Ecological Character Description

Piccaninnie Ponds Karst Wetlands

Ecological Character Description for Piccaninnie Ponds Karst Wetlands.

Prepared by: Water's Edge Consulting and Associates for the Department of Environment, Water and Natural Resources, Mt Gambier

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Introductory Notes

This Ecological Character Description (ECD Publication) has been prepared in accordance with the National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (National Framework) (Department of the Environment, Water, Heritage and the Arts, 2008).

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) prohibits actions that are likely to have a significant impact on the ecological character of a Ramsar wetland unless the Commonwealth Environment Minister has approved the taking of the action, or some other provision in the EPBC Act allows the action to be taken. The information in this ECD Publication does not indicate any commitment to a particular course of action, policy position or decision. Further, it does not provide assessment of any particular action within the meaning of the EPBC Act, nor replace the role of the Minister or his delegate in making an informed decision to approve an action.

This ECD Publication is provided without prejudice to any final decision by the Administrative Authority for Ramsar in Australia on change in ecological character in accordance with the requirements of Article 3.2 of the Ramsar Convention.

Disclaimer

Note: There may be differences in the type of information contained in this ECD publication, to those of other Ramsar wetlands.

Table of Contents

List of Abbreviations

BONN	Bonn Convention on Migratory Species.
CAMBA	China Australia Migratory Bird Agreement.
CDAA	Cave Diving Association Australia.
CEPA	Communication, Education, Participation and Awareness.
CITES	Convention on International Trade in Endangered Species.
DfW	Department for Water, South Australia.
DEH	Department for Environment and Heritage, South Australia.
DEWNR	Department of Environment, Water and Natural Resources, South Australia, formerly DEH and DENR.
DEWHA	Department of Environment, Water, Heritage and the Arts (Commonwealth).
DIWA	Directory of Important Wetlands in Australia (Environment Australia 2001).
DLWBC	Department of Land, Water and Biodiversity Conservation.
ECD	Ecological Character Description.
EPBC Act	*Environment Protection and Biodiversity Act1999* (Commonwealth).
IUCN	International Union for Conservation of Nature.
JAMBA	Japan Australia Migratory Bird Agreement.
LAC	Limits of Acceptable Change.
NRM	Natural Resource Management.
OBP	Orange-bellied parrot.
RIS	Ramsar information sheet.
RMP	Ramsar management plan.
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement.
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities, formerly DEWHA.
WAP	Water Allocation Plan.

Executive Summary

This Ecological Character Description (ECD) was prepared to support the nomination of Piccaninnie Ponds Karst Wetlands for listing as a Wetland of International Importance. The Piccaninnie Ponds Karst Wetlands are located in the South East of the state of South Australia. The site is situated 30 kilometres south east of Mount Gambier which has a population of 24 000. The site is bounded by the South Australia – Victoria border on the east, the Southern Ocean on the south, and privately owned cropping and grazing land to the north and west (Figure E1).

