° 34’ 1.2”S and 135° 36’ 39.0”E, and Wanilla GPS 34° 33.04’S and 135° 39.59’E. These sites have a low to medium degree of naturalness as they have been isolated from their headwaters and from other areas of waterlogged flats. In essence they are remnants of the wetlands which characterised this region and they represent what once was a connected and seasonally renewable freshwater system. Vegetation assemblages are invaded by weeds and are subject to grazing and increasingly frequent fires, thus decreasing their original diversity. These sites are important because they represent habitats which were once much more widely dispersed, but now are scarce.

This site needs to be managed to preserve what is now only a remnant of the wetland systems typical of this area. This will require active management to prevent further loss of habitat, invasion by weeds and destruction by grazing and fire. It may require re-vegetation and linking by ecological and hydrological corridors to other remnants.

Murninnie suite

GPS 33° 19’S and 137° 22’E. This site has a high degree of naturalness and represents a scarce wetland type on Eyre Peninsula. It also has important geomorphic, hydrologic, and biological values. This is a very unusual wetland in terms of its type, size, origin and hydrological maintenance. The wetland is a megascale flat with cheniers on the surface, a tidal creek and pools at the coastal edge and leptoscale creeks inland. There are several possibilities for its origin. It may have originally been formed by marine processes which gradually have been replaced by terrestrial processes as the flat prograded seawards. It may have been a flat formed entirely by alluvial processes which is now being re-worked at the seaward margin by marine processes. Alternatively, it may be a merging of two or more flats with different origins. Currently, it is maintained by several hydrological processes: direct rainfall, groundwater rise and tidal inundation. Discharge is also a mix of marine and terrestrial processes: drainage by tidal retreat and tidal creek flow, drainage by groundwater discharge at the coast, drainage by inland creek flow, and evapo-transpiration.

Cheniers, creeks, pools and the increasing distance from the coast produce a number of habitats. Plant assemblages are species rich at the coastal margin (*Halosarcia* spp., *Maireana* spp., *Schlerostegia* spp.) and become increasingly uniform inland.

This site needs to be managed to preserve its naturalness and size. Its uniqueness and value are partly dependent on the total area being managed so that the gradation from tidally influenced area to alluvial flat to inland hills where the creek headwaters are located is preserved. Hydrological and sedimentary links need to be maintained.

Pinthaput suite

These sites represent wetland types in this setting: their geometry, scale, sediment types and history. They have a high degree of natural dynamism. For example, they exhibit precipitation and dissolution of gypsum crystals at the surface in response to changing environmental conditions, as well as indicators of changing salt accumulation, and features (mounds) which indicate depositional and erosional processes within the basins. Pinthaput site 1 exhibits a diversity of samphire species.

These sites need to be managed to preserve their naturalness and dynamic sedimentary and hydrochemical processes.

Samphire Flat suite

Samphire Flat GPS 33^{o} 10.52'S and 135^{o} 28.41'E. This site has a high degree of naturalness as well as important geomorphic and palaeoclimate values. This wetland is a large feature, a megascale flat with peripheral fingers and irregularities aligned with the northwest to southeast orientation of the linear dune field in which it lies. The wetland surface has many small scale geomorphic features, all of which give clues to the kinds of processes which shape this wetland and cause it to evolve: low parallel ridges, scours from surface water flows and wind deflation, hollows where surface water collects intermittently, sand shadow mounds trapped behind plants, and low dunes. Alternating layers of gypseous mud, quartz sands, gypsum sands, and calcrete layers indicate a record of wetter and drier phases throughout the history of the wetland.

This site needs to be managed to preserve its naturalness and geomorphic integrity.

Munyaroo suite

These sites have a high degree of naturalness as well as geomorphic, aesthetic and educational values. The wetlands are typical "windows to the water table". They are located in the swales between linear dune ridges where depth to groundwater is minimal. The plant assemblages of low samphire shrublands contrast with the surrounding mallee open scrub and woodlands. Wetlands in the Munyaroo Conservation Park are the eastern and coastal expression of wetlands in the Samphire Flat Suite. The setting ensures that the former wetlands are waterlogged for most of the year, in contrast to those near Wudinna, which are briefly seasonally or intermittently inundated. This spectrum may prove an important research or educational tool for wetland scientists, ecologists and land managers in the future.

These sites need to be managed to preserve their naturalness. Given the inaccessibility of the wetlands, the Munyaroo Conservation Park is currently adequate to achieve this goal.

Coffin Bay suite
Pillie Lake has a medium degree of naturalness. Groundwater abstraction in the Ulley Basin appears to have modified the water regime in this wetland. Water levels range within the same parameters as prior to abstraction but the length of time the wetland is inundated or even waterlogged has been affected by the drawdown. The wetland's main value is that is typical of those wetlands forming in the bowls of parabolic dunes, in that it is microscale, elongate to irregular, underlain by limestone, filled with calcareous sandy mud and intraclast sand, recharged by groundwater and seasonally inundated. Macrophyte communities are peripheral and zoned, and the aquatic assemblage comprises species of *Chara.*

This site needs to be managed to preserve its naturalness particularly with respect to its water regime.

Kilroy suite
Bramfield GPS 33^{o} 33.8'S and 135^{o} 04'E, Kilroy GPS 33^{o} 28.24'S and 135^{o} 04.51'E. These sites currently have a high degree of naturalness, but the landowner of Kilroy is in the process of clearing vegetation and appears to plan further action. The wetlands' main value is that they represent part of the undulating megascale flat which may have been the result of extensive blowouts. They are underlain by limestone, filled with calcareous sandy mud and intraclast sand, recharged by groundwater and seasonally waterlogged with intermittent inundation. Vegetation ranges from scrub and open shrubland to samphire open low shrubland.

This site needs to be managed to preserve its naturalness and prevent further vegetation clearing.

Hamilton suite
Lake Hamilton east GPS 33^{o} 57' 11.2'S and 135^{o} 16' 51.8'E, Lake Hamilton west GPS 34^{o} 1.9'S and 135^{o} 17.16'E. Lake Hamilton has a high degree of naturalness as well as important geomorphic, geoheritage, habitat diversity, ecological and aesthetic values. Lake Hamilton is situated in a karst landscape in a depression between limestone ridges. The basin itself is expanding. Along the west side are sink holes, vents, tidal channels and steep margins. As it expands, it encloses areas of limestone which have not yet been subjected to karst processes and these become islands. Karst processes in a gypsum and limestone environment give rise to the geomorphic and geoheritage values. The rapidity and dynamism of karst processes produce a large range of habitat types. In addition to those mentioned above, there are islands surrounded by sedimentary aprons, and shoals protruding from the lake margins. There are algal mats on the surface, and emergent relic stromatolite heads forming beach ridges and pavements. The depth and permanence of the surface water varies spatially and temporally, preferentially settling to the west and north when observed recently. Precipitation is perched in some places, in others it infiltrates to the water table. Fresh water from the eastern and western limestone ridges discharges into the lake. Marine vents occur on the western side of the lake. Groundwater salinity is variable. The number and diversity

of the geomorphic features and sediment fabrics combined with the variation in water depth and permanence, and the variation in pH and salinity, produce numerous habitats within the basin.

Ostracods and gastropods occur in the lake and tidal creek. *Atherinosoma microstoma* (small mouthed hardyhead) inhabits the marine vents. Plant structural formations (*Melaleuca* scrubland, tussock grassland, samphire low shrubland, sedgelands) and species richness reflect the range of habitat types. Well developed assemblages of *Gahnia trifida* at Lake Hamilton and Round Lake are significant not only in themselves as uncommon communities but also because they support the declared rare butterfly *Hesperilla flavescens* during crucial growth stages. Aquatic plants include *Lamprothamnium* sp. and the seagrass *Ruppia.*

This site needs to be managed to preserve its naturalness, geomorphic integrity, hydrological links with the coastal limestone, water flow paths, diversity of habitats, and plant assemblage zonation and diversity.

Lake Hamp GPS 33^o 38' 0.5"S and 134^o 53' 41.0"E. Lake Hamp has a low to medium degree of naturalness, but this could easily be addressed if the rubbish site were moved elsewhere. It is a very good example of wetlands which were probably originally sinkholes in a karst terrain and have now been infilled with carbonate mud. Several examples of sinkholes in earlier stages of evolution occur further to the north, GPS 33^o 41' 38.7"S and 134^o 57' 56.5"E, GPS 33^o 43' 20.5"S and 135^o 2' 19.5"E, GPS 33^o 43' 8.7"S and 135^o 1' 25.3"E.

This site needs to be managed to preserve its naturalness, in particular the rubbish tip needs to be re-located and current hydrochemical impacts ameliorated.

Gully suite

Wild Dog Gully GPS 33^o 44' 14.9"S and 135^o 3' 55.1"E. This site has a medium to high degree of naturalness. It requires re-vegetation. It is the only example of fluvial wetlands in a karst terrain.

This site needs to be managed to preserve its naturalness, in particular re-vegetation needs to be undertaken.

Calpatanna suite

Little Seagull Lake, GPS 32^o 57' 58 6"S and 134^o 12' 34.1"E. Little Seagull Lake has a high degree of naturalness as well as important geoheritage, ecological and aesthetic values. It is situated in karst terrain, and is a cliffed cavity around a marine vent in the underlying marine shelly limestone. Little Seagull Lake is connected on the surface to Seagull Lake via a narrow linear channel but appears to have a separate source of recharge to the main lake because surface water is maintained in this little basin when the larger basin is dry (pers. comm. Justine Graham EPNRMB), and water level fluctuations appear to be out of phase between the two basins.

Plant communities are peripheral and zoned, the inner zones comprising mat plants and the outer zone comprising open heath. The aquatics comprise species of *Chara, Acetabularia,* and *Ruppia*. Sea anemones, macro invertebrates, and marine gastropods are present.

Little Seagull Lake is juxtaposed between a coastal dune ridge of white calcareous sand and the larger Seagull Lake. Wetland vegetation is undisturbed and merges with dune and limestone species. The site has high aesthetic qualities and is sheltered, giving protection to migrant fauna.

This site needs to be managed to preserve its outstanding geoheritage characteristics pertaining to its karst setting, tidal influence, and marine water recharge, as well as its diverse mixture of biological assemblages and its outstanding aesthetic qualities.

Newland suite

North Lake Newland, middle Lake Newland GPS 33^o 24’ 13.2”S and 134^o 51’ 51.1”E; and south Lake Newland GPS 33^o 28’ 15.8”S and 134^o 53’ 16.0”E. Lake Newland has a high degree of naturalness as well as important diversity, ecological, recreation, cultural and aesthetic values. Lake Newland is, in fact, a megascale linear complex of basins, ranging from being permanently inundated to seasonally waterlogged, and separated by limestone hills and pavements. The wetland complex is situated in a karst landscape but overprinting the karst geometry are modern wave built beachridges, cuspate forelands, beaches and sand shoals.

Some of the basins are groundwater recharged and others perch rain at the surface. Springs occur at the eastern margins, fed from the limestone aquifer.

Habitat diversity is high and includes: areas of permanent water, areas of seasonal surface water, and areas that are seasonally waterlogged by rain infiltration or groundwater rise. In each case the salinity and pH will differ; water salinity ranges from hypersaline to slightly brackish. Inundation can be the result of discharge from springs, groundwater discharge or surface water ponding. Basements comprise calcareous mud, calcareous sand, limestone or combinations of the three. Vegetation ranges from shrubs, sedge, and rush, to samphire low shrublands, grasslands and herblands. Plants of conservation significance in these habitats include: *Austrofestuca littoralis, Cyperus laevigatus, Hemichroa pentandra, Leptorhynchos squamatus, Triglochin striatum* (DEH 2003).

Lake Newland is a drought refuge for several avifaunal populations: Banded stilts, Chestnut Teal, Red-necked Stint, Cape Barren Goose (threatened species), and Black Swan. Several migratory wading species listed under international agreements also use the site, including Sharp-tailed sandpiper and Curlew sandpiper (DEH 2003). In addition to that mentioned above, several species of waterbirds, listed as threatened species, have been observed at the site (de Jong & Stanton 1995): Hooded Plover, Fairy Tern, and Eastern Reef Egret. Lake Newland is well known for its bird life and tourists to the Elliston region regularly visit (Elliston Park Caravan park pers. comm.).

Seventeen cultural sites pertaining to Aboriginal history, some of which are designated archaeological sites, are located within the Lake Newland Conservation Park boundary. Some of these are associated with camping and hunting on and beside the wetlands.

Aesthetically, the Lake Newland complex is impressive. It is situated behind a white calcareous sand dune and exhibits vistas of red, yellow, orange, purple, green and grey in the vegetation, vistas of round and linear wetland basins and islands amongst ridges and pavements, and salt and gypsum crystal surfaces.

This site needs to be managed to preserve its diversity of wetland habitats from lake to dampland, from freshwater to hypersaline. In managing the wetland and dryland habitats, other attributes such as its geomorphic features and important biological values (abundant avifaunal populations and rare or uncommon plant species and assemblages) are likely to be well managed also. It will also be important to manage visitor access to protect some of the biological values.

Yanerbie suite

GPS 32^{o} 54' 6 6"S and 134^{o} 9' 40"E. Yanerbie has a high degree of naturalness and is a very good example of wetlands in a karst terrain which have now been infilled with gypseous and dolomitic mud and sand. It also displays clear samphire differentiation with respect to waterlogging tolerance, in the repetitive beachridge swale assemblages.

This site needs to be managed to preserve its naturalness as an example of a wetland of this type and setting.

Anxious Bay suite

Newland Barrier GPS 33^{o} 20' 0 4"S and 134^{o} 48' 26.5"E. Newland Barrier wetlands have a high degree of naturalness, restricted distribution, and important ecological and aesthetic values. This suite occurs in wind deflated hollows within the calcareous sand dunes of a coastal barrier. This is an unusual occurrence, and these wetlands may be the youngest on the Eyre Peninsula.

Wetlands are colonised by grasses, sedges, rushes, samphires and herbs. Elsewhere, the habitat often supports orchids and uncommon annuals. It is a dynamic habitat with processes of sheetwash and aeolian infilling constantly replenishing the geo chemical environment and therefore plant assemblages are often diverse responding to the various stages of infilling, scouring, waterlogging, aeration, soil pedogenesis and sediment diagenesis, which are taking place (Semeniuk & C A Semeniuk 2004, 2006). In a dune terrain these wetlands serve as oases for migrant fauna.

Aesthetically the wetlands form a contrast to the surrounding dune terrain and their typical plant physiognomies.

This site needs to be managed to preserve its naturalness, particularly with respect to rubbish dumping and trampling.

Stamford Hill suite

Stamford Hill GPS 33^{o} 20' 0 4"S and 134^{o} 48' 26.5"E. Stanford Hill wetland has a high degree of naturalness, representativeness, restricted distribution, and ecological values. The wetlands are the result of sedimentary infilling of small bays by marine processes and then barring by dunes. Stamford Hill is a very good example of a wetland with a marine origin that is now wholly maintained by terrestrial wetland processes. The wetland fill and basin/ridge morphology also testify to its pluralistic origins.

The vegetation is correspondingly zoned with respect to water depth across these ridges and swales and both of these features are undisturbed. Insects (beetles, moths) are abundant at this site. There is some invasion by weeds (*Limonium companionus*) but these appear to be ephemeral and easily competed against.

This site needs to be managed to preserve its naturalness. Currently, in this setting, this would mean addressing trampling and damage by vehicles.

9.2 Description of threats

Activities within and adjacent to any wetland and surrounds have the potential to significantly alter hydrological regimes. An integrated approach is required across the catchment, regardless of tenure, to protect hydrological systems and the biota that depend on them.

In this section threats are discussed at the regional and local scale.

Threats at regional scale

1. Lack of recognition of wetlands

At the regional scale, the major problem encountered was the lack of recognition of wetlands, that is, there are types which members of the community clearly do not identify as wetlands. These wetlands fall mainly into the categories of seasonally waterlogged and intermittently inundated wetlands, *i.e*., palusplains, damplands, creeks, wadis, and barlkarras. In temperate climates such as that which occurs on Eyre Peninsula, these are the truly representative wetland types. Adding to the problem is the distinction drawn by many members of the community between freshwater and saline wetland habitats. In some instances seasonally inundated wetlands were not recognised because they were saline, and because the inundation period was short. An education programme based on the diversity of wetland types on Eyre Peninsula and their values should be undertaken.

2. Groundwater drawdown

This problem potentially affects wetlands located near the major groundwater sources of fresh, potable water. As groundwater is extracted for community use the normal annual water table fluctuations resulting from rainwater recharge and evapotranspirative discharge are dampened. Either the period of waterlogging and inundation is shortened or the water levels are lowered thus reducing waterlogging of the surface sediments. In Pillie Lake both of these processes appear to be occurring. Reduction in water availability can have the following effects: change in water salinity regime, change in sediment production, exposure of wetland surface to erosion or re-working. These factors, coupled with reduced water supply, will result in impacts on the plant community composition and faunal populations which inhabit the wetland. Research into timing and frequency of environmental needs should be undertaken and an allocation plan designed to maintain wetland water regimes.

3. Disruption of hydrological processes and groundwater flows.
Activities within the littoral zone or adjacent to wetland boundaries have the potential to significantly alter hydrological regimes, water quality, drainage patterns and surface-subsurface water interactions. As the wetlands are large, often macro-to-megascale, the protection of their hydrological systems and the biota that depend on them, require an integrated approach across the catchment. Proposals for isolated activities at various locations need to be assessed in terms of their total impact on the wetland system rather than as individual development projects which on their own may not generate a significant impact. Examples include lowering of the regional water table at one location, extraction of groundwater at a particular season, point source pollution, interception of surface or groundwater flows by dams or barriers, and discharge of effluent or excess water into the wetland from an outside source. The Lake Malata wetlands, Greenly suite (specifically Duck Lake, Lake Wangary, and Little Swamp), the Tod River and Salt Creek (Miltalie suite) are susceptible to this kind of alteration.

4. Impacts of agricultural practices on wetlands
At the regional scale, for those wetlands that are located in former valley tracts, either along current riverine systems (such as the Tod River drainage basin, or Wanilla drainage basin), or as basins at the distal (terminal) end of a naturally dammed valley tract (such as Lake Greenly, Little Swamp, or Lake Malata), the catchment agricultural practices potentially can deliver nutrient enriched waters from fertilising practices, heavy metal contaminated waters (with heavy metals deriving from fertilisers), increased water table levels due to clearing, and increased sediment loads also due to clearing and increased catchment erosion. Nutrient enrichment is expressed in the wetlands as algal blooms, and increased vegetation productivity. Increased run-off and erosion in the catchment is expressed as increased sedimentation. Also at the regional scale, there appears to have been a rise in water table levels, and increase in surface groundwater salinity (salinisation), due to agricultural clearing practices, and this has resulted in the death of peripheral vegetation due to inundation and salinity.

Nutrient enrichment in wetlands, resulting in algal blooms, and increased vegetation productivity, often is evident in the thin dark grey to black sludge of organic matter on the floor of wetland basins, indicating periodic phytoplankton and macrophytic blooms over extended periods of decades. In the Eyre Peninsula region, there often is a thin sludge of organic matter on the floor of the wetland composed of accumulated organic material from algal blooms, and other planktonic and benthic biota. The limited analyses of water samples undertaken in 2006 for nutrient enrichment in terms of N and P, and heavy metals (to indicate waters derived from fertiliser-affected groundwaters and surface waters) show that little agriculturally derived contaminants are present in the standing water, and it appears that biological processes seem to have rapidly incorporated these chemical species into their biomass (sedimented as organic sludge, or evident as macrophyte blooms), and into the sediment. However, the sampling in 2006 was not extensive nor temporally consistent enough (in relation, for instance, to specific rain storm events) to conclusively show that agriculture is having little effect on the wetlands. That is, the water sampling did not implicate impacts of agriculture on wetlands in terms of nutrients and heavy metals, but the sedimentological evidence points to contaminant delivery and its rapid incorporation into the biomass, and then into the sedimentary record.

Increased sediment load due to clearing and erosion has resulted in locally increased rates of sedimentation into wetlands, and this is expressed as small scale deltas, and sheet deposits. Towards the northern, more arid portions of the Eyre Peninsula, while some clearing has taken place, wheat production, and hence fertiliser application, is diminished, and the effects of increased sediment loading, nutrient loading, and heavy metal contamination is likely to decrease.

Threats at local scale

1. Mining of gypsum

At the local scale the most important threat is mining of gypsum, whether this be gypsum dunes or gypsum muds within the basins. This activity fundamentally changes the geomorphology and stratigraphy of the wetland. The altered geomorphology will change the water regime and present assemblage of plant communities. The altered stratigraphy will change the geochemistry, hydrochemistry, and sediment moisture capacity. Given a large enough scale of mining activity, the fundamental attributes of the wetland will be lost. There is no known way to technologically rehabilitate such profound changes even on a local scale. This problem needs to be addressed by creating conservation areas representing the wetland type. At this stage the wetland systems of Malata, Greenly and Calpatanna are under threat.

2. Vegetation clearance

Vegetation clearance has occurred in areas once used for agriculture or other horticultural activities. Clearance has resulted in weed invasion and also in some erosion. Areas from this study requiring re-vegetation include Little Swamp, Merintha Creek and Tod River.

3. Fire

Local episodes of fire did not seem to be a widespread or frequent problem for wetlands in this region. This may be due to the lack of flammable material in the wetland sediments (peat), the general lack of vegetation cover across wetland basins for many wetlands, and in the open to very open structures of the peripheral plant communities. Duck Lake and Merintha Creek were the only examples of wetlands which had experienced fire recently. The *Melaleucas* were beginning to regenerate but the understorey seemed to be responding much more slowly. The first species to return was *Sarcocornia quinqueflora* which is rhizomatous. In general, species of *Melaleuca* do not cope well with fire and require protection so as to maintain population numbers.

4. Weeds

Most of the wetlands exhibited very few invasive species. Species which invaded were grasses. Invasion occurred as a result of grazing and vegetation clearance. Freshwater habitats appear to be more susceptible to this threat and often the invading species are more virulent than the endemic flora. Examples of an invasive species is *Schoenoplectus* sp. which occurs at Elliston, Lake Newland and Lake Hamilton.

5. Trampling and vehicles

Trampling could become a widespread problem in tourist areas such as Lake Newland and Lake Hamilton, as the samphires do not appear to regenerate in wheel tyre tracks or other disturbed sediments. Where the thin layer of sand overlying the calcilutite fills has been removed, recruitment is not likely to take place. Restricted entry and well placed paths can overcome this potential problem. Trampling can also potentially become a problem in fragile environments such as creek margins (Koppio suite, Miltalie suite) and the flat at Murninie which is tidal at the coastal edge and alluvial inland. The thin veneer of sand overlying the mud substrate needs to be protected in order to sustain the present diversity of plants.