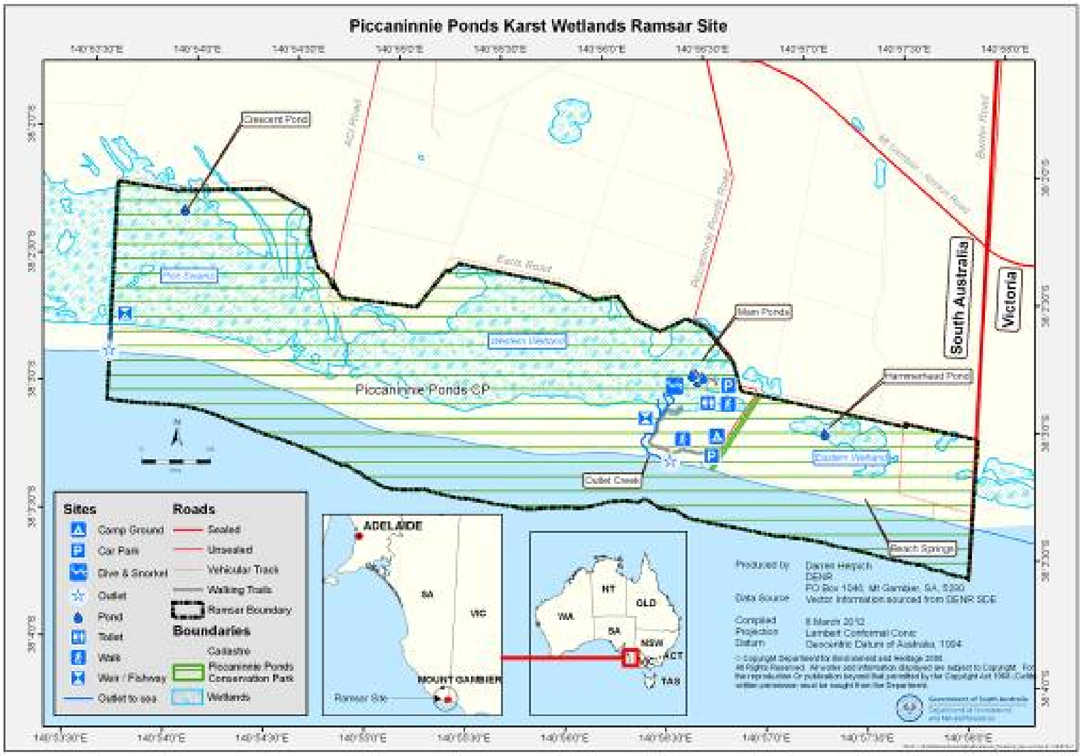


Figure E1: Site map of the Piccaninnie Ponds Karst Wetlands

Encompassing an area of approximately 862 hectares, the system is an important remnant of an extensive system of wetlands that once occupied much of the South East of South Australia. Key areas within the site include the major groundwater discharge sites of Piccaninnie Ponds, referred to as the Main Ponds, Hammerhead Pond and Crescent Pond. Water leaves the site via a number of outlets, principally Outlet Creek (also called Ellards Creek) and the Pick Swamp drain outlet (on the far Western boundary of the site), which connect the site to the marine environment. Along the beach are a number of fresh groundwater beach springs. Throughout the site there are a number of small additional, unmapped and unnamed springs, which are also groundwater discharge points.

The Piccaninnie Ponds Karst Wetlands meets the following five of nine criteria for listing as a Wetland of International Importance:

Criterion 1: ***A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region*.**
The site represents an outstanding example of two rare wetland types within the South East Coast Drainage Division. Karst and other subterranean hydrological systems have a range of conservation and cultural values and are recognised as being globally important. Fen peatlands are one of the most vulnerable wetland types being highly susceptible to degradation. The Piccaninnie Ponds Karst Wetlands is a unique combination of karst and coastal fen wetlands in good condition. The site includes a series of rising spring karst systems as well as several substantial groundwater beach springs along the foreshore of the beach. The continual discharge of groundwater has led to the water logging of soils and the formation of extensive peatland fens.

The hydrological and geomorphic combination of karst wetland, fen wetland and beach springs, all in very good condition, makes this site truly unique at the bioregion, if not national scale, thus clearly meeting this criterion.

Criterion 2: ***A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.***
The site supports seven nationally or internationally listed species of conservation significance including: Australasian bittern (*Botaurus poiciloptilus*), orange-bellied parrot (*Neophema chrysogaster*), Yarra pygmy perch (*Nannoperca obscura*), dwarf galaxias (*Galaxiella pusilla*), Glenelg spiny freshwater crayfish (*Euastacus bispinosus*), swamp greenhood (*Pterostylis tenuissima*) and the maroon leek-orchid (*Prasophyllum frenchii*).