6. Grazing

Grazing can lead to compaction of surface sediments, nutrient enrichment of wetland surface and groundwaters, introduction of alien grasses, and trampling of samphires. Soil or sediment compaction makes any re-vegetation difficult. The impact of nutrient enrichment depends on whether the wetland system is open or closed, and on whether it is underlain by sands or muds. In open areas where flushing takes place enrichment is short lived, however in closed systems like Lake Malata and Samphire Flat, the nutrients would remain in the system for a longer time. In some wetlands excess nutrients would be stored in the water and in others, in the sediments. Different sediments have different binding properties, *e.g.*, orthophosphate can be chemically bonded to calcilutite, but will pass through sands into the groundwater.

7. Pollution of groundwater

Pollution of groundwater by nutrients and/or heavy metals is a risk in agricultural areas where these types of products are constituents of fertilisers, pesticides or insecticides, and adjacent to main roads where traffic frequency is sufficient to generate high concentrations in the stormwater runoff. Flash floods can remobilise these elements and wash them into adjacent wetland habitat. Areas such as Big Swamp and Lake Hamilton, traversed by Flinders Hwy, and Wanilla alluvial fan, traversed by the road to Cummins, are susceptible to these threats. Settling basins can be constructed to collect this runoff and slow the velocity of the water movement, facilitating the absorption of these elements onto the host material provided.

8. Agriculture and wetlands

The wetlands of the Eyre Peninsula reside in a largely agricultural setting, with the consequence that they may be impacted by agricultural practices. The land in many areas has been cleared for crops and pasture (with wheat and sheep being the main activities), and fertilisers have been applied for crops.

At the local scale, *i.e*., in the immediate upland setting of a given wetland basin or channel/flat, the effect of fertiliser impacts (as phytoplankton and macrophytic blooms resulting in the production of sludge), rising water table, and salinity increase, are more marked, but more local. In this context, for some wetlands, it is difficult to separate regional effect from local effects.

One of the most significant local effects of agriculture is stock damage to riverine banks and flats, and to the periphery of basins. The effect of grazing stock on river banks and shore zones of basins is evident in many locations. Here, the vegetation is trampled, and the soils structure is disrupted as stock attempt to graze the hygrophylic vegetation peripheral to the channels or basins, or attempt to obtain water.

9. Acid sulphate soils

In the oxygen-depleted zone (anoxic zone) in wetland sediments, the dark grey nature of the material (of soils and sediments) is due to the presence of sulphide, most commonly as iron sulphide. Formation and residency of iron sulphide is a normal part of wetland sediment development and its geochemical evolution. Concomitant with sulphide development, there also may be chemical fixing of heavy metals and arsenic. Anthropogenically induced aeration of such sulphide rich material, however, either through excavations of soils or drains, or through lowering of the water table by draining, leads to exposure of such material to oxygen - the result is that the sulphide is oxidised to sulphate, and there is concomitant production of H^+, hence the soils and sediments became acidic. In the Eyre Peninsula, there has been some development of acid sulphate soils due to lowering of the water table locally (*e.g*., the Wangary area) and due to excavations to form drains. In the former case, the normally anoxic sediment is exposed to aerating conditions as water tables are lowered, and in the latter, the material normally residing in the water saturated anoxic zone has been brought to the oxygen rich surface as “spoil material”.

9.3 Assessment of level of degradation

Wetlands are complex, interactive, dynamic systems. With respect to assessing the level of degradation, there are some factors on which impacts and change are directly discernible *e.g*., geomorphology, some hydrological factors, vegetation, hydrochemistry, faunal presence/absence and cultural values. There are other questions about impacts and change on wetland maintenance processes, self regulating mechanisms, and internal resilience potential *etc*. which are more complex and difficult to discern. Any evaluation of such a system requires that ideally both of these aspects of degradation be considered. Therefore, a multi dimensional approach, as well as a grading of many different factors is required. In addition to a multidimensional approach, some kind of weighting of factors is needed in order to encompass questions that are largely directly unanswerable. Some wetland features and processes are recognised as being more fundamental than others in the on-going maintenance and function of the wetland.

A “wetland” is fundamentally made up of a wetness factor (water) and land. As described earlier, hydrology and geomorphology are the two fundamental factors determining the presence/absence of wetlands throughout the region as well as the range of wetland features that occur. Secondary, but specific products and processes, derive from this interaction of water on the land: aquatic or waterlogged sediments, hydrochemical and geochemical fields, plant assemblages tolerant to inundation or waterlogging, aquatic fauna, and numerous ecological processes. So that if either the hydrology or geomorphology of a wetland is disturbed to a significant degree, the current wetland functions, wetland type, and diversity of ecological functions can be irrevocably altered. Therefore these two factors were weighted the most with regard to assessing level of degradation.

As indicators of anthropogenic change, vegetation was used for short to medium term measures, and sediments and stratigraphic profiles were used for longer term assessments. For methods please refer to C A Semeniuk (2007). As an example, a plant species/community adapted to subhaline water being replaced by a plant species/community adapted to hyposaline water indicates a change in the wetland’s natural state and function. However, the occurrence of plant species tolerant to the range of fresh - subhaline water in a wetland which has become either permanently fresh or permanently subhaline is difficult to interpret as this could be the result of two competing communities, or a natural mixed community, or a community undergoing a longer term change from poikilohaline to stasohaline conditions. Whether this change is the result of variability in climatic conditions, a change in water source or a change in water regime is another question which needs to be answered. In cases, where a particular plant species is tolerant to a limited range of salinity, plant indicators are very reliable. However, on the Eyre Peninsula, there are many species of plants which are tolerant of a wide range of salinity conditions, especially if one or other is short lived, and so the occurrence of these plants can not be used as a reliable indicator of either hydrochemical change or degradation.

In the case of water regime, the most reliable indicators are the sediments, because aquatic sediments are very different to waterlogged sediments. In the case of Pillie Lake, for instance, the sediments clearly indicate that it was formerly a sumpland, but hydrographs in this study indicate that the wetland is now less frequently inundated.

In cases where water levels have dropped, but the wetland category has not changed, the sediments may not reflect this change, *e.g.*, a deep sumpland becomes a shallow sumpland or a deep creek becomes a shallow creek.

Changes to water regime also incorporated altered recharge mechanisms or discharge mechanisms, which were apparent where the wetland sediments had been excavated, groundwater extraction was continuing, the wetland was alienated by road construction or from other hydrological links, or the regional flow was impeded by draining, damming or diversion. Changes in hydrological seasonality and hydroperiod were noted from the hydrographs, and also from the sediment composition. Changes to water levels alone, unless the change was severe enough to alter the wetland category, were inconclusive. In the case of some wetlands the data collected to construct hydrographs were insufficient (1-2 months) to interpret change (Little Sleaford, Lake Newland, Lake Hamp, Stamford Hill, Little Seagull Lake).

Assessment of wetlands also included information on the status and condition of the following wetland features: geomorphology, wetland type, water salinity, water quality, recharge/discharge mechanisms, hydroperiod, vegetation clearing, weed invasion, effects of fire, presence of plant understorey. For reasons outlined above, emphasis was placed on alteration to geomorphology and hydrological mechanisms, the fundamental attributes of wetlands. Short-term effects and impacts were assessed as being low levels of degradation while longer term effects to water regime or landform were assessed as being high levels of degradation. For this assessment, some water samples were analysed for nutrients and heavy metals, aerial photography was used to assess vegetation cover, and field work was used to assess mining, land/soil excavation, infilling, and drainage.

The assessment of degradation applies only to the sites visited during this study. This has been done to avoid confusion in assessments at different scales, that is, assessment of degradation can be undertaken at various scales as follows:

1. site degradation, *i.e.*, assessment at a site-specific wetland
2. degradation elsewhere within the consanguineous suite, *i.e.*, assessment of the entire suite of wetlands within a given consanguineous suite; and
3. overall degradation in the surrounding region or catchment, *i.e.*, the wetland may be well vegetated and in reasonable condition, but the surrounding terrain is degraded.

For example, the individual wetland basin sites within the Malata suite selected for this study showed very little current degradation and would benefit from being maintained in their present condition and protected from future impacts. Elsewhere in the Malata suite the basins are under threat and many exhibit impacts, which although considerable in intensity (dredging, mining, pumping, groundwater extraction, vegetation clearing, removal of sediments, and grazing by stock), appear to be localised.

A second example further explains the effect of scale. The site chosen for the Tod River shows very little impact on its geomorphology, hydrology, hydrochemistry or sediments. At the scale of the consanguineous suite, the upper tributaries of the Tod River, of which this site is a component, exhibit different levels of impact to the lower tributaries because of the location of the Reservoir and its impoundment effect. At a larger scale again, the region surrounding the Tod River and its tributaries is largely cleared and there are impacts on the regional hydrology and vegetation.

In this study, the assessment was of the site-specific wetland selected for monitoring. Attributes which can be used for assessment include (Table 8): geomorphology, water regime, hydrochemistry, sediments, vegetation, wetland vertebrates, and macroinvertebrates.

In this study, indicators of wetland macroinvertebrate were omitted because baseline data are yet to be collected. Thus, only the following were assessed:

A). geomorphology,
B). water regime,
C). hydrochemistry,
D). sediments,
E). vegetation,
F). wetland vertebrates.

Assessment of these readily discernible features was graded into 5 levels, commencing with the smallest and most easily reversible impacts and building to the larger, more durable impacts, and those capable of creating secondary effects. Grades range from: very low, low, medium, high, to very high, and these are numerically rated as 1, 2, 3, 4, & 5. Examples are provided in Table 8 to help define these grades.

Table 8 Summary of ranking of grades in assessment of wetland site degradation

Factor	Grade of impact	Selected examples	Numerical rating
geomorphology			
	very low impact	no obvious change to natural morphology	1
	low impact	trampling of edges, margins, or compaction	2
	medium impact	road bisection, or remnant	3
	high impact	small farm dam excavation, minor erosion	4
	very high impact	dredging, or mining, or infilling, or cement containment, or realignment	5
water regime			
	very low impact	<10 cm change in water levels and seasonal fluctuations, no change in hydroperiod or period of inundation	1
	low impact	5-10% change in inundation or waterlogging frequency, not enough to affect biota or sediments	2
	medium impact	minor irrigation discharge, or change to period of waterlogging or inundation	3
	high impact	major irrigation discharge, or major change to period of waterlogging or inundation, or small drains, or seasonal groundwater extraction within range of maximum and minimum water levels	4
	very high impact	large drains, or pumping, or major groundwater extraction, or groundwater rise and increased waterlogging due to clearing of surrounding vegetation, or damming of upstream channel, change of wetland type, *e.g.*, from sumpland to lake	5
hydrochemistry			
	very low impact	minor fluctuations but no perceptible change in salinity class or nutrient composition	1
	low impact	minor impact on seasonal salinity, same class range	2
	medium impact	change in seasonal salinity, or minor seasonal nutrient enrichment, enough to be reflected in microbiota, macrophytes, and macroinvertebrates	3
	high impact	small change in perennial salinity, or regular seasonal nutrient enrichment and algal blooms	4
	very high impact	large change in perennial salinity, or excessive nutrient enrichment, or heavy metal contamination	5
sediments			
	very low impact	minor changes to sediments but no obvious change to natural stratigraphy	1
	low impact	partial oxidation of anoxic sediments, or brecciation of peats, surface compaction	2
	medium impact	fire damage to surface peat	3
	high impact	contamination of sediments	4
	very high impact	removal of sediments (carbonate/gypsum sands and muds), or development of acid sulphate soils	5
vegetation			
	very low impact	minor change in plant cover, composition, or structure	1
	low impact	<5% change in plant structure, or density, or minor weed invasion	2
	medium impact	change in plant composition, or density, or weeds predominate	3
	high impact	no understorey, or partly cleared	4
	very high impact	cleared	5

vertebrates			
	very low impact	minor change to natural population numbers and composition	1
	low impact	fencing which affects faunal migration	2
	medium impact	alienation by tunnels, weirs	3
	high impact	loss of faunal habitat niches	4
	very high impact	competitive feral animals, or diseases, or introduction of predators, or loss of habitat required for specific faunal functions (*e.g.*, nesting or breeding sites)	5
macroinvertebrates			
	very low impact	fluctuations in but no obvious change to natural population numbers and composition	1
	low impact	invasion by nuisance species	2
	medium impact	populations maintaining natural diversity but with dominance by nuisance species	3
	high impact	loss of habitat niches, decline in natural diversity	4
	very high impact	loss of habitat, loss of diversity	5

The results of the assessment of degradation for each wetland that was selected for monitoring within each of the suites are presented in Table 9 with the exception of macroinvertebrate use (as collection of data on macroinvertebrates is earmarked for a second stage to this study, it could not be assessed). Table 9 contains the independent grade for each wetland factor and the overall level of degradation. The wetland attributes of (A) geomorphology, (B) water regime, (C) hydrochemistry, (D) sediments, (E) vegetation, and (F) wetland vertebrates are arranged in order in the "grades of impact for each attribute), *viz*., the numerical; ranking if 1, 2, 3, 4 & 5 have been applied to the Tod River at Koppio, and the various attributers have been graded as;

	Attribute	Degradation Level
A	geomorphology	= grade 1
B	water regime,	= grade 1
C	hydrochemistry,	= grade 3
D	sediments,	= grade 1
E	vegetation,	= grade 1
F	wetland vertebrates.	= grade 2

Thus in the entry on Tod River at Koppio the gradings are listed as 1,1,3,1,1,2.

Table 9 Assessment of degradation of wetland sites for 2005-2006

Wetland site	Grades of impact for each attribute A,B,C,D,E,F	Assessment of level of overall degradation
Tod River at Koppio	1,1,3,1,1,2	Low to medium
Salt Creek, Little Salt Cr., Miltalie Cr.	2,3,1,1,2,1	Low to medium
Sleaford Mere	1,1,1,1,2,1	Low
Little Sleaford	1,1,1,1,2,1	Low
Mt Wudinna	1,1,1,1,1,1	Very low
Lake Malata	1,1,1,1,2,3	Low to medium
Un-named basin (Malata site 1)	1,1,1,1,1,3	Low to medium
Un-named basin (Malata site 1D)	1,1,1,1,2,3	Low to medium
Lake Greenly	1,1,1,1,3,1	Very low to medium
Little Swamp	1,4,3,3,5,2	High to very high
Duck Lake	3,1,2,1,2,2	Medium
Merintha Creek, Wanilla	3,5,2,2,4,3	High
Moonabie Flat at Murninnie	1,1,1,1,1,3	Very low to medium
Pinthaput 1	3,1,1,1,2,1	Medium
Samphire Flat	3,1,1,1,2,2	Medium
Pinthaput 2	1,5,1,1,4,2	Medium to high
Munyaroo Conservation Park wetlands	1,1,1,1,1,1	Very low
Pillie Lake	1,2-4,1,1,2,1	Low to possibly high
Kilroy	1,1,1,1,4,3	Low to high
Bramfield	3,1,1,1,1,2	Low to medium
Lake Hamilton	2,1,1,1,2,3	Low to medium
Round Lake	1,4,1,1,4 3	Low to high
Lake Hamp	1,1,5,4,3,1	High
Wild Dog Gully	1,1,1,1,4,1	Low to high
Little Seagull Lake	1,1,1,1,1,1	Very low
Paddy’s vent	1,1,1,1,2,1	Low
Doline	1,2,4,1,1,1	Very low to high
Lake Newland	1,1,1,1,1,1	Very low
Yanerbie	1,1,1,1,2,3	Low to medium
Newland Barrier, 1, 2, 3, 4	1,1,1,1,2,1	Low
Stamford Hill	1,1,1,1,1,1	Very low

Broad guidelines regarding the quality and quantity of management required for each level of degradation are presented in Table 10.

Table 10 Suggested management for corresponding assessment of degradation

Assessment level of degradation	Level and type of management required
Very low	requiring passive management only
Low	requiring active management of weeds, rubbish dumping, fire, trampling by cattle and people
Medium	requiring re-vegetation, purification of water quality
High	requiring active rehabilitation in part of the wetland and planning for future risk containment
Very high	requiring rehabilitation of one or both of the fundamental attributes of wetlands, *i.e.*, their geomorphology or hydrology

10.0 Management

10.1 Vision
To recognise the similarities and differences in wetland types, processes and functions, and to put in place a combined legislative, scientific and social programme, employing monitoring, active decision making, and passive or active rehabilitation, in order to make wetlands symbols of the Eyre Peninsula landscape and successfully sustain their values in the long term.

10.2 Legislative framework
There are State and Federal Acts which may be used in a broad context to develop policy concerning wetland protection and conservation. The Federal EPBC Act (1999) sets out requirements for environmental approvals and recognises the importance of Ramsar wetlands and listed threatened ecological communities and species. *The Wildlife Conservation Act* (1950), *National Parks and Wildlife Act* (1972), *Native Vegetation Act* (1991) and *Natural Resource Management Act* (2004) may also be considered in regard to identifying threatened species and communities, native vegetation and preserving natural resources of land and water. The *Aboriginal Heritage Act* (1988) may also be useful when considering ecological and cultural values of wetlands. The *Environmental Protection Act* (1993) has provisions for the implementation of statutory environmental protection policies. Its broad aims are conservation, preservation, protection, enhancement, and management of the natural environment and natural resources. Also, in assessing projects, proposals, and amendments, new policy may be created.

Applications can also be made to have wetlands recognised as being of international importance and designated as sites under the Ramsar Convention, to which Australia is signatory.

10.3 Management Recommendations
Below are a series of management objectives as well as suggestions and tasks for implementing or meeting them.

1. The objective is to maintain the geological and geomorphological diversity and processes of the wetland and surrounds and protect sites of known geoheritage, *e.g.* Sleaford Mere stromatolites, Lake Malata beachridges and gypsum dunes, Greenly Lake contact between Tertiary alluvial sediments and Pleistocene limestones, Lake Newland springs and barrier dune, Calpatanna dolines, Poelpena Swamp.

- Educate the community about the range of wetland types.
- Ensure geoconservation values are taken into consideration as part of broader assessments of proposed additions to the public conservation estate /or intended proposals for development.
- Educate the community about geoconservation values.

2. The objective is to maintain the hydrological regimes (quality and quantity) of the wetland and surrounds *e.g.*, Pillie Lake.

- Establish baseline monthly hydrographs for selected wetlands for one year with average, one year with below average and one year with above average annual rainfall or for a period of 5 consecutive years.
- Identify and quantify regional and local recharge areas and flows to each representative wetland.
- Protect the catchment of influent water sources to each representative wetland.

3. The objective is to conserve the diversity of native plants, plant communities and vegetation structure of the wetland and surrounds, and to maintain viable populations of threatened or otherwise significant flora *e.g.*, Mt Wudinna.

- Develop a comprehensive spatial inventory of plant species and communities.
- Ensure recovery plans for any threatened species or community.
- Minimise impacts on native flora or communities from visitor use.

4. The objective is to conserve the diversity of native fauna and habitat types, and to maintain viable populations of threatened or otherwise significant fauna.

- Manage factors that can lead to loss or degradation of faunal habitat such as alterations to water regime, water salinity, weed invasion.
- Restrict public access at various seasons to minimise disturbance to faunal functions.

5. The objective is to reduce the impact of weeds (and high priority weeds in particular) on the conservation values of the wetland and surrounds.

- Map weed communities to assist planning of weed control.
- Liaise with neighbouring landholders to facilitate effective, co-ordinated weed management.

6. The objective is to minimise the impact of introduced and problem animals on the conservation values of the wetland and surrounds.

- Liaise with neighbouring landholders to ensure appropriate stock control measures
- Use fencing or other exclusion control measures.

7. The objective is to maintain biodiversity and protect ecologically sensitive areas from inappropriate fire frequency or large intensive wildfires *e.g.*, Duck Lake, Little Swamp.

- Maintain an emergency response plan to facilitate the suppression of wildfires that threaten human life and property and significant conservation values or fire sensitive species or habitats.

8. The objective is to restore ecosystems to a point where they are resilient, self-sustaining and assist ecosystem processes, *e.g.*, Little Swamp.

- Manage the wetland to avoid further disturbance of soils, vegetation and water regime.
- Consider soil conservation, re-vegetation and introduced plant and animal control programmes in an integrated way across the wider landscape involving landowners and managers as necessary.
- Facilitate natural re-vegetation of disturbed areas.

9. The objective is to conserve the indigenous and cultural heritage values of the wetland and surrounds so that current and future generations can benefit.

- Ensure that traditional custodians have a primary and active role in managing their heritage (through the National Parks Board or DEH) and planning heritage education.
- Ensure that new Aboriginal sites are protected in accordance with the traditional custodians of the area and the requirements of the Aboriginal Heritage Act and Australian Heritage Council Act.
- Ensure that the traditional custodians are involved in indigenous heritage site identification surveys.

10. The objective is to provide visitors with a range of sustainable nature based experiences, by providing access that does not adversely impact on the values of the wetland and surrounds, and facilitates visitor appreciation of its values.

- Gazette clearly delineated areas for overnight camping, day visits, walking, and no entry.
- Construct walking trails.

11. The objective is to ensure that non-commercial, education, scientific research and not for profit activities such as wildlife viewing, are compatible with other wetland and surrounds management objectives.

- Schedule activities and duration of stay.
- Plan litter disposal.
- Construct toilet facilities which will not contaminate springs or groundwater.

12. The objective is to protect the ecological values of the wetland and surrounds from the adverse impacts of raw material extraction, mineral exploration and development *e.g.*, Lake Malata, Greenly Lake.

- Provide formal advice to DEH, Dept Industry & Resources, Water Corporation in relation to mining proposals so as to maintain ecosystem integrity.
- Refer exploration or mining proposals with the potential to impact upon the wetland to the Environmental Protection Authority for their consideration and assessment under the Environmental Protection Act.

- Encourage rehabilitation of all mineral extraction sites and borrow pits within wetland areas according to Departmental rehabilitation standards.

13. The objective is to prevent human activities within and adjacent to the wetland and surrounds from adversely impacting on the quality and quantity of groundwater *e.g.*, Lake Hamilton, Lake Malata.

- Provide formal advice to Water Corporation in relation to proposals so as to maintain ecosystem integrity.
- Refer extraction or drainage proposals with the potential to impact upon the wetland to the Environmental Protection Authority for their consideration and assessment under the Environmental Protection Act.
- Issue water removal permits.
- Disperse information on water requirements, water budgets and recharge and discharge mechanisms to landholders, community groups, government agencies and visitors.

11.0 Community monitoring programme

11.1 Tasks undertaken for this project

In this project, for the first time, the diversity of wetlands on Eyre Peninsula was established in a systematic way. In addition, baseline data were collected across the board for each of the wetland suites, and a number of sites were set up, using tested and reliable scientific methods, for future monitoring. The results of this endeavour are summarised below.

1. For this project groups of consanguineous wetlands were established, related by setting, origin, geometry, wetland type and aspects of their hydrology, water salinity, and stratigraphy. 20 groups were identified, including 3 previously little known wetlands.
2. Each site was evaluated using an evaluation system designed to assess the attributes of naturalness, scarcity and representativeness.
3. An assessment of the level of degradation was undertaken for each site, incorporating geomorphology, water regime, hydrochemistry, sediments, vegetation, and vertebrate use.
4. In each of these selected wetlands, piezometers and gauges were installed for the purposes of monitoring below and above ground water levels all year round on a monthly basis, and for collecting water samples for analyses of hydrochemical species. Where possible through hand augering, piezometers were installed in the basin centre, basin margin and the adjacent dune. Where hard sedimentary or rock layers were intersected beneath the wetland, both shallow and deep piezometers were installed in order to compare groundwater levels, and to detect sources and directions of groundwater flow.
5. The stratigraphy was sampled at 10 cm intervals and described using microscopic analyses and X-Ray Diffraction where required. The stratigraphic profiles were tied in to the surveyed profile of each wetland.
6. Monthly surface/groundwater levels were graphed for June 2005 to November 2006.
7. Water samples were analysed for salinity and wetlands were classified as having a constant or changing annual salinity. The identification of different chemical signatures in various water bodies also identified a number of sources for groundwater.
8. Waters were sampled for pH values and these too were found to be variable at different times of the year and in different locations suggesting a late winter and spring mixing of both ground and surface waters and waters from different aquifers. These hydrochemical results will be especially important in designing criteria for habitat selection for plant and animal collecting and counting.
9. A subsample of waters was tested for nutrient, cation and heavy metal content, in order to identify sites which were contaminated. This was also undertaken at sites which were perceived to be both important and vulnerable, that is, where there were freshwater springs and small tributaries.
10. Vegetation along transect was described and species identified. The distribution of plant species was plotted along transect, and assemblages were described using structural terms and dominants. In some cases plant distribution was linked to habitat.
11. Faunal species were opportunistically noted.
12. Personnel from EPNRM staff were trained in techniques of consanguineous suite identification, site selection, piezometer installation, water level measuring, and water sampling and storage. They were educated about wetland natural history, regional geology, and wetland dynamics and evolution.
13. A workshop was presented to members of EPNRMB, Rural Solutions SA, SA Water Staff, DEH, and interested community members. Following the workshop individuals were taken into the field and monitoring techniques were demonstrated.

11.2 Recommendations for specific tasks to be undertaken at each site and in selected suites in the immediate future

The most important task to be implemented at this stage is to continue the monthly water level monitoring at each site for 5 years. This is necessary in order to determine normal fluctuations within the current climatic regime and to identify potential trends in wetland water level behaviour. It is important to know whether the water regimes which have been identified and described for 2006-2007 are typical or atypical. It is important to know what the extreme situations are likely to be and to know the range of normal parameters within which the wetland most commonly functions. It is important to identify which aspects of the hydrological regime are the most crucial for the sustaining of flora and fauna assemblages which are dependent on it, *i.e.*, hydroperiod, frequency of inundation, size of seasonal fluctuation, rate of recharge, timing of recharge, rate of discharge, or maximum and minimum water level requirements.

The second most important task is to commence Stage 2 of the project in which plant and faunal assemblages, diversity, distribution and stresses are looked at in detail and to develop a realistic research strategy for achieving conservation objectives. It is important to design this second stage of the project such that the information from Stage 1 is used efficiently. The framework of consanguineous suites has been established but within this framework there will need to be subsets of sampling areas to embrace the range of wetland types from permanently inundated, seasonally inundated, intermittently inundated to seasonally waterlogged, from open to closed systems, and from each salinity class. The established transects can be used for habitat surveys and the installed piezometers can be used in conjunction with quadrat surveys.

The data herein on the wetland sites and their values can be used as the basis for submissions to international, national and state conservation bodies, drawing on the differences between the consanguineous suites to show the uniqueness of specific wetlands and arguing the importance of having at least one representative of each suite in the National Heritage or State Conservation Estate.

The data herein on the wetland sites and their values can be used as the basis for education pamphlets, brochures and workshops for landowners, and the wider community about the wetlands on Eyre Peninsula. New wetlands such as the Anxious Bay wetlands, Murninnie and Munyaroo wetlands could be used to flag such publications.

Other tasks which are considered necessary are listed below in Table 11.

Table 11 Tasks which could be commenced almost immediately

Site	Recommended tasks at the site	Recommended task for the consanguineous suite
Tod River	create a vegetated wetland buffer	fence sites upstream of dams from livestock
Miltalie	create a vegetated wetland buffer	fence sites upstream of dams from livestock
Wudinna	obtain data on water regime	identify sites with declared rare flora
Little Sleaford	add to National Park	
Murninnie	signs, prevention of off road vehicles, monitor grazing activity and vegetation changes	
Munyaroo	collect additional data on sediments water quality and vegetation assemblages	
Samphire Flat	limit unauthorised access, collect further data on sediments and hydrology from deep drilling	
Pinthaput	create vegetated buffer zones	
Wanilla	re-vegetate, fence from livestock	
Lake Malata	create a buffer	educate people about its values, plan protection of wetlands given the constraint of mining leases
Lake Greenly	re-vegetate margins	educate people about its values
Duck Lake	create a buffer	
Little Swamp	re-vegetate margins	
Lake Hamilton	restrict landuse on western side adjacent to lakeside vegetation, prevent further vegetation clearing	
Round Lake	maintain current vegetation and encourage expansion of vegetation naturally	
Lake Hamp	re-locate rubbish site, fence off to off road vehicles	negotiate at least one representative of the wetlands at Elliston for the conservation estate
Lake Newland	management plan	
Little Seagull Lake	management plan	
Yanerbie		educate landowners with respect to its importance and values
Newland Barrier wetlands	fencing from vehicle track, signs	

11.3 The next stage

1. In the wetland inventory for Eyre Peninsula (Seaman 2002), seven wetlands were recommended for monitoring: Sleaford Mere, Lake Newland, Pillie Lake, Lake Hamp, Myrtle Swamp, Sheringa Lagoon and Cemetery Swamp at Elliston. The first four of this list were included in this study. Of the remainder, Myrtle Swamp was not included on the primary list of wetlands issued to the research team. Sheringa Lagoon is part of the Hamilton suite which is represented by Lake Hamilton itself and Lake Hamp. Cemetery Swamp is also part of the Hamilton suite but is much more disturbed than Lake Hamp with surface runnels, mounds and excavations throughout. However, these wetlands could be added to the existing subsample of wetlands for monitoring once piezometers have been installed and stratigraphy documented.

2. Now that consanguineous suites have been identified there is the opportunity to assign all the wetlands on Eyre Peninsula to one of the existing suites, and/or identify wetlands which can not be classified into the established suites. This will necessitate gathering information about the location and setting of each additional wetland, and its classification, sediment fill, water salinity, methods of hydrological recharge and discharge, and its origin. (Professional wetland scientist or staff of EPNRMB).

3. As a result of this regional study there is now a more pressing need to identify all the wetlands on Eyre Peninsula and map and classify them to provide a record of the resource base and its distribution. For mapping, each wetland boundary should be identified, using acceptable criteria. For classification, categories should be chosen which are few in number (for mapping purposes), easy to apply, consistent over time and based on fundamental wetland attributes. (Wetland scientist/cartographer and classification expert).

4. The current site specific hydrological data may be augmented by a number of further simple studies. For example, by continuing the current water level and rainfall monitoring programme for 5 years, to clarify the relationship between groundwater movement and rainfall. Or in some locations (Lake Malata, Kilroy, Sleaford Mere, or Samphire Flat), drilling down to the regional water table (or 5 metres) and logging the stratigraphy at 10 cm intervals to determine the regional and local water flows and their characteristics. (Community in conjunction with SA Water staff)

5. Within the established geomorphic/geologic/hydrologic framework of this baseline survey and within the categories of *in situ* wetland types based on water permanence (permanent, seasonal, intermittent inundation or waterlogging), surveys of the study wetlands may be undertaken for flora and fauna. Data on species' composition and abundance could be collected to be analysed for community groupings, species richness, relationships with environmental parameters, and diversity indices. This information could also be added to the current evaluation. (Community in conjunction with wetland ecologist).

6. Within the established geomorphic/geologic/hydrologic framework of this baseline survey and within the categories of *in situ* wetland types based on water permanence, a strategy for macroinvertebrate and avifauna sampling in wetlands in this study could be designed. Invertebrate sampling would be best carried out using the comprehensive and more intensive method of multiple sampling across habitats in each wetland to determine composition. Statistical analyses of invertebrate data would then be used to determine spatial and temporal variability. Univariate and multivariate statistical approaches could be used to test for trends and differences in condition in the macroinvertebrate fauna at each site using the SAS statistical package (Version 8.1 for Windows), which is a very powerful package for data analysis. (Community in conjunction with wetland ecologist).

7. Change in wetland condition may be monitored by establishing fixed vegetation quadrats near selected piezometers to measure current flora abundance and density. In five year's time plant abundance data would be re-collected and changes related to hydrological and hydrochemical aspects, *e.g.*, water levels and rainfall graphs. (Community in conjunction with wetland botanists, hydrologists and wetland scientists).

8. Almost immediately, surveys of some wetlands could be undertaken for flora and fauna, in order to apply for listing as wetlands of international importance under the Ramsar agreement. Wetlands which potentially conform to criteria for Ramsar wetlands include Seagull Lake, Lake Hamilton or Lake Greenly. (Wetland botanists and fauna ecologists, staff of EPNRMB, DEH).

9. Provide and promote opportunities for involvement of interested community members in management of the wetland and surrounds - publish information in newsletters, provide an annual report to the local papers, and hold annual workshops for participants so that they can see all the data at once and compare their own wetland to others elsewhere. (Staff of EPNRMB).

12.0 References

Anon 1995 Lower Eyre Peninsula District Soil Conservation Board - District Plan and three year programme. National Landcare Programme and Primary Industries SA

Boggon T 2005 A co-ordinated approach to wetland management on Eyre Peninsula. EPCWMB, DEH, DWLBC, EPNRMG

Boggon T & Evans I 2006 A co-ordinated approach to wetland management on Eyre Peninsula. Government of South Australia, EPNRMB.

Cowardin L M, Carter V, Golet F C, and La Roe E T 1979 Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79-31 US Fish and Wildlife Service Washington.

Coventry R J & Williams J 1984 Quantitative relationships between morphology and current soil hydrology in some Alfisols in semi-arid tropical Australia. *Geoderma* 33: 191-218.

Cresswell I D, Malafant K, & Semeniuk V 2000 Preliminary assessment of patterns of mollusc abundance and associations in Leschenault Inlet estuary. Royal Society of WA Special Issue on the Leschenault Inlet Estuary. Journal of the Royal Society of WA 83: 419-428.

Datsun B 2002 Samphires in Western Australia. A field guide to Chenopodiaceae tribe Salicornieae. Department Conservation and Land Management. WA p125

Day P, Das P Hunwick J & Clarke K 2004 Eyre Peninsula Catchment Report. EPCWMB S.A.

Day P, Das P & Clarke K 2005 Eyre Peninsula Catchment Water Management Plan. EPCWMB S.A.

De Deckker P, Bauld J & Burne R V 1982 Pillie Lake, Eyre Peninsula, South Australia: modern environment and biota, dolomite sedimentation, and Holocene history. *Transactions of Royal Soc of S Aust* 106(4):169-181

De Jong and Stanton (1995) In Australian Nature Conservation Agency (Ed.) A dierectory of important wetlands in Australia. 2nd. Ed. ANCA Canberra

Department for Environment and Heritage 2002 Biodiversity Plan for Eyre Peninsula South Australia. Adelaide DEH, NPW, NHT, Bushcare, Ark on Eyre

Department for Environment and Heritage 2003 Lake Newland Conservation Park Management Plan Western Eyre Peninsula. Adelaide

Drexel J F, Preiss W V & Parker A J (eds.) 1995 The geology of South Australia. Vol 1 The Precambrian. South Australia Geological Survey. Bulletin 54.

Drexel J F & Preiss W V (eds.) 1995 The geology of South Australia. Vol 2 The Phanerozoic. South Australia Geological Survey. Bulletin 54.

Dutkiewicz A & von der Borch C C 1995 Lake Greenly, Eyre Peninsula, South Australia: sedimentology, palaeoclimatic and palaeohydrologic cycles. *Palaeogeogr, Palaeocl, Palaeoecology* 113:43-56

Dutkiewicz A & von der Borch C C 2002 Stratigraphy of the Lake Malata playa basin, South Australia. *Transactions of Royal Soc of S Aust* 126(2):91-102

Dutkiewicz A, von der Borch C C & Prescott J R 2002 Geomorphology of the Lake Malata-Lake Greenly Complex, South Australia, and its implications for Late Quaternary palaeoclimate. *Transactions of Royal Soc of S Aust* 126(2):103-115

English J P, Shepherd K A, Colmer T D, Jasper D A, and McFarlane T 2002 Minerals and Energy Research Institute of WA Report No 225, East Perth p44

Firman J B 2006 A stratigraphic guide to the evolution of ancient weathering zones, pedocretes and paleosols on the Australian Precambrian Shield and in adjoining sedimentary basins. Journal of the Royal Society of WA 89(2): 57-82.

Golet F C & Larson J S 1974 Classification of freshwater wetlands in the glaciated northeast. Resource Publication 116. US Fish and Wildlife Service, Washington D.C.

Gravestock D I Callen R A Alexander E M and Hill A J (1995) Strzelecki, South Australia Sheet SH54-2 South Australia. Geological Survey 1:250,000 Series – Explanatory Notes

Greenway M (1997) Wetlands in a dry land: understanding for management, Albury, NSW 29-30 Environment Australia

Hammer U T 1986 Saline lake ecosystems of the world. Dr W Junk Publishers

Hill A, Semeniuk C A, Semeniuk V & Del Marco A 1996 Wetlands of the Swan Coastal Plain Volume 2A: Wetland mapping classification, and evaluation. Water & Rivers Commission, Perth (ISBN 0 7309 3748 8).

Laut P, Heyligers P C, Keig G, Loffler E, Margules C, Scott R M & Sullivan M E 1977 Environments of South Australia, Province 4, Eyre and Yorke Peninsulas. CSIOR Australia (Division of Land Use Research, Caqnberra).

Lefor M W & Kennard W C 1977 Inland Wetland definitions. Report 28 Institute of water resources, University of Connecticut, Storrs, CT

Morelli J and de Jong M 1996 Important wetlands in South Australia. In Australian Nature Conservation Agency A Directory of important wetlands 2nd ed. Canberra

Parker A J, Fanning C M and Flint R B 1985 Geology. In Twidale C R, Tyler M J and Davies M (eds.) Natural History of Eyre Peninsula. Royal Society of South Australia (Inc). p21-47

Pen L, Semeniuk V & Semeniuk C A 2000 Peripheral wetland habitats and vegetation of Leschenault Inlet estuary. Royal Society of WA Special Issue on the Leschenault Inlet Estuary. Journal of the Royal Society of WA 83: 293-316.

Robinson A C & Heard L M B 1985 National Parks. In Twidale C R, Tyler M J and Davies M (eds.) Natural History of Eyre Peninsula. Royal Society of South Australia (Inc). p201-225

Schwerdtfeger P 1985 Climate. In Twidale C R, Tyler M J and Davies M (eds.) Natural History of Eyre Peninsula. Royal Society of South Australia (Inc). p89-101

Seaman R L 2002 Wetland Inventory for Eyre Peninsula, South Australia. Department for Environment and Heritage

Semeniuk C A 1987 Wetlands of the Darling System - A geomorphic approach to habitat classification. Journal of the Royal Society of WA 69(3):95-112

Semeniuk C A 1988 Consanguineous wetlands and their distribution in the Darling System, Southwestern Australia. Journal of the Royal Society of WA 70(3):69-87

Semeniuk C A 2007 The Becher Wetlands - a Ramsar site. Springer, Amsterdam.

Semeniuk C A and Semeniuk V 1990 The coastal landforms and peripheral wetlands of the Peel-Harvey Estuarine System. Journal of the Royal Society of WA 73: 9-21

Semeniuk C A and Semeniuk V 1995 A geomorphic approach to global classification for inland wetlands. *Vegetatio* 118:103-124

Semeniuk C A and Semeniuk V 2007 A comprehensive classification of wetlands - inland. coastal, and anthropogenic. MS to Journal of the Royal Society of WA

Semeniuk C A, Semeniuk V, Cresswell I D and Marchant N G 1990 Wetlands of the Darling System, southwestern Australia: a descriptive classification using vegetation pattern and form. Journal of the Royal Society of WA 69(3):95-112

Semeniuk V 1983 Regional and local mangrove distribution in Northwestern Australia in relationship to freshwater seepage. *Vegetatio*, 53: 11-31.

Semeniuk V 1986 Terminology for geomorphic units and habitats along the tropical coast of Western Australia. Journal of the Royal Society of WA 68: 53-79.

Semeniuk V 1996 Coastal forms and Quaternary processes along the arid Pilbara coast of northwestern Australia. Palaeo 3: 49-84.

Semeniuk V 2000 Sedimentology and Holocene stratigraphy of Leschenault Inlet. Royal Society of WA Special Issue on the Leschenault Inlet Estuary. Journal of the Royal Society of WA 83: 255-274.

Semeniuk V 2004 Tidal flats *In*: Schwartz M.L., (ed), Encyclopaedia of coastal science. Kluwer Academic Publishers.

Semeniuk V & Johnson D P 1982 Recent and Pleistocene beach and dune sequences, WA. Sedimentary Geology, 32: 301-328.

Semeniuk V & Semeniuk C A 1997 The geomorphic approach to global classification for natural inland wetlands and rationalization of the system used by the Ramsar Bureau - a discussion. Wetland Ecology & Management 5: 145-158.

Semeniuk V & Semeniuk C A 2004 Sedimentary fill of basin wetlands, central Swan Coastal Plain, southwestern Australia. Part 1: sediment particles, typical sediments, and classification of depositional systems.. Journal of the Royal Society of WA 87: 139-186

Semeniuk V & Semeniuk C A 2006 Sedimentary fill of basin wetlands, central Swan Coastal Plain, southwestern Australia. Part 2: distribution of sediment types and their stratigraphy. Journal of the Royal Society of WA 89: 185-220

Semeniuk V, Semeniuk T A, & Unno J 2000 The Leschenault Inlet estuary - an overview. Royal Society of WA Special Issue on the Leschenault Inlet Estuary. Journal of the Royal Society of WA 83: 207-228.

Semeniuk V & Withers P C (eds) 2000 The Leschenault Inlet estuary - Royal Society of WA Special Issue on the Leschenault Inlet Estuary. Journal of the Royal Society of WA 83: 205-512.

Semeniuk V & Wurm P A S 1987 Mangroves of Dampier Archipelago, Western Australia. Journal of the Royal Society of WA 69: 29-87.

Semeniuk V & Wurm P A S 2000 Molluscs of the Leschenault Inlet estuary - their diversity, distribution, and population dynamics. Royal Society of WA Special Issue on the Leschenault Inlet Estuary. Journal of the Royal Society of WA 83: 377-418

Shepherd R 1985 Hydrology. In Twidale C R, Tyler M J and Davies M (eds.) Natural History of Eyre Peninsula. Royal Society of South Australia (Inc). p101-105

Sindicic M 2002 Cummins – Wanilla Basin Catchment Management Plan. DWLBC, NHT, PIR South Australia

Specht, R. L. 1981 Foliage projective cover and standing biomass. In A. N. Gillison & D. J. Anderson (Eds.) *Vegetation Classification in Australia*. Proceedings of a workshop by CSIRO Division of Land Use Research Canberra

Twidale C R, Tyler M J and Davies M (eds.) 1985 Natural History of Eyre Peninsula. Royal Society of South Australia (Inc).

Twidale C R & Campbell E M 1985 The form of the land surface. In Twidale C R, Tyler M J and Davies M (eds.) Natural History of Eyre Peninsula. Royal Society of South Australia (Inc). p57-77

UNESCO 1971 Convention on wetlands of international significance especially as a waterfowl habitat. published in Australia 1976 for Department of Foreign Affairs by the Australian Government Publishing Service Treaty Series 1975 No 48.

V & C Semeniuk Research Group 2007 Lake Newland Baseline Survey and Literature Review, Eyre Peninsula. Report to Eyre Peninsula Catchment Water Management Board by V & C Semeniuk Research Group, April 2007.

Wetlands Advisory Committee 1977 The status of wetland reserves in System 6. Report of the Wetlands Advisory Committee to the Environmental Advisory Committee.

Williams W D 1984 Lakes Australia. *Verh Internat Verein Limnol* 22:1208-1215

Wilson P 1980 A revision of the Australian species of Salicornieae (Chenopodiaceae). Nuytsia 3 (1) WA Herbarium.

Wright, M J 1985 Soils. *In*: Twidale C R, Tyler M J and Davies M (eds.) Natural History of Eyre Peninsula. Royal Society of South Australia. pp 77-87

Wurm P A S & Semeniuk V 2000 The Leschenault Inlet estuary - its physical features and habitats for benthic fauna. Royal Society of WA Special Issue on the Leschenault Inlet Estuary 83: 229-250

Zoltai S C & Pollett F C 1983 Wetlands in Canada: their classification, distribution, and use. In: Gore AJP (ed) Ecosystems of the World - 4B. Mires, swamp, bog, fen and moor. Regional studies. Elsevier Scientific Publishing, 245-268.

V & C Semeniuk Research Group

A baseline survey of the wetlands of the Eyre Peninsula 2005-2007

APPENDICES 1-4:

Appendix 1: Amalgamation of data for each wetland suite

Appendix 2: Salinity and pH of surface waters and groundwaters : June 2005 - September 2006

Appendix 3: Selected water chemistry

Appendix 4: Groundwater hydrographs showing the length of time water levels in piezometers took to equilibrate

APPENDIX 1 – Amalgamation of data for each wetland suite

Description of consanguineous suites and selected representative sites
Twenty wetland suites incorporating forty sites are described below. Descriptions include setting, wetland type, stratigraphy, hydrology, water quality, vegetation and evaluation.

Koppio Suite (Fig. 11)
7 sites were visited including tributaries of the Tod and White Rivers. Two sites were selected for monitoring: Yallanda Flat GPS 34^o 20.76'S and 135^o 52.64' E; and Tod River at Koppio GPS 34^o 21.55'S and 135^o 52.35' E. At both sites a piezometer was installed for monthly water level readings.

Setting: This suite is located in the low relief, dissected, lateritic hills and valleys, underlain by bedrock (gneiss, quartzite, and schist).

Wetland types: Creeks, floodplains, palusplains.

Description: Wetlands consist of small scale (5m wide x 1.5 m deep) seasonal, meandering, incised channels with cliffed sides, exhibiting point bar development, small levees, and narrow floodplains with inundation pools.

Stratigraphy: The cliffed sides may be cut into alluvial fans comprising muddy sand or gneissic or schist bedrock, and the channels are clogged with bedloads of gravel and shoals of sand. Floodplains are underlain by kaolin mud and sandy mud.

Hydrology: The wetlands are recharged directly by rainfall and by surface runoff and subsurface seepage. Discharge is via surface flow, discharge to local groundwater and evapo-transpiration. The direction of sub surface seepage depends on the relative water levels in the channel and the surrounding flats. During the period of study, flows were dominantly from the creek to the groundwater aquifer. Groundwater levels fluctuate seasonally from 35-80 cm. Water levels in the channel are generally reduced to a shallow trickle in the dry season but rise approximately 35 cm in winter.