Criterion 3: ***A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.***
The site is a unique karst wetland system which provides habitat for an extensive and diverse assemblage of endangered, rare and other flora and fauna, highly representative of the pre-European biodiversity of the Lower Limestone Coast region of South Australia. The karst wetland system on which this biodiversity is dependent, is rare within the bioregion, and represents one of the few remaining areas of permanent freshwater in the South East of South Australia. The biota of the subterranean areas of the karst wetlands are believed to be significant and contribute a unique element to the regional biodiversity. The site falls within a national biodiversity ‘hotspot’. The site is species rich supporting similar or greater numbers of waterbirds compared to larger nearby coastal wetlands and Bool and Hacks Lagoons Ramsar site to the north of Mount Gambier. Over 30 floral associations and 250 plant species have been recorded from the site, a number of which are used by six butterfly species which are of conservation concern. The site supports 10 of the 21 native fish species found in the drainage division.

Criterion 4: ***A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.***
The site is a known winter roosting and feeding location for the Critically Endangered orange-bellied parrot (*Neophema chrysogaster*). The site also provides habitat for 79 waterbird species including 24 species listed under international agreements: CAMBA (20), JAMBA (19), ROKAMBA (16), BONN (17) and 50 Australian migratory or marine species. Native fish populations include seven species which are diadromous and three freshwater obligate species which rely on permanent freshwater. This site represents one of the few remaining permanent freshwater wetlands in the lower South East of South Australia and is believed to be a drought refuge.

Criterion 8: ***A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.***
The site is an important spawning ground for the Yarra pygmy perch (*Nannoperca obscura*) and dwarf galaxias (*Galaxiella pusilla*) in South Australia. Despite the karst system being relatively isolated, this system supports species that spawn both within the freshwater wetlands as well as in the nearby marine environment including spotted galaxias (*Galaxias truttaceus*), climbing galaxias (*Galaxias brevipinnis*) and pouched lamprey (*Geotria australis*).

Overview of Piccaninnie Ponds Karst Wetlands ECD
An ECD identifies and describes the essential and critical components, processes and services, benchmarked to the time of listing. Limits of Acceptable Change (LAC) are developed for each of the critical components, processes and services identified. Essential components and processes are those which are not necessarily critical to the sites character but play an important role in supporting the critical components, processes and services. At Piccaninnie Ponds Karst Wetlands these include climate, geomorphic setting, soils, algae, and invertebrates. The site is characterised by the karstic landscape and peat soils. Constant groundwater discharge from the karst wetlands has inundated the surrounding landscape with water ponding on the surface as drainage is impeded by the coastal dunes. The Main Ponds are the best understood as these are the main area in which cave diving occurs. The Main Ponds include First Pond, Turtle Pond, the Chasm and Cathedral.

The karst wetlands have a unique macrophyte community including a number of macroalgae that grow to considerable depths in the Piccaninnie Main Ponds. These and associated macrophytes are densely covered with periphyton providing a unique environment for cave diving. The invertebrate fauna of the site is poorly documented but is expected to harbour unusual elements in the karst wetlands. The surface waters of Pick Swamp support the Glenelg spiny freshwater crayfish, one of seven nationally listed species found at the site.

Components and processes which are considered critical to the ecological character of the site include: hydrology, water quality, vegetation, fish, and waterbirds. The climate, geomorphic setting and the hydrological regime provides the physical template for the site. The wetlands are fed by continual groundwater discharge into the karst wetlands. The main discharge point is the Main Ponds, with greatest inflow in the Chasm. Fractures in the face of the limestone of the Chasm at approximately 36 metres deep represent the point of greatest discharge, although groundwater discharges into the Chasm along most of the limestone face as well as into First Pond and Turtle Pond.

Water quality in the Main Ponds is characterised by high clarity, low turbidity, and high nitrogen. The ponds are slightly alkaline. The majority of the nitrogen is in dissolved bioavailable form and may be a contributing factor to the periphyton growth. Salinity is variable across the site with the Main Ponds recording higher salinities than surrounding wetlands and in Outlet Creek. This is possibly due to sea water intrusion into the Chasm. The Main Ponds show a seasonal pattern in salinity with higher readings in winter. Salinity in Pick Swamp surface water reflect the more normal summer peaks in salinity, an indication that evaporation plays a role in the salinity levels in this part of the site.