Water quality: The surface and groundwaters at Koppio and Yallanda Flat were predominantly hyposaline (3,000-8,500 mg/L). For three or four weeks water salinity freshened to subhaline (1,000-3,000). Cation concentrations in the waters at the time of sampling were all low (Appendix 3), as were levels of arsenic, lead, copper and phosphorous. The waters fluctuated above neutral, the range being pH 7.8-8.6 with the more alkaline levels being recorded in the summer.

Vegetation: Point bars are vegetated by sparse shrubs of *Melaleuca brevifolia*, *Juncus kraussii* and *Baumea juncea*. Floodplains are vegetated by open woodlands of *Eucalyptus camaldulensis* and understoreys of species of Chenopodiaceae such as *Sueda australis, Sarcocornia quinqueflora* and *Halosarcia* sp.

Evaluation: Tod River at the Koppio site has a high degree of naturalness and ecological and aesthetic value. It displays the typical small scale seasonal, freshwater, meandering, incised channel with cliffed sides, point bar development, small levee, and narrow floodplain with inundation pools. The range of fluvial habitats has resulted in a number of small but diverse plant communities which include *Melaleuca brevifolia* shrubs, *Juncus kraussii* rush, *Baumea juncea* sedge, *Eucalyptus petiolaris* woodland, and samphires. As a result of disturbance to geomorphic habitat types, change in hydrochemistry or removal of vegetation elsewhere, this range of plant communities has disappeared from many other sites. The water is clear and free from the turbidity which often occurs in valley areas cleared of vegetation.

This site needs to be managed to preserve its ecological functions, naturalness and plant diversity.

Miltalie suite (Fig. 12)
4 sites were visited. Salt Creek crossing 33^o 25.285'S and 137^o 00.64' E; Miltalie Creek 33^o 31.97'S and 136^o 50.51' E; Salt Creek opposite Midgee 33^o 27' 6.8"S and 137^o 21' 48.1" E;

Setting: Low relief, dissected, lateritic hills and valleys, underlain by gneiss, quartzite, and schist.

Wetland types: Creeks, floodplains, palusplains.

Description: Structurally controlled, microscale shallow channels with broad adjacent flats.

Stratigraphy: Gneiss, schist outcrop and bedloads of terrestrial clay and quartz/feldspathic sand.

Hydrology: Wetlands are recharged by direct precipitation and run-off. Discharge is via surface flow, discharge to local groundwater and evapo-transpiration. Groundwater levels are generally near the surface in the dry season (-20 cm) but rise approximately 60 cm in winter.

Water Quality: Single samples, taken in April 2006, of the surface and groundwaters at Miltalie sites, were mesosaline (25,000-36,000 mg/L). The salinity values suggest that although salt concentrations would increase over a dry summer and decrease during the winter months, they probably always remain in the mesosaline category. The waters were slightly above neutral, the range being pH 7.8-8.0.

Vegetation: On the floodplains communities are small and patchy (maculiform) and comprise samphires, *Halosarcia pergranulata, H. indicans, H. halocnemoides*, *Sarcocornia quinqueflora*, *Mairiana erioclada.* The channel is lined by the rush *Juncus kraussii*, and scattered shrubs of *Melaleuca halmatururoum*. Charophytes occur in quiet shallow pools of the channel.

Evaluation: Miltalie Creek site has a high degree of naturalness and as well as important ecologic, recreation and aesthetic values. In an area where many other locations have disturbed geomorphology, hydrochemistry and/or vegetation, this site stands out. It encompasses an undisturbed channel thalweg and margins, with point bars, mid stream shoals and intact banks. Riparian vegetation gradually merges into upland assemblages.

This site needs to be managed to preserve its naturalness, geomorphic integrity, water quality, transitional ecological zones, and aesthetics.

Sleaford suite (Fig. 13)
4 sites were visited. Two sites were selected for monitoring: Sleaford Mere GPS 34^o 49' 26.5"S and 135^o 44' 26.3"E; and Little Sleaford GPS 34^o 51' 43.9"S and 135^o 43' 16.8" E. At Sleaford Mere two piezometers and a guage were installed and at Little Sleaford, two piezometers were installed, for monthly water level readings.

Setting: The contact between the low relief dissected ridge of lateritised metamorphic rocks of the Gawler Craton and the adjacent swale underlain by limestone.

Wetland types: Lake, sumpland

Description: This suite consists of one megascale elongate irregular basin, Sleaford Mere, and one mesoscale round basin, un-named, which is referred to herein as Little Sleaford. Sleaford Mere is permanently inundated and the un-named wetland is seasonally inundated. In the central basin, fossil stromatolites form islands and reefs standing about 50 cm above the present water level. At the margins they form relic beaches, pavements and beach ridges.

Stratigraphy: Both basins are surrounded and underlain by limestone and ferricreted clays and gravel. At Sleaford Mere, the wetland fill comprises waterlogged calcareous ooze and intraclastic calcareous sand and gravel with a surface crust of fossil stromatolites and cemented algal mat. At the un-named sumpland, the wetland fill comprises calcareous mud overlying the basement of orange terrigenous clay and ferricrete, exemplifying the limestone/ironstone contact wherein it lies.

Hydrology: Mechanisms of recharge to Sleaford Mere require further investigation, but include direct precipitation and seepage from adjacent ridges. Groundwater and surface water fluctuations correspond varying approximately 20 cm annually. At the un-named basin water levels fluctuate up to 90 cm and towards the end of winter, groundwater levels are higher than the surface water.

Water quality: The surface water of Sleaford Mere has a consistent pH around 8.2 which is alkaline and typical of limestone aquifers. The groundwater chemistry is variable, at one end closely approximating rainwater and at the other end highly alkaline (pH 6.9-9.4). This suggests that there are a number of sources for groundwater recharge. Near the main basin, the salinity of both surface waters and groundwaters are similar, lying predominantly in the mesosaline range (24,000-29,000 mg/L), but concentrations can be diluted by direct rainfall input. At the lake margins, groundwater is subhaline (1600 mg/L) indicating subsurface seepage from the adjacent ridges of limestone and iron materials. Cation concentrations in the waters at the time of sampling were mostly low with some medium peaks in sodium and magnesium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were also low. At the sumpland, the groundwater chemistry is neutral, (pH 6.9), but the salinity of groundwater perched above the iron cemented layer is hypersaline (70,000 mg/L).

Vegetation: The vegetation cover forms a mosaic of communities and is peripheral (bacataform). The surface crust of fossil stromatolites and cemented algal mat are not vegetated, the upper pavements above mean water level are vegetated by mat plants of *Limonium companionus*, *Hemichroa pentandra*, *Schoenus* sp., while the ridges of eroded stromatolites on the margin of the lake support closed heath giving way to shrubland. Closed heath comprises several species of *Melaleuca: M.* h*almaturorum*, *M. lanceolata, M. cassytha,* and *Gahnia triffida* or *filum, Cryptandra leucopogon, Acrotriche cordufa, Leucopogon parviflorus, Lasiopetalum discolor, Olearia axillaris.* Shrubland is dominated by *Gahnia filum* and *Acacia leiophylla.* At the Little Sleaford sumpland, the vegetation is also peripheral (bacataform). Charaphytes and species of Chenopods colonise the central basin. At the lake margins, where groundwater salinity is probably lowered by subsurface seepage from the adjacent ridges of limestone and iron impregnated and cemented materials, closed heath and then shrubs comprise two species of *Melaleuca, M. brevifolia* and *M. halmaturorum.*

Evaluation: Sleaford Mere has a high degree of naturalness and uniqueness as well as important geoheritage and biological values. The hydrological regime appears to be natural. Groundwater abstraction is not evident and hydrographs show a seasonal reponse to rainfall and groundwater fluctuations. At the lake margins there is subsurface seepage from the adjacent ridges. The hydrochemistry also appears unaltered, in that surface water has pH around 8.2 which is typical of limestone aquifers, and the groundwater chemistry is neutral, approximating rainwater (pH 6.9-7.1).

Geoheritage values include its setting, origin, hydrological maintenance and periodicity, and stromatolite development. Sleaford Mere is located along the contact of the lateritised metamorphic rocks of the Gawler Craton (schist, iron, amphibolite) and the limestone and is one of only two wetlands to occur in this setting. The origin of Sleaford Mere and its continuing hydrological functioning are still not fully resolved, but there are indicators that the wetland is under both marine (tidal) and terrestrial influences. This type of wetland maintenance is uncommon. In the central basin of Sleaford Mere, algal mats are currently forming and at various times and in various places are undergoing cementation, growth and destruction. Also in the central basin, fossil stromatolites form islands and reefs standing about 50 cm above the present water level. At the margins they form relic beaches, pavements and beach ridges.

Biologically, the terrestrial populations of Southern Bush Rats, the breeding populations of Chestnut Teal and the aquatic population of skates are important and unusual occurrences (Robinson & Heard 1985).

This site needs to be managed to preserve its naturalness, geoheritage values, scientific information, its uniqueness as an example of a wetland of this type and setting, its water quality, biological values and aesthetics.

Wudinna suite (Fig. 14)
Locations include:Yarwondutta Rocks, Minnipa Rocks, Uncontitchie Hill, and Pildappa Hill. No sites were selected for monitoring because of the potential risk to declared rare flora.

Setting: Isolated rounded granitic hills and inselbergs with gnamma holes and rillen.

Wetland types: Sumplands, damplands

Description: The gnamma holes and rillen in the granite monadknocks comprise the wetland types in this suite.

Stratigraphy: The wetland fill comprises organic enriched muddy sand. The basement is granitic rock.

Hydrology: The leptoscale wetlands are recharged directly by rainfall and are freshwater and seasonal. Discharge occurs through seepage and evapotranspiration.

Water quality: Freshwater.

Vegetation: Plant communities contain herbs and grasses with occasional shrubs of *Melaleuca armillaris.*

Evaluation: This site has a high degree of naturalness as well as important geoheritage, biological and recreational values. The gnamma holes and rillen are recharged by rainfall which discharges through seepage and evapotranspiration. The wetlands themselves are restricted to the granite monadknocks in the region of Wudinna and exhibit various stages of development from hollows in the bedrock surface to deeper cavities with established soil profiles which are seasonally waterlogged. The wetland plant communities contain herbs and grasses with occasional shrubs of *Melaleuca armillaris* which is rare throughout both the Eyre Peninsula region and the state of South Australia, and species of aquatic plants restricted in habitat distribution (*Limosella granitica*) (EPCWMB 2004).

The sites are popular for picnicking, walking and photography.

This site needs to be managed to preserve its naturalness, geoheritage values, scientific information, its example of a wetland of this type and setting, its water quality, declared rare flora, recreation values and aesthetics.

Malata suite (Figs. 15, 16, 17)
4 sites were visited. Three sites were selected for monitoring: Sites 1 and 2 GPS 34^o 09.41'S and 135^o 31.99'E; and Lake Malata itself, GPS 34^o 11.13'S and 135^o 29.11'E. Four piezometers were installed at sites 1 and 2, and at Lake Malata, two piezometers were installed, for monthly water level readings.

Setting: Undulating alluvial plain of valley tract; line of circular basins separated by ridges and lunettes, and underlain by red brown alluvial sandy clay.

Wetland types: Sumplands, damplands

Description: This suite consists of one megascale rounded basin, Lake Malata, and multiple microscale to mesoscale sub-roundes to ellipsoid basins, which are un-named. Many of these basins, including Lake Malata are seasonally inundated. Lake Malata complex has a complex history of wet and dry conditions but is presently a seasonal groundwater discharge area.

Stratigraphy: The Malata wetland system is surrounded and underlain by alluvial clays, silts, sands and gravel. In the central basins, and at the margins there are ridges and lunettes respectively underlain by gypsum silt and sand. At Lake Malata, the wetland fill comprises calcareous mud, sand (gypsum, quartz), and muddy sand (gypsum, clay mineral, quartz) with layers of shell fragments.

Hydrology: Hydrographs of groundwater levels do not exhibit seasonality. Groundwater levels directly fluctuate in response to separate rainfall events, but when no rain falls, levels remain steady. There appear to be separate groundwater aquifers, the shallower one receiving a continual slow discharge from the surface and the deeper one being recharged by lateral flow. Shallower groundwater levels fluctuate around 70 cm and deeper groundwater levels around 125 cm annually.

Water Quality: The water salinity of both surface and groundwaters, is hypersaline (44,000-266,000 mg/L). The exception is the groundwater on the western margin of Lake Malata itself which is slightly less saline than seawater (28,000-35,000 mg/L). Cation concentrations in Lake Malata exhibit high concentrations of sodium, potassium and magnesium (Appendix 3), indicating that it acts as a closed system. Levels of arsenic, lead, copper and phosphorous were low. The surface and groundwaters fluctuated around neutral, the range being pH 6.9-7.6. Exceptions were the groundwater flowing from the western side into Lake Malata which had a slightly higher mean of pH 7.9 and the groundwater at the edge of the Lake which had a lower mean of pH 6.7 with the more acidic levels being recorded in spring. Again, these results suggest different sources of recharge to the lake.

Vegetation: The centre of many of the basins is unvegetated but the margins, where steep, exhibit patches of heath and low shrubs: *Melaleuca brevifolia*, *Halosarcia syncarpa, Lawrencia spicata* and *Threlkeldia diffusa*. Margins which are wider and less steep exhibit mosaics of samphires (bacatform), *Halosarcia halocnemoides, Halosarcia indicans bidens*, *Halosarcia syncarpa*, *Halosarcia pruinosa*, *Halosarcia pergranulata*, and *Sarcocornia quinqueflora.* The gypsum ridges are vegetated by open low shrub communities *Halosarcia pruinosa, Frankenia pauciflora, Mairiana oppositifolia* and *L. spicata* and the declared rare flora *Halosarcia flabelliformis* forms pure and mixed stands in one of the smaller basins.

Evaluation: The Malata suite has important geoheritage, cultural and biological values. The Malata wetland system is a dammed drainage channel within a valley tract. Geomorphological features include: basins, islands, spits, lunettes, irregular sub-parabolic dunes, beach ridges, and beaches. Smaller basins are evidence of processes of deflation and groundwater discharge. Although situated in an alluvial environment, Lake Malata fill is dominated by relatively mud free gypseous sediments, a feature made more interesting by the fact that its neighbour Lake Greenly is filled with carbonate mud (calcite and dolomite). Strandline features contain a rich record of major climatic change which extends back into the Pleistocene (approximately 320,000 years) with evidence of 4 major phases of lunette deposition, and sediments associated with alternate wet (aquatic sediments) and dry conditions (dessication, calcrete and soil horizons) (Dutkiewicz *et al.* 2002).

An undisturbed Aboriginal campsite comprising stone grinding plate and scraping tools is present in one of the foredunes.

Although overall the vegetation associations have been altered through grazing and clearing, the declared rare flora *Halosarcia flabelliformis* forms pure and mixed stands in at least one of the smaller basins.

This site needs to be managed to preserve its naturalness, scientific and cultural values, its example of a wetland of this type and setting, its water quality, declared rare flora, and aesthetics.

Greenly suite (Figs. 18, 19, 20)
9 sites were visited, including Lake Greenly, Little Swamp, Big Swamp, Lake Wangary, Duck Lake, Pillana Lagoon, Lake Baird and un-named wetlands. Three sites were selected for monitoring: Little Swamp, GPS 34^o 41.50'S and 135^o 48.19'E, Duck Lake GPS 34^o 31.03'S and 135^o 30.35'E; and Lake Greenly GPS 34^o 19.32'S and 135^o 26.79'E. Two piezometers were installed at Little Swamp one deep and one shallow and a surface water guage, two piezometers were installed at Duck Lake and two surface water guages, and at Lake Greenly, in addition to the 3 piezometers installed by Flinders University, a deeper piezometer was installed at the margin of the lake, for monthly water level readings.

Setting: These wetland systems lie in valley tracts and are partly surrounded and underlain by alluvial clays, silts, sands and gravel, but at the southern end of each wetland system lies the contact with the limestone in which the southern part of the basin and southern channels are embedded.

Wetland types: Sumplands.

Description: This suite consists of megascale to mesoscale ovoid to semi-circular basins, and small scale connecting, inflowing or outflowing channels. These wetlands are seasonally inundated, but Lake Wangary has become permanently inundated by damming the head of the southern exit channel.

Hydrology: Recharge occurs via direct precipitation and inflow, and short-term perching occurs after the first rains, while discharge is much slower. As a result, water levels fluctuate 70 - 100 cm annually. In Little Swamp, groundwater eventually rises to merge with the ponded surface water, but in Lake Greenly the length of the rain season and the volume of input are insufficient for the groundwater table to rise and intersect the basin surface, thus maintaining the separate water bodies throughout the year. Water movement in both basins is generally downward.

Stratigraphy: The wetland fills change slightly in composition and stratigraphy as the climatic setting changes from humid with adequate rainfall to more arid, however calcareous mud is present at all sites. At Little Swamp, the calcareous mud and intraclasts, which predominate the fill, are overlain by peat and overlie basal sediments composed of a mix of kaolin clay, carbonate mud and quartz sand. At Duck Lake, the wetland fill comprises a mix of calcareous and kaolinitic mud, and at Lake Greenly, it comprises solely calcareous mud. Sponge spicules, *Chara* oogonia, forams, diatoms, ostracods, gastropod and bi-valve shells, pellets and other skeletal material occur throughout the sedimentary profiles.

Water Quality: The water salinity of surface waters is generally hyposaline (2,700-17,000 mg/L) while groundwaters range from hyposaline to hypersaline (8,000-170,000 mg/L). These wetlands exhibit the greatest variability in salt content, peaks occurring at the onset of rain (June 2005). Cation concentrations reflect the same patterns with low to high levels of sodium, potassium and magnesium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. The surface and groundwaters fluctuated around neutral, the range being pH 6.9-7.8. Little Swamp exhibited more alkaline waters (up to p H 9.1). Little Swamp has several sources of water recharge, groundwater rise, inflowing streams carrying water from flash floods, and direct rainfall. It is pprobable that the waters from these three sources do not mix until late winter when the resulting salinity becomes a mixture of three independent water bodies.

Vegetation: The centres of many of the basins are unvegetated but the margins, where narrow and more sloping, exhibit open shrublands of *Melaleuca halmaturorum,* with open ground cover of *Halosarcia lepidosperma*, *Halosarcia pergranulata*, *Sarcocornia quinqueflora* and *Hemichroa pentandra*. Margins, which are wider and less sloping, exhibit zones within the samphire communities. Beginning at the upland edge, samphire communities were dominated by *Halosarcia syncarpa,* then *Halosarcia pergranulata,* and then *Sarcocornia quinqueflora (*Fig. 20D). Of the flats bordering the channels, the seasonally inundated part is maculiform, vegetated by low shrubland of *Halosarcia lepidosperma*, *Halosarcia pergranulata* and *Melaleuca halmaturorum* and the seasonally waterlogged zone is latiform, vegetated by *Gahnia trifida* with scattered shrubs of *Melaleuca halmaturorum*. Aquatics included species of *Chara*.

Evaluation: Lake Greenly has a medium to high degree of naturalness as well as important geomorphic, sedimentary and biological values. Local hydrological mechanisms appear to be unaltered as do regional areas immediately to the northeast in the Malata system and between the two wetlands, although the latter may be at risk with continued mining of the Malata wetlands. Re-vegetation is required in a number of shoreline areas. Geomorphological features include: the basin, basement cliffs, lunettes, beach ridges, and beaches, lateral marginal seepage spring zones and surface drainage channels. Although these wetland systems lie in valley tracts underlain by alluvial sediments, the southern end of each wetland system is in embedded in limestone. There is a rich assemblage of biotic grains throughout the profile, which suggests that a variety of organisms inhabit this environment, *e.g*., sponge spicules, *Chara* oogonia, forams, diatoms, ostracods, gastropod and bi-valve shells, pellets and other skeletal material.

The plant assemblages at the margins are quite diverse, and zoned with respect to distance from the shore and slope, where they are relatively uniform, and with respect to water availability and sediment chemistry, where there is beachridge/swale topography. Assemblages include: 1) *Melaleuca* 2) low shrubs of *Halosarcia halocnemoides* and *Threlkeldia diffusa,* and 3) low shrubs of *Halosarcia halocnemoides, H. indicans bidens, Sarcocornia quinqueflora,* and *Frankenia pauciflora* 4) low shrubs of *H. halocnemoides* and *Lawrencia spicata* and 5) sedge *Gahnia trifida* with scattered shrubs of *Melaleuca brevifolia*. Well developed assemblages of *Gahnia trifida* and *Gahnia filum* at Lake Greenly and Duck Lake are significant not only in themselves as uncommon communities but also because they support the declared rare butterfly *Hesperilla flavescens* during crucial growth stages.

This site needs to be managed to preserve its naturalness, geomorphic integrity, hydrological links with Lake Malata and its connection to the coastal limestone, water flow paths, scientific values, and plant assemblage zonation and diversity.

Wanilla suite (Fig. 21)
3 sites were visited. Two sites were selected for monitoring: Merintha Creek, GPS 34° 34 1.2”S and 135° 36’ 39.9”E, and Wanilla GPS 34° 33.04’S and 135° 39.59’E. One piezometer was installed at Merintha Creek on the flat, and one piezometer on the flat and a surface water guage near the creek were installed at Wanilla for monthly water level readings.

Setting: Small scale alluvial fans underlain by orange-brown quartz sand, sandy clay, silt, gravel and calcrete nodules.

Wetland types: Creeks, palusplains

Description: This suite consists of short microscale channels which descend from the Lincoln Hills, traverse the alluvial fans at the base, and thereafter become waterlogged flats. These wetlands are seasonally inundated or seasonally waterlogged.

Hydrology: The creeks are shallow (20 cm) and have flow periods of approximately 5 months, recharged by direct rainfall and runoff from Lincoln Hills. In the wetter season, rainwater infiltrates and waterlogs the top 50 cm of sediment under the adjacent flats. Under current conditions, water from the creek discharges to the groundwater under the adjacent flats.

Stratigraphy: Wetlands are underlain by alluvial clay mineral muddy sands, quartz silt, and ferricrete, and gravel composed of quartz, veined calcrete, feldspar and nodular weathered shale. Phytoliths are present in the surface layers of the sedimentary profile. The basement is feldspathic and lithoclastic very coarse sand and gravel.

Water Quality: The water salinity of all waters was generally hyposaline (2,800-18,000 mg/L), groundwater being slightly higher than surface water. Cation concentrations were low (Appendix 3), as were levels of arsenic, lead, copper and phosphorous. The surface and groundwaters fluctuated around slightly alkaline (pH 8.4), the range being pH 7.6-8.8.

Vegetation: The riparian vegetation and waterlogged plains support open shrublands of *Melaleuca brevifolia* sometimes with an understorey of sedge *Carex* sp. and grass *Sporobolus virginicus*.

Evaluation: Merintha Creek, and Wanilla sites have a low to medium degree of naturalness as they have been isolated from their headwaters and from other areas of waterlogged flats. In essence they are remnants of the wetlands which characterised this region and they represent what once was a connected and seasonally renewable freshwater system. Vegetation assemblages are invaded by weeds and are subject to grazing and increasingly frequent fires, thus decreasing their original diversity. These sites are important because they represent habitats which were once much more widely dispersed, but now are scarce.

These sites need to be managed to preserve what is now only a remnant of the wetland systems typical of this area. This will require active management to prevent further loss of habitat, invasion by weeds and destruction by grazing and fire. It may require re-vegetation and linking by ecological and hydrological corridors to other remnants.

Murninnie suite (Fig. 22)
3 sites were visited. No sites were set up for monitoring, on the advice that at the time community support in this area was unknown.

Setting: Large scale merging alluvial and tidal flats underlain by clay soil veneer on red-brown sand over calcrete.

Wetland types: Palusplain, creeks

Description: This suite contains a megascale flat with cheniers on the surface, a tidal creek and pools at the coastal edge and leptoscale creeks inland.

Hydrology: The portion of the flat nearest the coast is recharged by tidal marine waters; inland the flat is hydrologically recharged by groundwater rise and discharged by creeks and evapo-transpiration.

Stratigraphy: On the tidal flat the wetland fill is brown calcareous mud with some kaolinitic mud and quartz silt. Further inland this becomes red kaolinitic muddy sand. The basement material is quartz sand.

Water Quality: No data

Vegetation: A tidal flat with maculiform low samphire shrub vegetation, *Halosarcia halocnemoides, Halosarcia pruinosa, Halosarcia pergranulata, Frankenia pauciflora, Schlerostegia arbuscular, Maireana oppositifolia*, grades into palusplain with diverse low samphire shrubland of *Schlerostegia disarticulata, Atriplex vesicaria, H. pruinosa, Hemichroa diandra, Maireana appressa, Minuria cunninghami*, which gives way inland to a low open shrubland of Bluebush (*Maireana sedifolia*).

Evaluation: This site has a high degree of naturalness and represents a scarce wetland type on Eyre Peninsula. It also has important geomorphic, hydrologic, and biological values. This is a very unusual wetland in terms of its type, size, origin and hydrological maintenance. The wetland is a megascale flat with cheniers on the surface, a tidal creek and pools at the coastal edge and leptoscale creeks inland. There are several possibilities for its origin. It may have originally been formed by marine processes which gradually have been replaced by terrestrial processes as the flat prograded seawards. It may have been a flat formed entirely by alluvial processes which is now being re-worked at the seaward margin by marine processes. Alternatively, it may be a merging of two or more flats with different origins. Currently, it is maintained by several hydrological processes: direct rainfall, groundwater rise and tidal inundation. Discharge is also a mix of marine and terrestrial processes: drainage by tidal retreat and tidal creek flow, drainage by groundwater discharge at the coast, drainage by inland creek flow, and evapo-transpiration.

Cheniers, creeks, pools and the increasing distance from the coast produce a number of habitats. Plant assemblages are species rich at the coastal margin (*Halosarcia* spp., *Maireana* spp., *Schlerostegia* spp.) and become increasingly uniform inland.

This site needs to be managed to preserve its naturalness and size. Its uniqueness and value are partly dependent on the total area being managed so that the gradation from tidally influenced area to alluvial flat to inland hills where the creek headwaters are located is preserved. Hydrological and sedimentary links need to be maintained.

Pinthaput suite (Figs. 23, 24)
3 sites were visited including un-named wetlands. Two sites were selected for monitoring: Simpson Rd, GPS 33° 6.72'S and 135° 25.49'E and Cocata Hill Rd GPS 33° 14.24'S and. 135° 26.24'E One piezometer was installed at Simpson Rd, and three (one deep and one shallow in the centre and one at the margin) piezometers were installed at Cocata Hill Rd for monthly water level readings.

Setting: Sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand or quartz sand overlying alluvium.

Wetland types: Sumplands.

Description: This suite consists of mesoscale to microscale linear basins aligned with the northwest to southeast orientation of the linear dune and swale field in which they lie.

Hydrology: There appears to be very little annual fluctuation (15 cm) in the water table due either to recharge or discharge. The water table lies close (< 25 cm) to the ground surface waterlogging the shallow sediments, and during the wet season, it rises to the surface. Rain infiltrating the near surface sediments at the basin margins discharges to the central basin. Perching of surface or near surface water occurs during the wetter months.

Stratigraphy: The wetland fills predominantly are filled with sandy muds and muddy sands. Kaolinitic mud occurs throughout the profile but the sands are variable in composition. Quartz may occur alone or variably mixed with gypsum or carbonate mud intraclasts in various proportions. Sometimes, gypsum fine sand or gypsum mud constitute the surface layers. The basement material is quartz sand.

Water Quality: The water salinity of all waters was hypersaline (41,000-270,000 mg/L), the upper level indicating gypsum precipitating conditions. Cation concentrations were high (Appendix 3), especially sodium and magnesium, but levels of arsenic, lead, copper and phosphorous were low. Waters were acidic with a mean of pH 4.5 ranging from pH 3.5-7.1, suggesting current dissolution of gypsum crystals.

Vegetation: At the contact between the wetland and adjacent calcretised sand dune, a narrow band of open shrubland may occur *Eucalyptus* sp., *Melaleuca uncinata* and *Melaleuca halmaturorum* with an understorey of *Maireana brevifolia*. On the flatter parts of the wetlands low samphire shrubland dominates: *Halosarcia pruinosa, Hemichroa diandra, Lawrencia spicata, Disphyma crassifolium, Maireana erioclada, Maireana brevifolia, Osteocarpum salsaginosum,* and *Nitraria billardierei*.

These sites represent wetland types in this setting: their geometry, scale, sediment types and history. They have a high degree of natural dynamism. For example, they exhibit precipitation and dissolution of gypsum crystals at the surface in response to changing environmental conditions, as well as indicators of changing salt accumulation, and features (mounds) which indicate depositional and erosional processes within the basins. Pinthaput site 1 exhibits a diversity of samphire species.

These sites need to be managed to preserve their naturalness and dynamic sedimentary and hydrochemical processes.

Samphire Flat suite (Fig. 25)
1 site was visited and selected for monitoring: Samphire Flat GPS 33^{o} 10.52'S and 135^{o} 28.41'E. Two piezometers were installed at Samphire Flat for monthly water level readings.

Setting: Sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand or quartz sand overlying massive calcrete, limestone, granite, or alluvium.

Wetland types: Palusplain or barkharra.

Description: This suite consists of megascale to mesoscale flats with peripheral fingers and irregularities aligned with the northwest to southeast orientation of the linear dune and swale field in which it lies. The wetland surface is undulating, due to many small scale features: low parallel ridges, scours from surface water flows and wind deflation, hollows where surface water collects intermittently, sand shadow mounds trapped behind plants, and low dunes.

Hydrology: There appears to be very little annual fluctuation (15 cm) in the water table due either to recharge or discharge. Perching of surface or near surface water occurs during the wetter months. In Samphire Flat itself, waterlogging is probably intermittent, groundwater being contained between semi-confining layers of calcrete, gysum crystals and gypsum sands (-100 cm, -250 cm). Seasonal inundation (< 20 cm) occurs where and when there is perching of surface water.

Stratigraphy: The wetland fills predominantly are filled with sandy muds and muddy sands. Kaolinitic mud occurs throughout the profile but the sands are variable in composition. Quartz may occur alone or variably mixed with gypsum or carbonate mud intraclasts in various proportions. Sometimes, gypsum fine sand or gypsum mud constitute the surface layers. Calcrete layers (massive and nodular) are also present throughout the wetland profile and adjacent dunes. This sedimentary sequence seems to indicate a record of wetter and drier phases throughout the history of the wetlands, the quartz, carbonate mud intraclasts and gypsum sand forming during drier periods and the crystalline gypsum, gypseous mud and clay mineral mud accumulating during inundation. Salt crystals also occur in the surface layers. The basement material is quartz sand.

Water Quality: The water salinity of all waters was hypersaline (41,000-270,000 mg/L), the upper level indicating gypsum precipitating conditions. Cation concentrations were high (Appendix 3), especially sodium and magnesium, but levels of arsenic, lead, copper and phosphorous were low. Waters were acidic with a mean of pH 4.5 ranging from pH 3.5-7.1, suggesting current dissolution of gypsum crystals.

Vegetation: Low samphire shrubland dominates: *Halosarcia pruinosa, Hemichroa diandra, Lawrencia spicata, Disphyma crassifolium, Maireana erioclada,* and *Maireana brevifolia*.

Evaluation: This site has a high degree of naturalness as well as important geomorphic and palaeoclimate values. This wetland is a large feature, a megascale flat with peripheral fingers and irregularities aligned with the northwest to southeast orientation of the linear dune field in which it lies. The wetland surface has many small scale geomorphic features, all of which give clues to the kinds of processes which shape this wetland and cause it to evolve: low parallel ridges, scours from surface water flows and wind deflation, hollows where surface water collects intermittently, sand shadow mounds trapped behind plants, and low dunes. Alternating layers of gypseous mud, quartz sands, gypsum sands, and calcrete layers indicate a record of wetter and drier phases throughout the history of the wetland.

This site needs to be managed to preserve its naturalness and geomorphic integrity.

Munyaroo suite (Fig. 26)
4 un-named wetland sites were visited. No sites were selected for monitoring because of the difficulty of access.

Setting: Coastal expression of the sand ridge plains with NW to SE trending longitudinal dunes underlain by quartz sand or quartz sand overlying massive calcrete, limestone, granite, or alluvium .

Wetland types: Sumplands, damplands

Description: This suite contains microscale linear ovoid wetlands in the inter dune depressions of the linear dune field at the coast. These wetlands are seasonally waterlogged and may occasionally be inundated. Wetlands initially have been scoured out by marine processes and then the breach has been healed by the construction of shore parallel ridges. The regional water table is quite close to the surface at this location and probably maintains waterlogged conditions for most of the year.

Stratigraphy: The wetland fills have a layer of calcareous mud at the surface which overlies red dune sand or cream re-worked sand. Calcrete layers are also present throughout the wetland profile and adjacent dunes.

Water Quality: No data

Vegetation: Low samphire shrubland.

Evaluation: These sites have a high degree of naturalness as well as geomorphic, aesthetic and educational values. The wetlands are typical “windows to the water table”. They are located in the swales between linear dune ridges where depth to groundwater is minimal. The plant assemblages of low samphire shrublands contrast with the surrounding mallee open scrub and woodlands. Wetlands in the Munyaroo Conservation Park are the eastern and coastal expression of wetlands in the Samphire Flat Suite. The setting ensures that the former wetlands are waterlogged for most of the year, in contrast to those near Wudinna, which are briefly seasonally or intermittently inundated. This spectrum may prove an important research or educational tool for wetland scientists, ecologists and land managers in the future.

These sites need to be managed to preserve their naturalness. Given the inaccessibility of the wetlands, the Munyaroo Conservation Park is currently adequate to achieve this goal.

Coffin Bay suite (Fig. 27)
6 sites were visited. One site was selected for monitoring: Pillie Lake, GPS 34^o 49' 16.4"S and 135^o 51' 25.0"E. Two piezometers were installed, one deep and one shallow, for monthly water level readings.

Setting: Bowls of parabolic dunes underlain by limestone.

Wetland types: Sumplands.

Description: This suite consists of microscale elongate linear to irregular basins. These wetlands are seasonally inundated. The wetland surface is covered by a thin veneer of clasts and low beach ridges and strandlines are also composed of this material which has been eroded from the relic polygons and stromatolites.

Hydrology: Recharge appears to be via direct rainfall and groundwater recharge. Average annual water level fluctuations are 50 cm. Water flow in the basin is downward.

Stratigraphy: The sedimentary fill above the limestone is composed of calcareous sandy mud overlying calcareous intraclast sand. Ostracod and bivalve shells occur throughout.

Water Quality: The salinity concentrations in the groundwaters at Pillie Lake indicate that there are two distinct aquifers; the shallow one containing water which is dominantly mesosaline (30,000-40,000 mg/L) and the deeper one containing water which is hyposaline (5,000-16,000 mg/L). For three or four weeks annually, water salinity in the shallow aquifer is diluted by rainfall. Cation concentrations in the waters at the time of sampling were all low (Appendix 3), as were levels of arsenic, lead, copper and phosphorous. The water in the deeper aquifer is more alkaline (mean pH 8.3) than in the shallow aquifer (mean pH 7.7).

Vegetation: Macrophyte communities are peripheral and zoned (zoniform), the inner zone comprising *Wilsonia backhousei* and *Sarcocornia quinqueflora* and the outer zone comprising open heath of *Melaleuca brevifolia* and *Gahnia trifida.* The aquatics comprise species of *Chara.*

Evaluation: Pillie Lake has a medium degree of naturalness. Groundwater abstraction in the Ulley Basin has modified the water regime in this wetland. Water levels range within the same parameters as prior to abstraction but the length of time the wetland is inundated or even waterlogged has been affected by the drawdown. The wetland's main value is that is typical of those wetlands forming in the bowls of parabolic dunes, in that it is microscale, elongate to irregular, underlain by limestone, filled with calcareous sandy mud and intraclast sand, recharged by groundwater and seasonally inundated. Macrophyte communities are peripheral and zoned, and the aquatic assemblage comprises species of *Chara.*

This site needs to be managed to preserve its naturalness particularly with respect to its water regime.

Subdivision of the Coffin Bay suite
Kilroy suite (Fig. 28)
3 sites were visited. No sites were selected for monitoring given the difficulty of access and the owner's intention to clear much of the endemic assemblages.

Setting: Low undulating flat set amidst limestone hills and underlain by limestone.

Wetland types: Palusplain, barlkarra

Description: This suite consists of an undulating megascale flat which may have been an extensive area of blowouts. The wetland is intermittently inundated now with areas that are seasonally waterlogged but it may once have been more regularly flooded. Recharge appears to be via direct rainfall and groundwater recharge.

Stratigraphy: The wetland surface is covered by a thin veneer of calcareous sandy mud (40 cm) and calcareous intraclast sand. Some surface areas are enriched by organic matter (0-15 cm). Diatomite may be present.

Water Quality: No data

Vegetation: Plant communities ranged from pure stands of *Melaleuca* sp. to *Melaleuca* open shrubland and scrub with an understorey of *Gahnia* to low open samphire shrubland.

Evaluation: Bramfield and Kilroy currently have a high degree of naturalness, but the landowner of Kilroy is in the process of clearing vegetation and appears to plan further action. The wetlands' main value is that they represent part of the undulating megascale flat which may have been the result of extensive blowouts. They are underlain by limestone, filled with calcareous sandy mud and intraclast sand, recharged by groundwater and seasonally waterlogged with intermittent inundation. Vegetation ranges from scrub and open shrubland to samphire open low shrubland.

This site needs to be managed to preserve its naturalness and prevent further vegetation clearing.

Hamilton suite (Figs. 29, 30, 31)
16 sites were visited. Three sites were selected for monitoring: Round Lake, GPS 33^o 56' 24.4"S and 135^o 16' 40.8"E, Lake Hamilton east GPS 33^o 57' 11.9"S and 135^o 16' 49.2"E, and Lake Hamp, GPS 33^o 38' 0.5"S and 134^o 53' 41.0"E. Three piezometers and a surface water gauge were installed at Round Lake, a surface water gauge and two piezometers, one deep and one shallow, were installed at Lake Hamilton east, and two piezometers were installed at Lake Hamp, for monthly water level readings.

Setting: These wetland systems occur in a karst landscape, in depressions between the successive limestone ridges, former bowls of parabolic dunes, or infilled sink holes, and are surrounded and underlain by limestone.

Wetland types: Sumplands.

Description: This suite consists of mesoscale to microscale ovoid basins and a megascale elongate linear basin. These wetlands are seasonally inundated.

Hydrology: In Lake Hamilton, recharge appears to be via several pathways. Direct precipitation is in many places perched (over shallow limestone, cemented calcarenite or calcilutite), although in other areas this may eventually infiltrate to the water table. Fresh water from the eastern and western limestone ridges discharges into the lake. On the western ridge such seepage lines have been mapped while on the eastern side springs are evident. Vents occur on the western side of the lake which appear to be the outlet for marine waters, and tidal channels transport this water from the western edge to the central basin.

In the Elliston wetlands, recharge appears to be via direct rainfall and infiltration to the shallow water table. Period of inundation is short, water being discharged via seepage through the limestone and evaporation.

Stratigraphy: The wetland fills in Lake Hamilton and Round Lake have an indurated crust at the surface underlain by calcareous intraclast sand over the main body of calcareous mud which sits on a limestone basement. The depth to limestone and therefore the thickness of the calcareous mud varies from site to site. Calcareous mud has cemented in some areas and occurs as a gelatinous waterlogged mud in others. Algal mats form on the surface, while emergent stromatolite heads form beach ridges and pavements. Ostracod and gastropod shells occur in surface layers.

The Elliston wetlands are underlain by relatively thick (2-3 m) white calcareous mud with calcrete sometimes at the surface, and sometimes in the subsurface, capping layered Pleistocene cemented calcareous mud. Mud composed of diatoms occurs at about 1 m from the surface in Lake Hamp. The sedimentary fill is underlain by limestone.

Water Quality: The salinity concentrations in Lake Hamilton and Round Lake varied both temporally and spatially. Within a single sampling period (April 2006), salinity concentrations in the groundwater varied from hyposaline to hypersaline (4,800-72,000 mg/L). Data collected from some of the same sites in September 2005 and January 2006 showed that salinity concentrations were just as volatile over seasons (Appendix 2). The surface water salinity was sampled at a number of sites: the vent, in the tidal creek and in the main lake body on the western and eastern sides. Measures of surface water were in the vent

32,000 mg/L, in the channel 28,000 mg/L, in the western part of the lake 27,000 mg/L, and in the eastern part of the lake 19,800 mg/L respectively, mostly in the mesosaline category but clearly demonstrating different sources. Water salinity in the shallow surface aquifer is diluted by rainfall and concentrated by evapo-transpiration. Cation concentrations in the waters at the time of sampling were low to medium with the greatest contribution from sodium and the least from potassium and calcium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. Spatial variability in pH was also evident, the most alkaline waters coming from the vent (pH 8.2) and the more neutral waters at the lake surface (pH 6.9).

The salinity concentrations in the groundwaters at Lake Hamp (Elliston) were hypersaline (96,000-105,000 mg/L). Cation concentrations in the waters at the time of sampling were all medium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. The groundwater was acidic (mean pH 6.7) which in the carbonate mud aquifer is unusual. It may be assumed that the carbonate mud is acting as a buffer, and that the inflowing waters are initially more acidic. The potential source of such acidic waters is probably the leachate from the rubbish dump.

Vegetation: Plant communities in Lake Hamilton are diverse and vary with substrate type and water chemistry. On intraclast sand, the community comprises shrubland of *Melaleuca brevifolia* and *Olearia axillaris* with an understorey of *Gahnia trifida, Isolepis nodosa*, and *Sarcocornia quinqueflora*. In waterlogged areas this is replaced with pure stands of *Gahnia trifida*. On calcareous mud, the plant communities tend to be low samphire shrublands comprising *Sarcocornia quinqueflora, Sarcocornia blackiana, Sueda australis, Halosarcia halocnemoides, Halosarcia pruinosa,* with *Wilsonia humilis, Hemichroa pentandra, Frankenia pauciflora,* and *Samolus repens.* On beachridges and on shoreline stromatolitic pavements, *Sueda australis* and *Sarcocornia quinqueflora* form open low shrublands. Around freshwater seepages and springs, *Juncus kraussii* and *Gahnia trifida* occur. Two of the dominant aquatic plants occurring are the charaphyte *Lamprothamnium* sp. and the seagrass *Ruppia* sp.

Plant communities at Lake Hamp are peripheral and zoned (zoniform), the inner zones comprising *Halosarcia pergranulata* with scattered *Sarcocornia blackiana,* then *Wilsonia humilis* and the outer zones comprising open heath of *Melaleuca halmaturorum* with an understorey of *Halosarcia pruinosa, and open shrubland of Melaleuca halmaturorum, Olearia axillaris, Leucopogon parviflorus,* and *Exocarpus syrticola.* The aquatics comprise species of *Chara.*

Evaluation: Lake Hamilton has a high degree of naturalness as well as important geomorphic, geoheritage, habitat diversity, ecological and aesthetic values. Lake Hamilton is situated in a karst landscape in a depression between limestone ridges. The basin itself is expanding. Along the west side are sink holes, vents, tidal channels and steep margins. As it expands, it encloses areas of limestone which have not yet been subjected to karst processes and these become islands. The islands are surrounded by sedimentary aprons, and shoals protrude from the lake margins. There are algal mats on the surface, and emergent relic stromatolite heads form beach ridges and pavements. The depth and permanence of the surface water varies spatially and temporally, preferentially settling to the west and north when observed recently. Precipitation is perched in some places, in others it infiltrates to the water table. Fresh water from the eastern and western limestone ridges discharges into the lake. Marine vents occur on the western side of the lake. Groundwater salinity is variable. The number and diversity of the geomorphic features and sediment fabrics combined with the variation in water depth and permanence, and the variation in pH and salinity, produce numerous habitats within the basin.

Ostracods and gastropods occur in the lake and tidal creek. *Atherinosoma microstoma* (small mouthed hardyhead) inhabits the marine vents. Plant communities are diverse and range from shrubs to sedge and rush to low shrub samphire. Well developed assemblages of *Gahnia trifida* at Lake Hamilton and Round Lake are significant not only in themselves as uncommon communities but also because they support the declared rare butterfly *Hesperilla flavescens* during crucial growth stages. Aquatic plants include *Lamprothamnium* sp.and the seagrass *Ruppia.*

This site needs to be managed to preserve its naturalness, geomorphic integrity, hydrological links with the coastal limestone, water flow paths, diversity of habitats, and plant assemblage zonation and diversity.

Lake Hamp has a low to medium degree of naturalness, but this could easily be addressed if the rubbish site were moved elsewhere. It is a very good example of wetlands which were probably originally sinkholes in a karst terrain and have now been infilled with carbonate mud. Several examples of sinkholes in earlier stages of evolution occur further to the north, GPS 33^{o} 41’ 38.7”S and 134^{o} 57’ 56.5”E, GPS 33^{o} 43’ 20.5”S and 135^{o} 2’ 19.5”E, GPS 33^{o} 43’ 8.7”S and 135^{o} 1’ 25.3”E.

This site needs to be managed to preserve its naturalness, in particular the rubbish tip needs to be re-located and current hydrochemical impacts ameliorated.

Subdivision of the Hamilton suite
Gully suite (Fig. 32)
1 site was visited: Wild Dog Gully. No sites were selected for monitoring, GPS 33^o 44’ 14.9”S and 135^o 03’ 55.1”E.

Setting: karst landscape:-swale between coastal dune ridges underlain by limestone

Wetland types: Wadi

Description: This suite consists of micoscale incised dendritic channels in steep gullies in the midst of limestone hills. The channels are seasonally to intermittently inundated for very short periods. Recharge appears to be via direct rainfall, local run-off and minor seepage with rapid infiltration to the water table.