Vegetation is characterised by distinctive zoned communities in the karst systems, with macrophytes and macroalgae growing to depths below 15 metres in the Main Ponds. In the rest of the site silky tea tree shrubland, covers much of the Western and Eastern wetlands and surround Crescent Pond. The peatland fens of Pick Swamp harbour different aquatic species again and there are substantial areas of sedge, rush and grasslands. Over 30 associations and 250 species have been recorded from the site.

The native fish fauna of the site is a mixture of rare and nationally endangered species, freshwater obligates and diadromous species. The connectivity to the marine environment is important for seven of the ten species found at the site. Waterbirds are diverse but not overly abundant. Seventy nine species including 24 migratory species listed under international treaties are found at the site. The site is significant for orange-bellied parrot, Australasian bittern, hooded plover and sanderling. Breeding records exist for 11 species.

The critical services identified for the site include one regulating service and five supporting, or ecological, services. The regulating service is that it maintains and regulates the hydrological regime through continuous groundwater discharge. This is closely linked to the fact that the site supports special ecological, physical and geomorphic features – the karst wetlands, beach springs and fen wetlands. Combined, the hydrology and geomorphology of the site in turn provide the physical habitat for waterbird breeding and feeding as well as supporting critical life stages. The site supports seven national listed threatened species and lies within a national biodiversity hotspot, supporting significant regional biodiversity values. Finally the site also plays a role in ecological connectivity providing key migrations routes for fish, albeit a short distance, from the inland karst wetlands to the marine environment via Outlet Creek.

The condition and biodiversity associated with the Piccaninnie Ponds Karst Wetlands is potentially at risk from a number of threats, which are often interrelated, and operating at multiple temporal and spatial scales. For example, vegetation patterns can be modified as a result of changed hydrology, land clearing and grazing pressure (individually or in combination), the effects of which may be a legacy of past practices or current activities. In addition, changes in land use and associated activities, in surrounding areas, increases the risk of invasion by weeds, introduced predators such as foxes pose risks to threatened fauna, while uncontrolled access for recreation increases the risks to wetland vegetation (for example via introduction of weeds or pathogens, or by physical damage).

While there are many potential threats that may impact on the habitat condition and biodiversity values of the wetland system, most are controlled under current management arrangements for the site. In addition, reinstatement of water levels in the Piccaninnie Ponds Karst Wetlands and other rehabilitation measures currently in place (or proposed) have the potential to improve the condition and protect the values of the wetland system.

The following are major threats to the Piccaninnie Ponds Karst Wetlands:

- Altered hydrology including threats to groundwater quantity;
- Land clearance and grazing by livestock (historic);
- Introduced species (weeds and animal pests) and pathogens;
- Water quality;
- Tourism and recreation;
- Aquatic vegetation die back;
- Climate change; and
- Wildfire and anthropogenic fire regimes.

There are a number of key knowledge gaps that limit the description of ecological character and the setting of limits of acceptable change for the Piccaninnie Ponds Karst Wetlands. These include:

- Limited understanding of the hydrology across the entire site;
- Understanding of type and extent of peat throughout the system and its influence on surface water patterns, productivity and diversity;
- Long-term water quality;
- The understanding of the composition and extent of karst vegetation communities is based on 20 year old data. Surface wetland vegetation associations have been recently mapped but there is no information on their condition;
- Community composition and abundance of invertebrates within the site; and
- Threatened species – records of several of the species are based on isolated or sporadic surveys.

To address these knowledge gaps and inform against the limits of acceptable change the monitoring needs for the Piccaninnie Ponds Karst Wetlands have been recommended.

The Limits of Acceptable Change which have been set for the site are summarised in Table E1.