Stratigraphy: basement limestone

Water Quality: No data

Vegetation: Plants have been grazed.

Wild Dog Gully has a medium to high degree of naturalness. It requires re-vegetation. It is the only example of fluvial wetlands in a karst terrain.

This site needs to be managed to preserve its naturalness, in particular re-vegetation needs to be undertaken.

Subdivision of the Hamilton suite

Calpatanna suite (Fig. 33)

6 sites were visited. Three sites were selected for monitoring: Little Seagull Lake, GPS 32° 57’ 58 6”S and 134° 12’ 34.1”E, the Doline , GPS 32° 56’ 53 6”S and 134° 12’ 59.6”E, and Paddy’s Vent GPS 32° 56’ 51.9”S and 134° 13’ 4.5”E. A water gauge was installed in Little Seagull Lake and in Paddy’s Vent for monthly water level readings.

Setting: Karst terrain of red sandy mud underlain by Pleistocene laminated limestone and calcrete.

Wetland types: Lakes, sumplands

Description: This suite consists of a macroscale to microscale oblong to irregular basins. Some of the wetlands are former dolines and others are cavities around vents in the underlying marine shelly limestone. Wetland margins exhibit erosion features such as cliffs (0.5-1.0 m) and infilling with sand from dissolution of limestone. Wetlands are permanently and seasonally inundated.

Hydrology: Recharge mechanisms include terrestrial and marine processes. Terrestrial processes include freshwater groundwater seepage from the coastal dune barrier and direct rainfall. The occurrence of marine organisms within the wetlands supports the conclusion that basins are also recharged by marine waters through conduits and vents in the limestone.

Stratigraphy: Calcareous mud and shelly intraclast sands and gravel are the dominant wetland fills with occasional gypsum crystal layers.

Water Quality: Surface water salinity ranged from mesosaline (marine) to hypersaline (34,000-60,000 mg/L). Cation concentrations in the waters at the time of sampling were all medium, the composition suggesting seawater input (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. pH varied from slightly below neutral to alkaline (pH6.9-8.1), suggesting that there may be a number of sources and pathways for recharge of the wetlands, *e.g*., marine conduits, freshwater seepage, groundwater and direct rainfall.

Vegetation: Plant communities are narrow, peripheral and zoned, the inner zones comprising *Halosarcia syncarpa*, *Sarcocornia quinqueflora, Hemichroa diandra,* then *Wilsonia humilis*, *Lawrencia spicata* and the outer zone comprising open heath of *Melaleuca lanceolata.* The aquatics comprise species of *Chara, Acetabularia,* and *Ruppia.* Sea anenomes, macro invertebrates, and marine gastropods are present.

Evaluation: Little Seagull Lake has a high degree of naturalness as well as important geoheritage, ecological and aesthetic values. It is situated in karst terrain, and is a cliffed cavity around a marine vent in the underlying marine shelly limestone. Little Seagull Lake is connected on the surface to Seagull Lake via a narrow linear channel but appears to have a separate source of recharge to the main lake because surface water is maintained in this little basin when the larger basin is dry (Pers. Comm. Justine Graham EPNRMB), and water level fluctuations appear to be out of phase between the two basins.

Plant communities are peripheral and zoned, the inner zones comprising mat plants and the outer zone comprising open heath. The aquatics comprise species of *Chara, Acetabularia,* and *Ruppia.* Sea anenomes, macro invertebrates, and marine gastropods are present.

Little Seagull Lake is juxtaposed between a coastal dune ridge of white calcareous sand and the larger Seagull Lake. Wetland vegetation is undisturbed and merges with dune and limestone species. The site has high aesthetic qulaities and is sheltered, giving protection to migrant fauna.

This site needs to be managed to preserve its outstanding geoheritage characteristics pertaining to its karst setting, tidal influence, and marine water recharge, as well as its diverse mixture of biological assemblages and its outstanding aesthetic qualities.

Subdivision of the Hamilton suite

Newland suite (Figs. 34, 35, 36)

10 sites were visited in the Newland complex itself and numerous sites along the coast road to un-named wetlands, sinkholes, and coastal shoreline cliffs and outcrops. Three sites were selected for monitoring: Middle Lake Newland Y and Z, GPS 33^{o} 24' 13.2"S and 134^{o} 51' 51.1"E; and south Lake Newland GPS 33^{o} 28' 15.8"S and 134^{o} 53' 16.0"E. One piezometer was installed at Y, one piezometer in the well, one piezometer and two surface water gauges at Z; one gauge was installed at the margin of the lake at south Newland for monthly water level readings. No piezometers were installed at north Lake Newland because of the danger of sink holes.

Setting: The wetland complex is situated in a karst landscape behind a dune barrier which encroaches upon the wetlands.

Wetland types: Lake, sumplands, damplands.

Description: This suite consists of a megascale linear complex of megascale to microscale, ovoid and irregular basins. These wetlands range from being permanently or seasonally inundated, to seasonally waterlogged. Basins are separated by limestone hills and pavements, and underlain by buried cliffs consistent with karst terrain. Sink holes are evident on the islands within the basins and along the basin margins themselves, some infilled with calcareous mud. Overprinting the karst geometry are modern wave built beachridges, cuspate forelands, beaches and sand shoals which encroach into the basins and subdivide them. Plants quickly colonise these shoals once they reach a minimum height above water level.

Hydrology: Some of the basins are groundwater recharged and others perch rain at the surface, particularly where the limestone is within the top 30 cm. On the eastern side, springs in the limestone aquifer occur at the margins, *e.g.*, Weepra Spring and LNS-S1. Discharge is predominantly due to evapo-transpiration and downward leakage.

Stratigraphy: The wetland calcareous mud fill ranges in depth but always overlies marine shelly limestone. In the northern part the wetland fill comprises fine to coarse intraclast sands and shelly calcareous mud. In the central part, wetland fill comprises fine sands and deeper basins are underlain by shelly, intraclastic calcareous mud. In the southern part, wetland fill comprises shelly, intraclastic, and quartz, sand and gravel. Throughout layers of shell grit (gastropods and pelecypods) or grainstone intraclasts occur.

Water Quality: The surface and groundwaters at most sites in the complex were hypersaline (38,000 mg/L to 118,000 mg/L) but can be higher (gypsum precipitating at 285,000mg/L). Where groundwater is confined in the limestone aquifer, the salinities were much lower, *i.e.*, hyposaline (5,100-7,000 mg/L) and in some areas, were close to freshwater (900-1,450 mg/L). Springs are fed from the limestone aquifer containing hyposaline water. Cation concentrations in the waters at the time of sampling were variable and showed no obvious pattern other than their concentration in the surface water, as a result of dissolution of salt precipitate residues on the wetland surface from the previous dry season. At other sites there were relatively low values of calcium and magnesium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. The chemistry of the waters fluctuated around neutral (pH 6.9 to 7.4). The spring waters exhibited slightly higher alkalinity around pH 8-8.3.

Vegetation: Plant assemblages vary according to habitat. There are 1) waterlogged basin assemblages, 2) peripheral assemblages around permanently and seasonally inundated basins, 3) assemblages on waterlogged flats underlain by calcareous mud 4) beach ridge assemblages, 5) limestone pavement assemblages, 6) limestone hill assemblages, 7) gypsum dune assemblages, and 8) assemblages associated with springs. Waterlogged basin assemblages comprise *Wilsonia humilis*, *Hemichroa pentandra.* Peripheral assemblages comprise scrub and heaths of *Melaleuca halmaturorum*, with clumps of *Juncus kraussii* or heath of *Halosarcia pruinosa* or low samphire shrublands of *Sarcocornia quinqueflora* and *Sueda australis, Schlerostegia arbuscular.* Calcareous mud flat assemblages comprise *Melaleuca halmaturorum* and *Gahnia trifida.* Beach ridge assemblages comprise *Melaleuca halmaturorum, Halosarcia pruinosa, Halosarcia halocnemoides, Gahnia trifida.* Limestone pavement assemblages comprise *Meariana oppositifolia, Halosarcia pruinosa, Halosarcia pergranulata, Frankenia pauciflora, Lawrencia spicata, Samolus repens, Dodonea sp.*. Limestone hills assemblages comprise *Pittosporum angustifolium* amongst others. Gypsum dune assemblages comprise low heaths of *Halosarcia pruinosa, H. halocnemoides, Olearia axillaris, Melaleuca halmaturorum, Olearia axillaris, Leucopogon parviflorus, Exocarpus syrticola, Maireana oppositifolia,* and *Frankenia pauciflora*. Spring assemblages comprise *Cyperus sp., Juncus kraussii, Isolepis nodosa, Baumea juncea* and *Sarcocornia quinqueflora*.

Evaluation: Lake Newland has a high degree of naturalness as well as important diversity, ecological, recreation, cultural and aesthetic values. Lake Newland is, in fact, a megascale linear complex of basins, ranging from being permanently inundated to seasonally waterlogged, and separated by limestone hills and pavements. The wetland complex is situated in a karst landscape but overprinting the karst geometry are modern wave built beachridges, cuspate forelands, beaches and sand shoals.

Some of the basins are groundwater recharged and others perch rain at the surface. Springs occur at the eastern margins, fed from the limestone aquifer.

Habitat diversity is high and includes: areas of permanent water, areas of seasonal surface water, and areas that are seasonally waterlogged by rain infiltration or groundwater rise. In each case the salinity and pH will differ; water salinity ranges from hypersaline to slightly brackish. Inundation can be the result of discharge from springs, groundwater discharge or surface water ponding. Basements comprise calcareous mud, calcareous sand, limestone or combinations of the three. Vegetation ranges from shrubs to sedge and rush to low samphire shrublands, grasslands and herblands. Plants of conservation significance in these habitats include: *Austrofestuca littoralis, Cyperus laevigatus, Hemichroa pentandra, Leptorhynchos squamatus, Triglochin striatum* (DEH 2003).

Lake Newland is a drought refuge for several avifaunal populations: Banded stilts, Chestnut Teal, Red-necked Stint, Cape Barren Goose (Declared Rare Fauna) and Black Swan. Several migratory wading species listed under international agreements also use the site, including Sharp-tailed sandpiper and Curlew sandpiper (DEH 2003). Lake Newland is well known for its birdlife and tourists to the Elliston region regularly visit (Elliston Park Caravan park pers. comm.).

Seventeen cultural sites pertaining to Aboriginal history, some of which are designated archaeological sites, are located within the Lake Newland Conservation Park boundary. Some of these are associated with camping and hunting on and beside the wetlands.

Aesthetically, the Lake Newland complex is impressive. It is situated behind a white calcareous sand dune and exhibits vistas of red, yellow, orange, purple, green and grey in the vegetation, vistas of round and linear wetland basins and islands amongst ridges and pavements, and salt and gypsum crystal surfaces.

This site needs to be managed to preserve its diversity of wetland habitats from lake to dampland, from freshwater to hypersaline. In managing the wetland and dryland habitats, other attributes such as its geomorphic features and important biological values (abundant avifaunal populations and rare or uncommon plant species and assemblages) are likely to be well managed also. It will also be important to manage visitor access to protect some of the biological values.

Yanerbie suite (Fig. 37)
2 sites were visited. One site was selected for monitoring: GPS 32^{o} 54’ 6 6”S and 134^{o} 9’ 40”E, and a piezometer was installed for monthly water level readings.

Setting: Contact between limestone flat and leading edge of a parabolic dune complex underlain by unconsolidated calcareous sand.

Wetland types: Sumplands.

Description: This suite consists of microscale rounded basins, with a series of internal low beachridges and swales. Wetlands are seasonally waterlogged.

Hydrology: Recharge occurs through a seasonal rise in the regional water table, and discharge via evapo-transpiration.

Stratigraphy: Wetland fill comprises surface layers of fine gypsum and shelly sand overlying calcareous mud overlying layers of coarse and fine gypsum and calcareous sands.

Water Quality: The groundwater was hypersaline (112,000 mg/L) but can be higher (gypsum precipitating). The chemistry of the waters was around neutral (pH 6.9).

Vegetation: Plant communities vary between the ridges, swales and central basin. The ridge assemblage comprises low open samphire shrubland of *Halosarcia halocnemoides*, with *Frankenia pauciflora, Disphyma crassifolium, Lawrencia spicata* and *Wilsonia humilis.* The swale and central basin assemblage comprises low open samphire shrubland of *Halosarcia pruinosa.*

Yanerbie has a high degree of naturalness and is a very good example of wetlands in a karst terrain which have now been infilled with gypseous and dolomitic mud and sand. It also displays clearly samphire differentiation with respect to waterlogging tolerance, in the repetetive beachridge swale assemblages.

This site needs to be managed to preserve its naturalness as an example of a wetland of this type and setting.

Anxious Bay suite (Fig. 38)
4 sites were visited. One site was selected for monitoring: GPS 33^{o} 20' 0 4"S and 134^{o} 48' 26.5"E, and two piezometers were installed for monthly water level readings.

Setting: Blowouts within mobile dune coastal barrier underlain by Pleistocene limestone and calcrete.

Wetland types: Sumplands.

Description: This suite consists of a microscale rounded basins. The wetlands occur in wind deflated hollows within the dunes, and there are low mounds within the basins where sand has been deposited by wind or sheet wash, and conical hill residuals where the surrounding area has been eroded. Wetlands are seasonally inundated.

Hydrology: Wetlands are recharged by seasonal groundwater rise but the water table is always near the surface (< 1 m).

Stratigraphy: Cream dune shelly calcareous/quartz sand underlies the wetlands with slight humic development at the surface. The basement is limestone.

Water Quality: The groundwater was fresh to hyposaline (900-4,000mg/L). The chemistry of the waters fluctuated from near neutral to alkaline (pH 7.2-8.3).
Vegetation: At the margins, plant communities comprised open heath and scattered sedgelands of *Olearia axillaris, Isolepis nodosa*, and *Juncus kraussii*, all colonising species of coastal wet hollows. The central basin was colonised by a low mat of *Sarcocornia quinqueflora, Sporobolus virginicus and Samolus repens.*

Evaluation: Newland Barrier wetlands have a high degree of naturalness, restricted distribution, and important ecological and aesthetic values. This suite occurs in wind deflated hollows within the calcareous sand dunes of a coastal barrier. This is an unusual occurrence, and these wetlands may be the youngest on the Eyre Peninsula.

Wetlands are colonised by grasses, sedges, rushes, samphires and herbs. Elsewhere, the habitat often supports orchids and uncommon annuals. It is a dynamic habitat with processes of sheetwash and aeolian infilling constantly replenishing the geo chemical environment and therefore plant assemblages are often diverse responding to the various stages of infilling, scouring, waterlogging, aeration, soil pedogenesis and sediment diagenesis, which are taking place (Semeniuk 2005). In a dune terrain these wetlands serve as oases for migrant fauna.

Aesthetically the wetlands form a contrast to the surrounding dune terrain and their typical plant physiognomies.

This site needs to be managed to preserve its naturalness, particularly with respect to rubbish dumping and trampling.

Stamford Hill suite (Fig. 39)
3 sites were visited: Stanford Hill, Lake Jessie and Yangie Bay. One site was selected for monitoring: GPS 33^o 20' 0 4"S and 134^o 48' 26.5"E, and two piezometers were installed for monthly water level readings.

Setting: Embayment prograding seaward between headlands.

Wetland types: Sumplands.

Description: This suite consists of microscale ovoid basins behind a coastal dune barrier. The wetlands are the result of coastal deposition. Sedimentary infilling of small bays occurs by marine processes. Eventually, a barrier forms at the seaward edge which reaches above mean sea level. Sand is subsequently deposited on this barrier by aeolian processes which heightens and widens the barrier over time thus disconnecting the marine wetland from its source. Terrestrial wetland processes then commence. The wetlands are seasonally inundated.

Hydrology: Wetlands are recharged by seasonal groundwater rise.

Stratigraphy: The surface is hummocky, covered by gypseous crusty mini-mounds. Under the veneer of algal gypseous crust, there is cream/brown calcilutite and mottled calcareous muddy sand and limestone. Under dense vegetation cover, a thin layer of organic matter enriched calcilutite forms.

Water Quality: Groundwater salinity was hypersaline (92,000 mg/L). Cation concentrations in the waters at the time of sampling exhibited elevated levels of potassium and medium concentrations of sodium, calcium and magnesium (Appendix 3). Levels of arsenic, lead, copper and phosphorous were low. pH was near neutral at pH 7.4. Evaporation during the summer depletes water in the capillary zone and at high salinities, gypsum precipitates at the surface overprinting the calcilutite.

Vegetation: At the margins, plant communities comprised shrubland of *Melaleuca lanceolata*, *Melaleuca halmaturorum* and then closed scrub of *M. halmaturorum*. In the basins were low samphire shrublands of *Sarcocornia quinqueflora*, *Sarcocornia blackiana*, *Halosarcia pergranulata*, *Halosarcia syncarpa*, *Schlerostegia arbuscular*, *Frankenia pauciflora*, *Sueda australis*, *Hemichroa pentandra*, herbs *Samolus repens* and *Atriplex palliudosa* and minor clumps of *Austostipa* and *Juncus kraussii*.

Evaluation: Stamford Hill wetland has a high degree of naturalness, representativeness, restricted distribution, and ecological values. The wetlands are the result of sedimentary infilling of small bays by marine processes and then barring by dunes. Stamford Hill is a very good example of a wetland with a marine origin that is now wholly maintained by terrestrial wetland processes. The wetland fill and basin/ridge morphology also testify to its pluralistic origins.

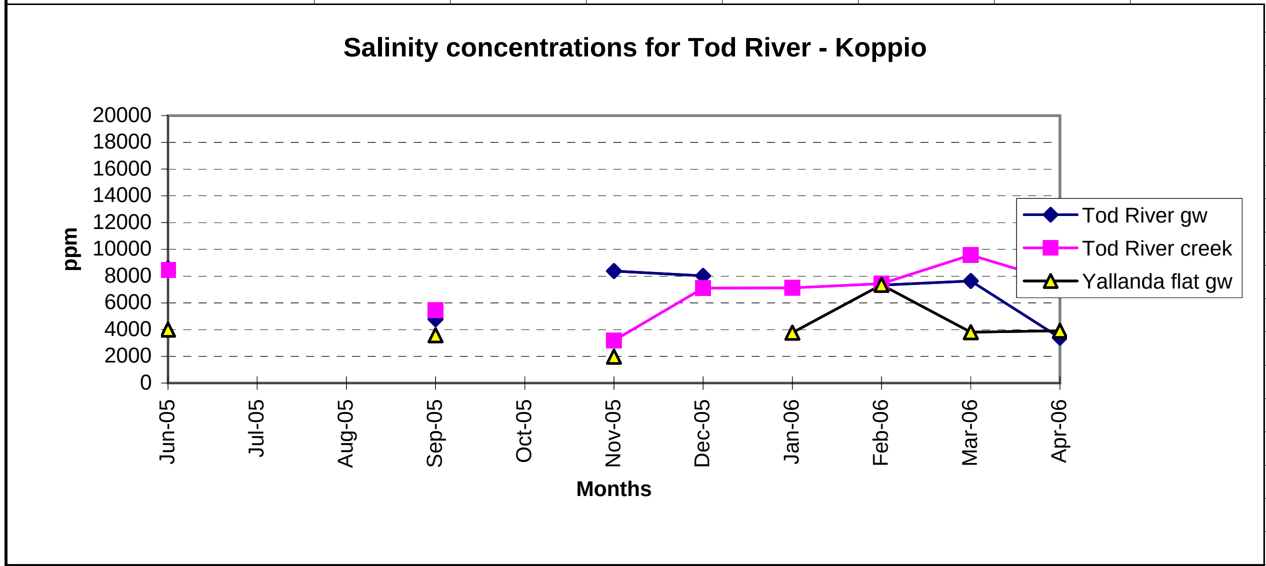
The vegetation is correspondingly zoned with respect to water depth across these ridges and swales and both of these features are undisturbed. Insects (beetles, moths) are abundant at this site. There is some invasion by weeds (*Limonium companionus*) but these appear to be emphemeral and easily competed against.

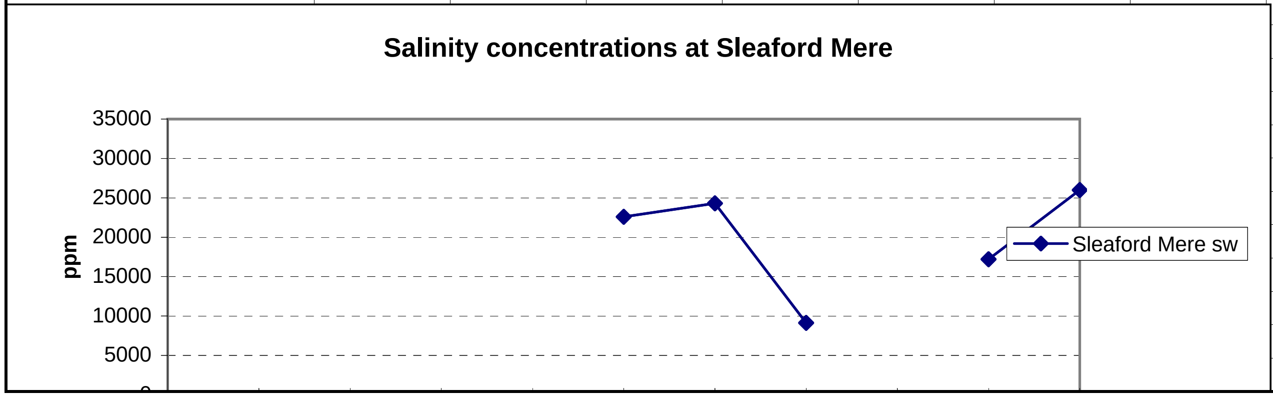
This site needs to be managed to preserve its naturalness. Currently, in this setting, this would mean addressing trampling and damage by vehicles.

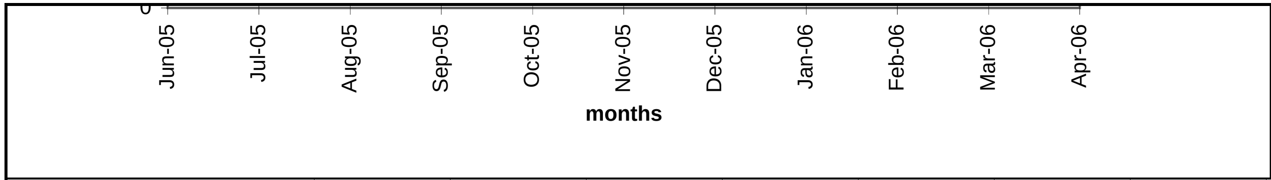
V & C Semeniuk Research Group - Baseline survey of wetlands, Eyre Peninsula, Appendix 2											
Salinity and pH of surface waters and groundwaters : June 2005 - September 2006											
				Salinity ppm							
	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06
Tod River gw	8570			4780		8380	8020		7320	7640	3390
Tod River creek	8450			5450		3180	7100	7120	7430	9580	7570
Yallanda flat gw	4000			3580		1970		3770	7350	3810	3910
Miltalie creek site D											35800
Miltalie creek site L											25300
Sleaford Mere gw											24000
Sleaford Mere sw						22600	24300	9130		17200	26000
Little Sleaford A gw											70000
Little Sleaford B gw											1690
Malata 1A gw	104000				198000	186000	204000	198000	200000	192000	200000
Malata 1A sw					62000	80000	178000				
Malata 1B gw					158000	146000	151000	144000	138000	140000	144000
Malata 1C gw	92900				130000	130000	128000	131000	134000	118000	140000
Malata 1C sw	44200					60000					
Malata 1D gw	107000				118000	98000	112000	136000	128000	146000	140000
Malata 1D sw	72100					27200	40100	174000	133000		152000
Malata 3A gw	117000				242000	230000	228000	240000	236000	232000	232000
Malata 3A sw								266000			
Malata 3B gw					28700	33800	34100	34200	34600	35900	33600
Greenly A gw					26600						
Greenly sw	22000										
Greenly B gw	170000	91200			104000	110000	103000			130000	
Duck Lake B gw	50000				38400	41300	35900	43300	40800	40100	43600
Duck Lake sw					5160	4460	6040	8330	7960	17300	5300
Little Swamp deep gw	24800				8550	11400	17000				11000

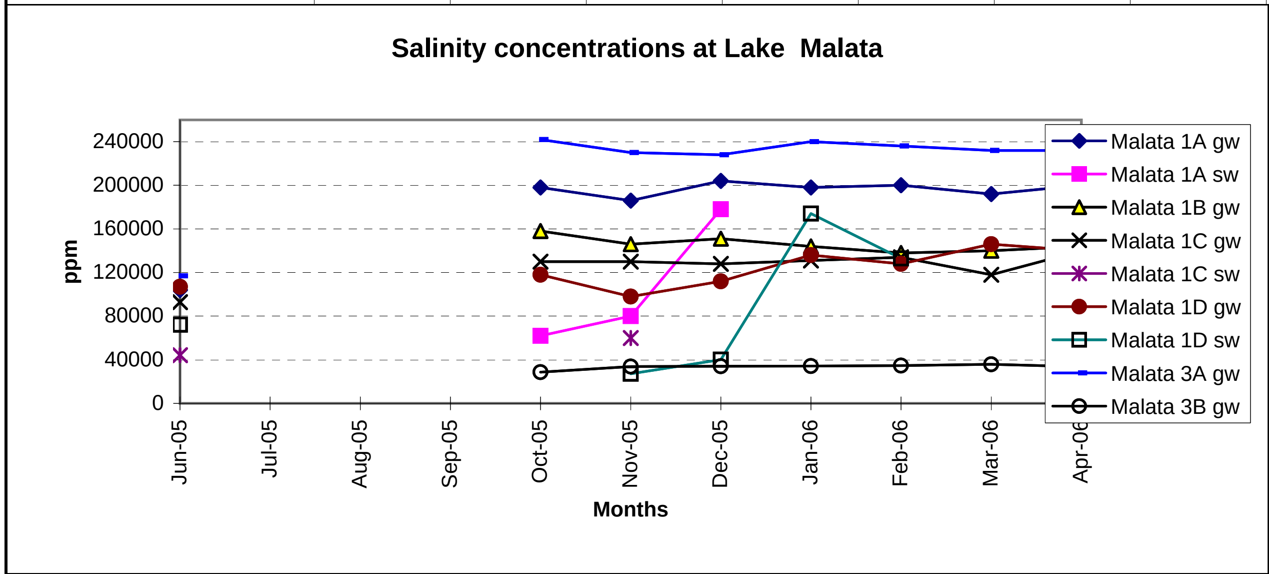
Little Swamp shallow gw					4570	4200	4940				6790
Little Swamp sw					2770	2770	4700				10100
RTW gw	18500					7520					17500
RTW sw	6460				4000	4840	6510	6790	5750		5480
Merintha creek A gw					2390	4200	9290				
Merintha creek C gw					2750	3700	3700	3230	7740		10100
Merintha creek sw	6980				2820		6940	8150			9670
Samphire Flat 1 gw	270000						236000	233000	227000	240000	
Samphire Flat 1 sw	116000										
Samphire Flat 2A gw	111000				160000		160000	147000	146000	149000	
Samphire Flat 2 sw	64600				120000		208000				
Samphire Flat 2B gw	47600				41500		51100	49600		47500	
Samphire Flat 3Ad gw					126000	138000	136000	141000		131000	
Samphire Flat 3As gw	90000				140000	140000	136000	140000	133000		
Samphire Flat 3Bs gw					129000	120000	125000	122000	128000	126000	
Pillie Lake shallow gw	6130				40100	30700	34000		31700		
Pillie Lake deep gw					5040	7690	10000	10300	7780	11600	16500
Lake Hamilton east gw				36600							5100
Lake Hamilton east sw				35000				30600			19800
Lake Hamilton west sw											27000
Lake Hamilton vent											32000
Lake Hamilton channel											28000
Lake Hamilton spring											4800
Round Lake A gw				8600							72000
Round Lake sw				40600							90000
Round Lake B gw											4300
Lake Hamp A gw											105000
Lake Hamp B gw											96000
Seagull Lake											34000
Doline											42000

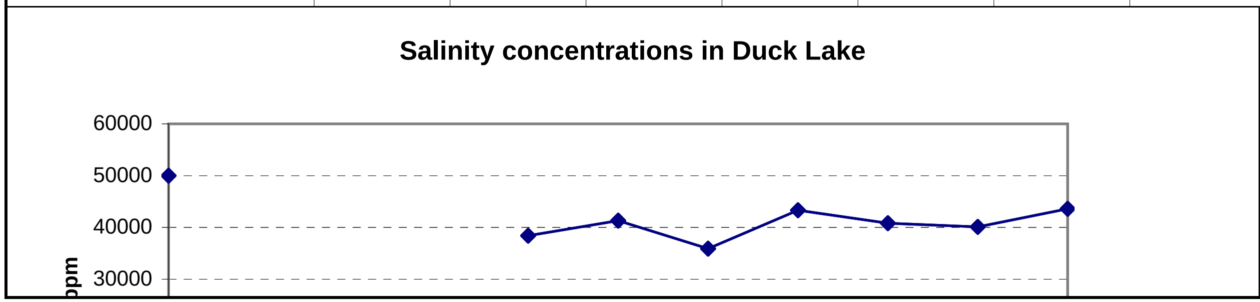
Paddy's vent											34000
Lake Newland south sw											68000
Lake Newland south gw											
Lake Newland middle X gw											
Lake Newland middle X sw				79000							90770
Lake Newland middle Y gw											114000
Lake Newland middle Y well											6100
Lake Newland middle Y sw											110000
Lake Newland middle Z-a gw											118000
Lake Newland middle Z sw											104000
Lake Newland middle Z-b gw											58000
Lake Newland Weipa spring											6260
Lake Newland south spring											4900
Lake Newland south spring LNS-S1											5900
Lake Newland north gw								16800			
Lake Newland north sw				11100				228000			
Lake Newland north sinkhole								42200			
Lake Newland limestone								7030			
Middle Lake Newland sth gw											140000
Middle Lake Newland sth sw											102000
Middle Lake Newland nth sw											285000
Weipa Spring											3500
Middle Lake Newland creek											38000
Lake Newland south S1-SS											5100
Lake Newland south S1 centre sw											69000
Lake Newland southsouthwest of lake sw											32000
Yanerbie											112000
Newland barrier gw								7340			38900
Newland barrier gw											1450
Newland barrier gw											900
Stanford Hill											92000

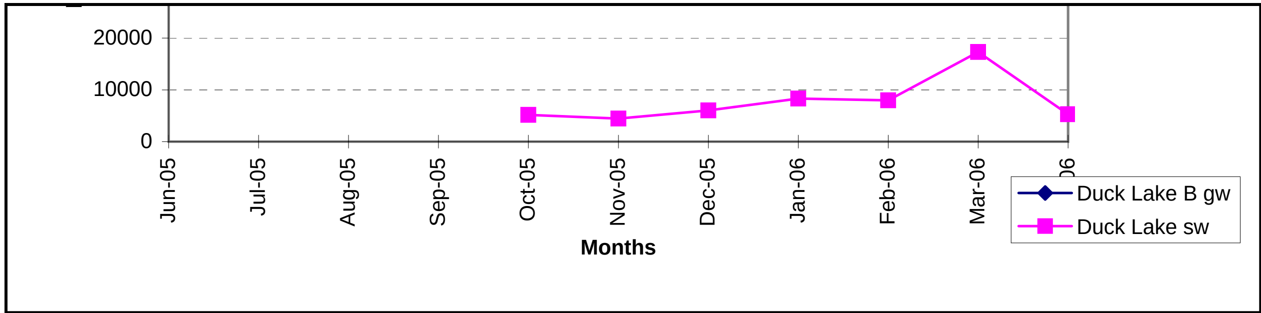

Salinity concentrations for Tod River - Koppio
ppm
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Jan-06
Feb-06
Mar-06
Apr-06
Months
Tod River gw
Tod River creek
Yallanda flat gw

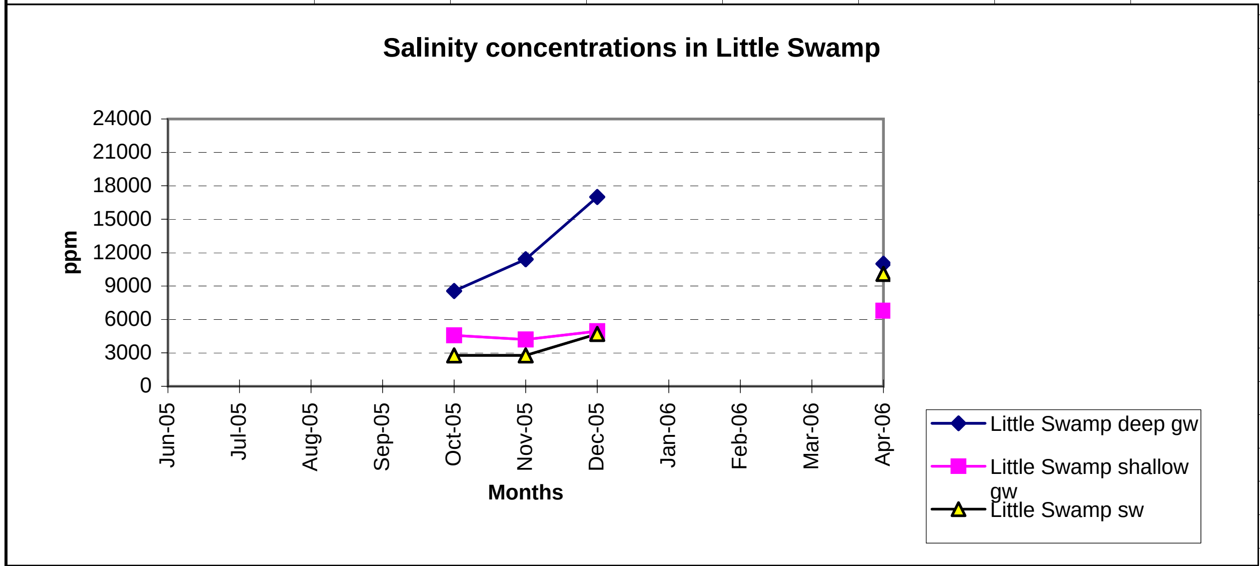

Salinity concentrations at Sleaford Mere
ppm
35000
30000
25000
20000
15000
10000
5000
Sleaford Mere sw

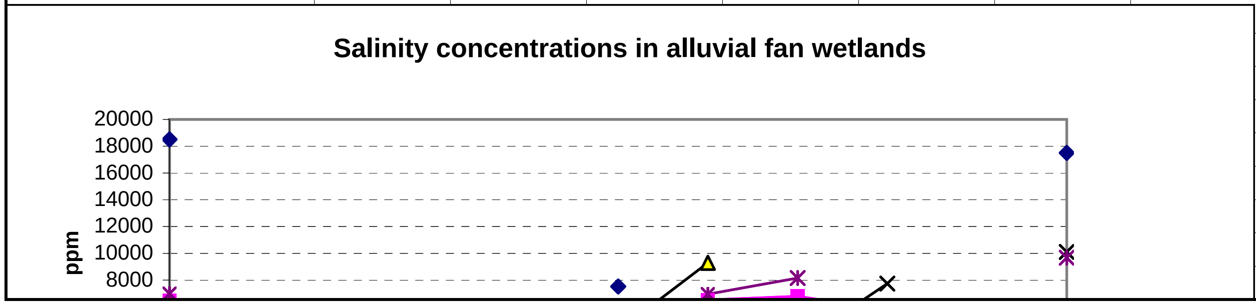

0
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Jan-06
Feb-06
Mar-06
Apr-06
months

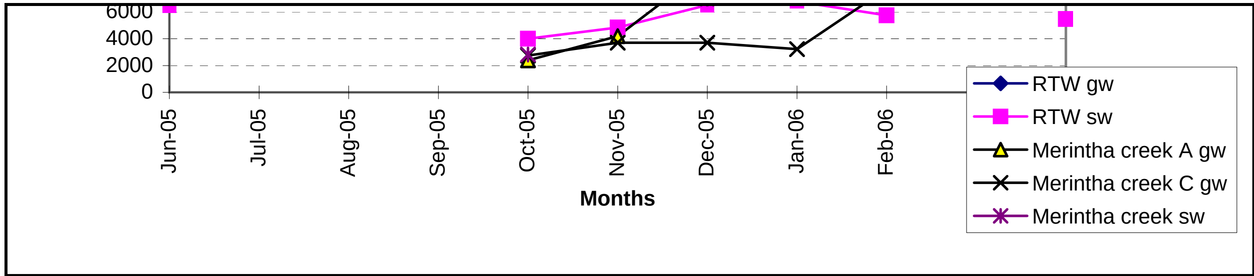

Salinity concentrations at Lake Malata
ppm
240000
200000
160000
120000
80000
40000
0
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Jan-06
Feb-06
Mar-06
Apr-06
Months
Malata 1A gw
Malata 1A sw
Malata 1B gw
Malata 1C gw
Malata 1C sw
Malata 1D gw
Malata 1D sw
Malata 3A gw
Malata 3B gw


Salinity concentrations in Duck Lake
ppm
60000
50000
40000
30000

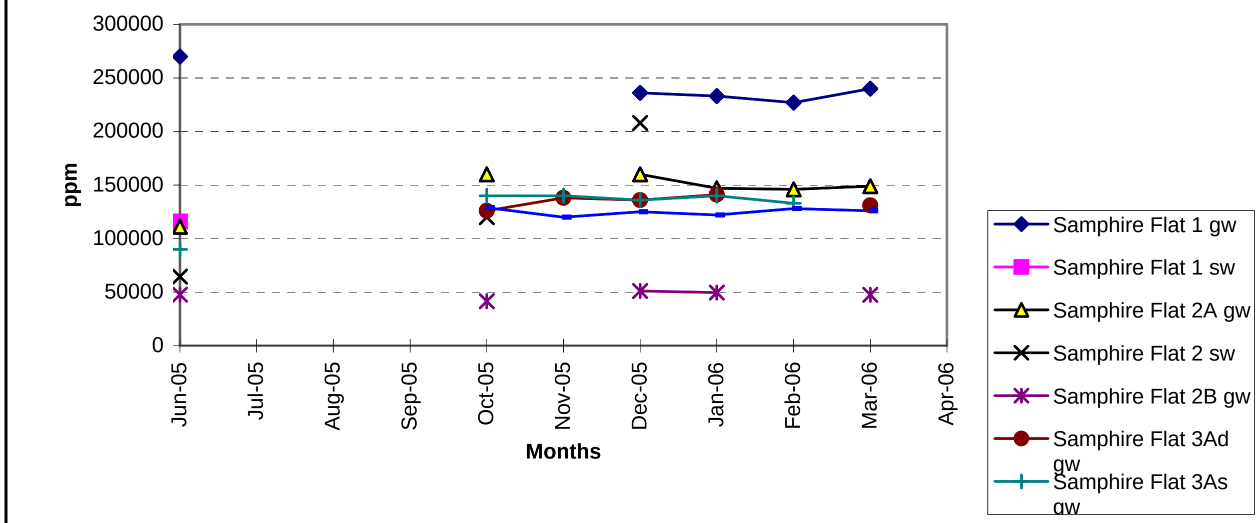

20000
10000
0
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Jan-06
Feb-06
Mar-06
Months
Duck Lake B gw
Duck Lake sw


Salinity concentrations in Little Swamp
ppm
24000
21000
18000
15000
12000
9000
6000
3000
0
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Jan-06
Feb-06
Mar-06
Apr-06
Months
Little Swamp deep gw
Little Swamp shallow gw
Little Swamp sw

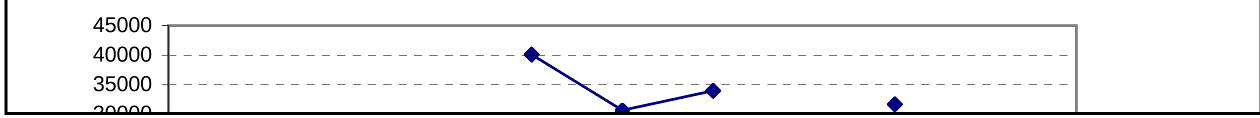

Salinity concentrations in alluvial fan wetlands
ppm
20000
18000
16000
14000
12000
10000
8000

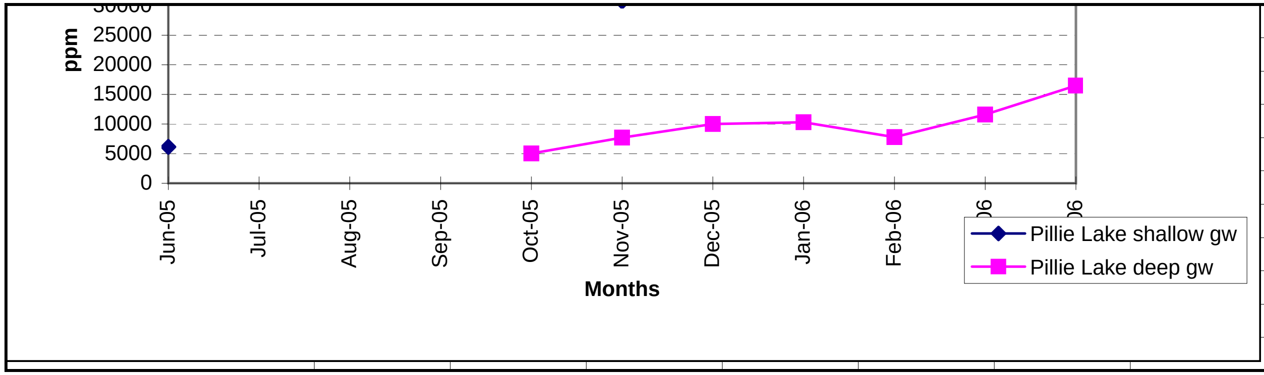


Salinity concentrations at Samphire Flat



Salinity concentrations in Pillie Lake





ppm
30000
25000
20000
15000
10000
5000
0
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Jan-06
Feb-06
Months
Pillie Lake shallow gw
Pillie Lake deep gw

		pH								
Sep-06		Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	Sep-06
		7.8		7.8	7.8		8.6	7.9	7.8	
		8.3		8.2	8.4	8.6	8.3	7.8	8.2	
		8.4		8.5		8.4	8.1	8.4	8.3	
									7.8	
									8	
					9.4	9.4	6.9	8.2	7.1	
				8	8.2	8.4		8.3	8.2	
									6.9	
			6.7	6.9	6.9	7	7.1	7.1	7.2	
			7.4	7.5	7.1					
			7.2	7.2	7.1	7.1	7.1	7.1	7.1	
			7.1	7.1	7.3	7.1	7.1	7.2	7.2	
				7.6						
			7.1	7.3	7.5	7.4	7.5	7.4	7.4	
				8.2	8.1	7.1	7.4		7.4	
			6.1	6.4	6.6	6.7	6.9	7	7	
						6.8				
			8.2	8	7.9	7.8	7.8	7.8	7.8	
			7.7							
			6.9	6.9	6.9			6.9		
			7.1	7.6						
			8.4						7.8	
8800			8.1	8	7.5				7.6	8.2

7840			8.5	8.2	8.2				7.4	8.9
6580			8.6	9.1	8.4				8	9.3
				8.2					8	
			8.6	8.8	7.8	8.6	8.5		8.3	
			8.5	8.2	7.9					
			8.4	8.4	8.4	8.4	8		7.8	
			8.2		8	8.4			7.6	
					7.1	6.9	7.1	7		
			5.2		4.7	4.2	4.3	4.2		
			6		3.5					
			4.6		4.5	4.5	4.5	4.5		
			5.2	5.3	5.5	5.6		5.9		
			4.7	5.4	5.4	5.8	5.8			
			6	6.1	6	6.2	6.2	6.2		
			7.1	7.5	7.4	8	8.4			
			8	8.1	8.4	8.5	8.5	8.2	8.4	
									7.8	
									7.1	
									6.9	
									8.2	
									8	
									7.2	
									7.4	
									6.6	
									6.8	
									7.6	
									8.1	

									7.4	
									7.8	
		77000 vic							6.9	7.4 vic
									7.1	
									7.5	
									7.4	
									7	
									7.4	
									6.9	
									7.9	
									8	
									8.3	
									7.4	
									7.4	
									6.4	
									7.9	
									7.2	
									7.8	
									7.5	
									7.8	
									6.9	
									7.2	
									8.3	
									8	
									7.4	

V & C Semeniuk Research Group - Baseline survey of wetlands, Eyre Peninsula:

Appendix 3:

Selected water chemistry

Analytical Methods
The solutions have not been treated other than by dilution.

K, Ca, Mg, Cu, P, Na
have been determined by Inductively Coupled Plasma (ICP) Optical Emission Spectrometry.

As, Pb
have been determined by Inductively Coupled Plasma (ICP) Mass Spectrometry.

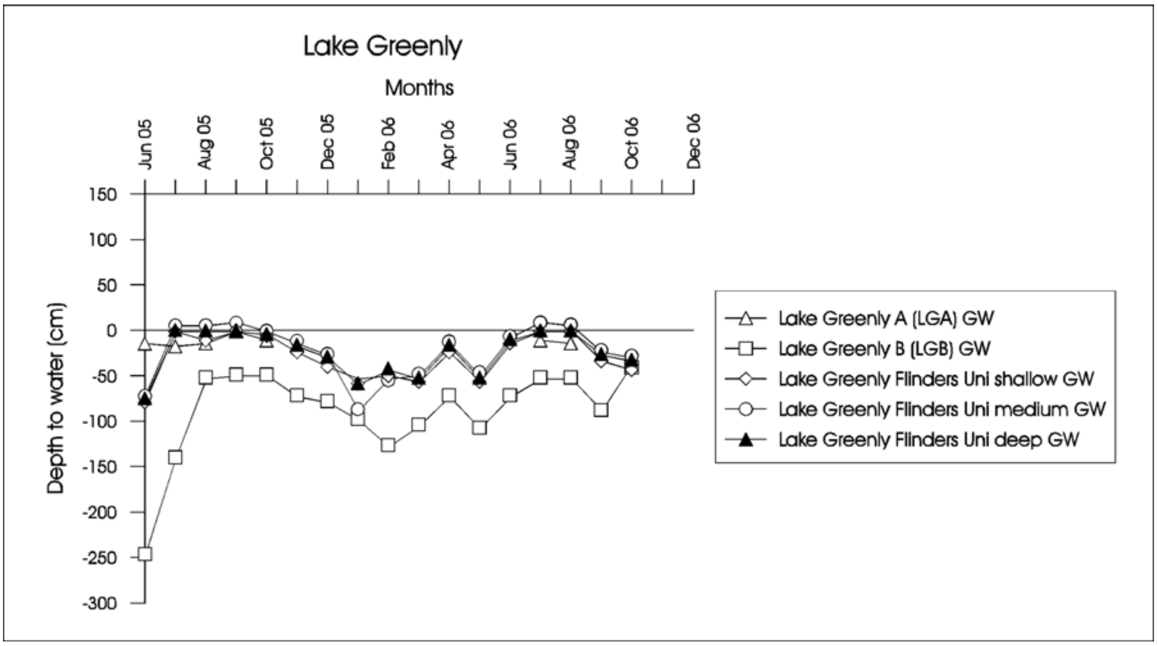
V & C Semeniuk Research Group - Baseline survey of wetlands, Eyre Peninsula: Appendix 3 selected water chemistry

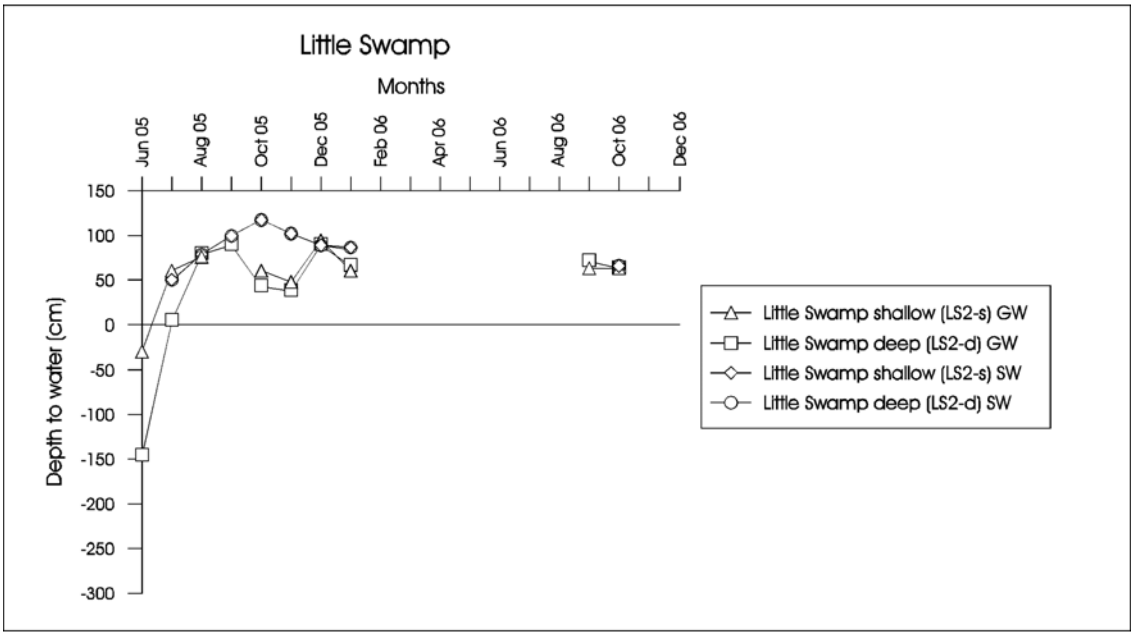
	Sites	TDS	Na	K	Ca	Mg	As	Pb	Cu	P
June 2005 samples			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EP0605 1	Greenly SW 12/06/05	22,000	110	8	37	11	-0.1	-0.05	-0.1	-1
EP0605 2	Greenly GW 12/06/05	2,000	110	8	47	15	-0.1	-0.05	-0.1	-1
EP0605 3	LS (Little Swamp) GW 07/06/05	36,000	40	-2	3	4	-0.1	0.05	-0.1	-1
EP0605 4	Greenly - 3 GW June05	171,000	55100	1170	1080	5510	-0.1	-0.05	-0.1	-1
EP0605 5	Greenly - 2 GW June05	15,000	5440	180	68	148	-0.1	-0.05	-0.1	-1
EP0605 6	Greenly - 1 GW June05	180,000	59400	1120	947	5490	-0.1	-0.05	-0.1	-1
EP0605 8	EP - Pillie centre- 09/06/05	10,000	1940	92	39	111	-0.1	-0.05	-0.1	-1
EP0605 9	SF 1 SW 11/06/05	250,000	104000	746	1260	2050	-0.1	-0.05	-0.1	-1
EP0605 10	ML - 1 - B - GW June 05	175,000	47000	900	1230	4100	-0.1	-0.05	-0.1	-1
EP0605 11	ML - 3 - A - GW J12/06/05	255,000	95000	1720	814	7310	-0.1	-0.05	-0.1	-1
EP0605 12	EP - TR - SW 12/06/05	10,000	1880	20	122	177	-0.1	-0.05	-0.1	1
EP0605 13	Yallanda -62 cm BG 12/06/05	4,000	1060	12	60	111	-0.1	-0.05	-0.1	-1
EP0605 14	EP - Merintha Crk 10/06/05	10,000	3040	50	113	332	-0.1	-0.05	-0.1	-1
September 2005 samples										
EP0905 1	DUCK LAKE B (DL-B) 30.09.05	38,400	13800	168	718	1580	-0.1	-0.05	-0.1	-1
EP0905 2	DUCK LAKE SW 30.09.05	5,160	2030	32	67	202	-0.1	-0.05	-0.1	-1
EP0905 5	M Crk-A 30.09.05	2,390	880	16	64	81	-0.1	-0.05	-0.1	-1
EP0905 6	M Crk 30.09.05	2,750	1020	24	57	92	-0.1	-0.05	-0.1	-1
EP0905 10	RTW CREEK SW 30.09.05	4,000	1550	28	64	155	-0.1	-0.05	-0.1	-1
EP0905 12	ML-3A 30.09.05	242,000	75000	2500	545	11500	-0.1	0.25	-0.1	-1
EP0905 13	ML-3-B 30.09.05	28,700	9770	218	352	1150	-0.1	-0.05	-0.1	-1
EP0905 19	TODD RIVER SW 30.09.05	5,450	2010	20	153	246	-0.1	-0.05	-0.1	-1
EP0905 22	LH-SS L 04.09.05	350	120	8	22	16	-0.1	-0.05	-0.1	-1
EP0905 23	LHS GW 04.09.05	36,600	14100	492	539	1510	-0.1	-0.05	-0.1	-1
EP0905 26	LHN2 FW FLOW 04.09.05	3,260	1390	42	90	161	-0.1	-0.05	-0.1	-1
EP0905 27	LHN2 SW 04.09.05	40,600	15400	512	439	1610	-0.1	-0.05	-0.1	-1
EP0905 28	LHN WT 20cm 04.09.05	8,600	4010	88	113	377	-0.1	-0.05	-0.1	-1
EP0905 29	LN-N SW 05.09.05	11,100	4640	146	98	462	-0.1	-0.05	-0.1	-1
EP0905 30	LN-N FW SPRING 05.09.05	5,120	2000	64	124	211	-0.1	-0.05	-0.1	-1
EP0905 32	SLEAFORD WATER 02.09.05	19,300	5900	150	50	687	-0.1	-0.05	-0.1	-1
EP0905 33	SLEAFORD SM-E SW 02.09.05	1,630	530	30	37	61	-0.1	-0.05	-0.1	-1
EP0905 34	CALPAT WELL 04.09.05	3,910	1360	66	97	121	-0.1	-0.05	-0.1	-1
December 2005 to January 2006 samples										
EP1205 14	BAIRD A 31.12.05	213,000	85200	1090	974	5340	-0.1	-0.05	-0.1	-1
EP1205 15	PILLARA 31.12.05	114,000	41000	734	671	3520	-0.1	-0.05	-0.1	-1
EP0106 19	SF-1-A	233,000	86300	1680	793	8750	-0.1	0.55	-0.1	-1
EP0106 20	SF-2-A	147,000	56100	1250	1230	4470	-0.1	1.05	-0.1	-1
EP0106 41	LN-N 200 m SW	228,000	76800	2530	775	8680	0.1	-0.05	-0.1	-1
EP0106 42	LN-N 200 m 30 cm WT	16,800	4910	168	293	569	-0.1	-0.05	-0.1	-1
EP0106 43	LN-N Island 40 cm WT	7,030	2590	120	145	223	-0.1	-0.05	-0.1	-1
EP0106 44	LN-N well slot	4,200	1540	76	100	167	-0.1	-0.05	-0.1	-1
April 2006 samples										
EP0406 8	THREE LAKES - WATER DAM	24,200	8200	332	108	806	-0.1	-0.05	-0.1	-1
EP0406 9	ROUND LAKE A SW	90,000	26900	568	969	4030	-0.1	-0.05	-0.1	-1
EP0406 10	ROUND LAKE A GW	72,000	22400	492	755	3050	-0.1	-0.05	-0.1	-1
EP0406 11	ROUND LAKE B (-- 60 cm)	3,650	1340	38	59	139	-0.1	-0.05	-0.1	-1
EP0406 23	L. HAMP -A GW	105,000	33200	830	957	4050	-0.1	-0.05	-0.1	-1
EP0406 24	L. HAMP-A2 GW	13,100	4280	146	618	393	-0.1	-0.05	-0.1	-1
EP0406 31	PADDYS VENT SW	34,700	12400	432	525	1390	-0.1	-0.05	-0.1	-1
EP0406 56	L. HAMILTON VENT SW	33,000	10800	372	420	1230	-0.1	-0.05	-0.1	-1
EP0406 59	SLEAFORD MERE SW	24,000	8300	210	74	966	-0.1	-0.05	-0.1	-1
EP0406 60	SLEAFORD MERE GW	26,000	9100	216	183	1070	-0.1	-0.05	-0.1	-1
EP0406 67	ST H-A GW	92,000	28400	1030	1280	3380	-0.1	-0.05	-0.1	-1

V & C Semeniuk Research Group –
Baseline survey of wetlands, Eyre Peninsula:

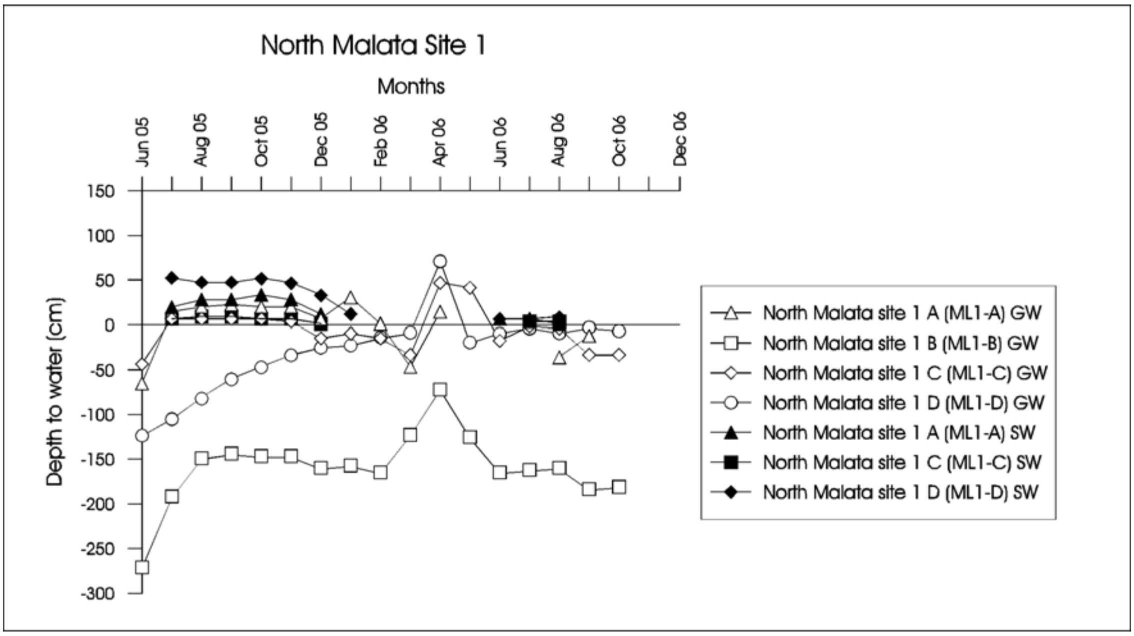
Appendix 4 –
Groundwater hydrographs showing the length of time water levels in piezometers took to equilibrate

At some sites, the hydrographs presented in the main report have had the water level measurements for the first one or two months deleted: Lake Greenly, Little Swamp, Lake Malata (sites 1 and 3), Samphire Flat, and Lake Pillie. This has been done because these measurements are misleading with respect to wetland water regime. After augering through thick layers of mud, the water table in the piezometer must readjust to the level of the local water table within the wetland sediments. In some cases the adjustment to equilibrium may take several hours, in some cases, several days and under the sites at Lakes Greenly and Pillie it took two months. These measurements, however, are important with reference to questions about the transmissivity of the underlying sediment, the nature of the hydrological flow paths, or the rate of infiltration from the surface to the water table. For these reasons, the graphs are re-presented in this Appendix 4 so that further deliberations or information may be used by the staff of EPNRM in the future.

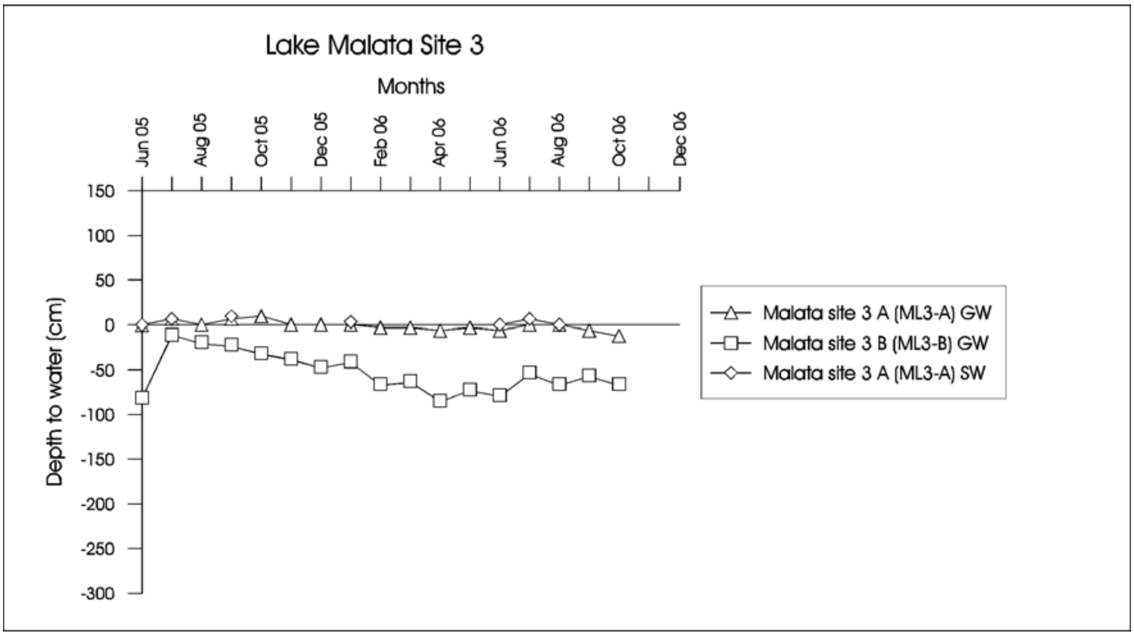




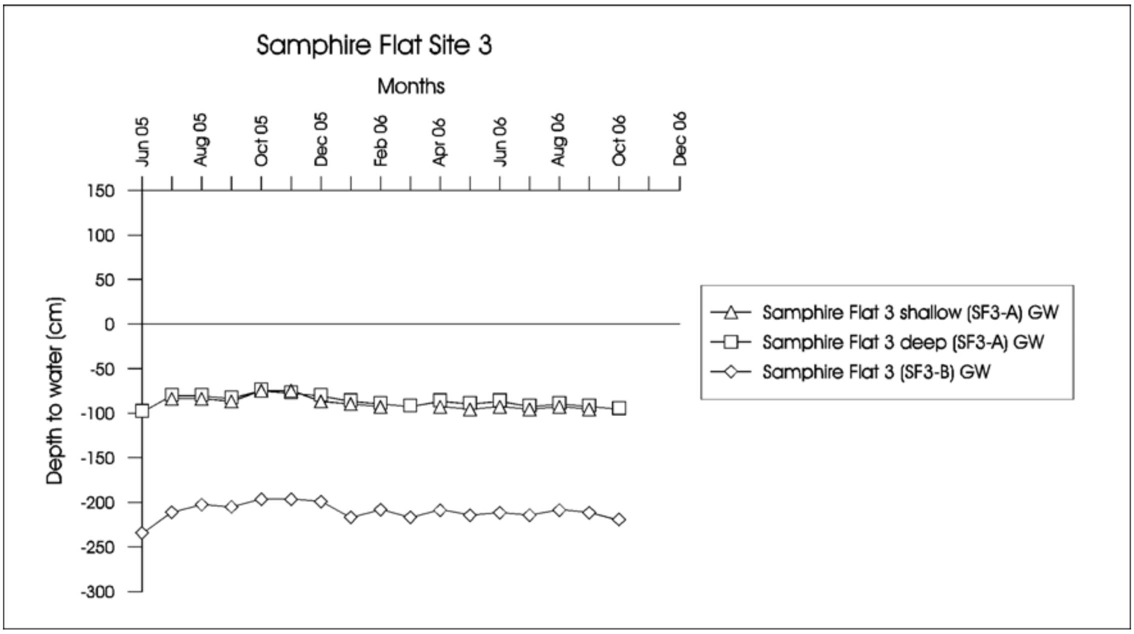
Little Swamp
Months
Jun 05
Aug 05
Oct 05
Dec 05
Feb 06
Apr 06
Jun 06
Aug 06
Oct 06
Dec 06
Depth to water (cm)
150
100
50
0
-50
-100
-150
-200
-250
-300
Little Swamp shallow (LS2-s) GW
Little Swamp deep (LS2-d) GW
Little Swamp shallow (LS2-s) SW
Little Swamp deep (LS2-d) SW



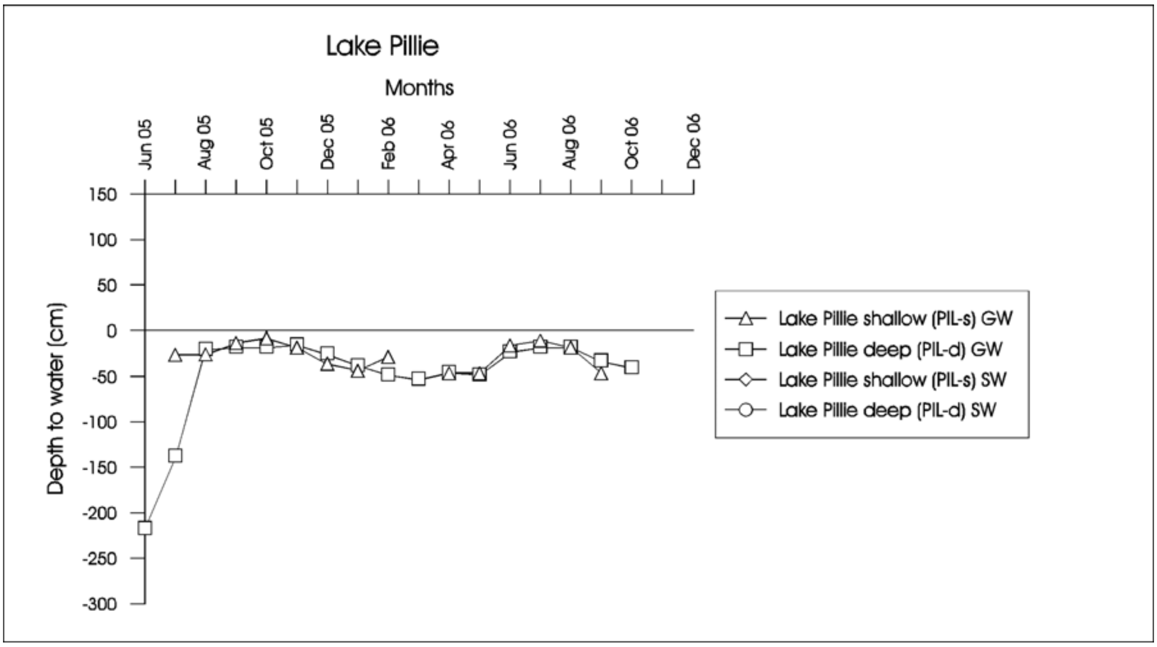
North Malata Site 1
Months
Jun 05
Aug 05
Oct 05
Dec 05
Feb 06
Apr 06
Jun 06
Aug 06
Oct 06
Dec 06
Depth to water (cm)
150
100
50
0
-50
-100
-150
-200
-250
-300
North Malata site 1 A (ML1-A) GW
North Malata site 1 B (ML1-B) GW
North Malata site 1 C (ML1-C) GW
North Malata site 1 D (ML1-D) GW
North Malata site 1 A (ML1-A) SW
North Malata site 1 C (ML1-C) SW
North Malata site 1 D (ML1-D) SW



Lake Malata Site 3
Months
Jun 05
Aug 05
Oct 05
Dec 05
Feb 06
Apr 06
Jun 06
Aug 06
Oct 06
Dec 06
150
100
50
0
-50
-100
-150
-200
-250
-300
Depth to water (cm)
Malata site 3 A (ML3-A) GW
Malata site 3 B (ML3-B) GW
Malata site 3 A (ML3-A) SW



Samphire Flat Site 3
Months
Jun 05
Aug 05
Oct 05
Dec 05
Feb 06
Apr 06
Jun 06
Aug 06
Oct 06
Dec 06
150
100
50
0
-50
-100
-150
-200
-250
-300
Depth to water (cm)
Samphire Flat 3 shallow (SF3-A) GW
Samphire Flat 3 deep (SF3-A) GW
Samphire Flat 3 (SF3-B) GW


Lake Pillie
Months
Jun 05
Aug 05
Oct 05
Dec 05
Feb 06
Apr 06
Jun 06
Aug 06
Oct 06
Dec 06
150
100
50
0
-50
-100
-150
-200
-250
-300
Depth to water (cm)
Lake Pillie shallow (PIL-s) GW
Lake Pillie deep (PIL-d) GW
Lake Pillie shallow (PIL-s) SW
Lake Pillie deep (PIL-d) SW