LACs are a tool by which ecological change can be measured. However, ECDs are not management plans and LACs do not constitute a management regime for the Ramsar site.

Exceeding or not meeting LACs does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting LACs may require investigation to determine whether there has been a change in ecological character.

Table E1: Limits of Acceptable Change for Piccaninnie Ponds Karst Wetlands.

Critical Components, Processes and Services	Limit of Acceptable Change	Confidence level
Hydrology – groundwater discharge	Average winter daily discharge rate is no less than 38 megalitres per day and average summer daily discharge is no less than 30 megalitres per day for three out of any five year period.	High.
Hydrology – wetland extent	No less than one hectare of karst (Ramsar type Zk(b)) springs (measured as surface area). No less than 69 hectares of peatlands (Ramsar type U). No less than 31 hectares of permanent freshwater marshes or pools on inorganic soils (Ramsar type Tp). No less than seven hectares of intermittent marshes or pools on inorganic soils (Ramsar type Ts). No less than 134 hectares of shrub dominated wetlands (Ramsar type W).	Medium.
Water quality - salinity	Salinity in Main Ponds is always less than 4000 milligrams per litre.	Low.
Water quality – nutrients	Nitrate not to exceed ten milligrams per litre for six consecutive months.	Low.
Water quality – turbidity	Less than 10 nephelometric turbidity units in Main Ponds at any time.	Medium.
Water quality – pH	Data insufficient to set LAC.	Not applicable.
Vegetation - Silky tea tree shrubland	Extent of silky tea tree shrubland as delineated by Ecological Associates (2008) vegetation associations N, P, and AB to be no less than 156 hectares.	High.
Vegetation - Sedgeland, rushland and grassland	Extent of sedgeland, rushland and grassland wetland habitat as delineated by Ecological Associates (2008) vegetation associations F, O, Q, W, Z and	Medium.

Critical Components, Processes and Services	Limit of Acceptable Change	Confidence level
	POW to be no less than 30 hectares.	
Vegetation - Aquatic vegetation community – karst	*Triglochin procerum* present within Main Ponds to at least two metres. *Myriophyllum propinquum* present within Main Ponds.	High.
Vegetation - Aquatic vegetation community – fen and marsh	Extent of fen and marsh as delineated by Ecological Associates (2008) vegetation associations A, B, D, G, H, I, and J to be no less than 60 hectares.	Medium.
Fish	Presence of at least eight native fish species over any three sampling events over a five year period in which all habitat including karst, Pick Swamp, and Outlet Creek are sampled. Small-mouthed hardyhead (*Atherinosoma microstoma*) and common galaxias (*Galaxias maculates)* present in each survey**.**	High.
Waterbirds – number of species	Presence of at least 37 species in at least 5 years of any 10 year period in which surveys are undertaken.	Medium.
Maintenance of hydrological regimes	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology, see LAC above.	Not applicable.
Special ecological, physical or geomorphic features – karst wetlands	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology, see LAC above.	Not applicable.
Physical habitat which supports waterbird breeding.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and vegetation see LAC above.	Not applicable.
Physical habitat which supports waterbird feeding.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and vegetation see LAC above.	Not applicable.
Threatened species – Australasian	Presence within Ramsar site on an annual basis.	Medium.

Critical Components, Processes and Services	Limit of Acceptable Change	Confidence level
bittern		
Threatened species – orange-bellied parrot	Presence within Ramsar site during winter migration periods every one in three years.	Low.
Threatened species – Yarra pygmy perch	Presence within Crescent Pond on an annual basis.	High.
Threatened species – dwarf galaxias	Presence within Hammerhead Pond and Pick Swamp on an annual basis.	High.
Threatened species – swamp greenhood	Presence within Ramsar site on an annual basis.	Low.
Biodiversity	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology, see LAC above.	Not applicable.
Ecological connectivity	Maintain fish passage between Main Ponds and Southern Ocean. To be measured on basis of continued presence of all diadromous fish species in any three of five years sampled.	High.

1 Introduction

1.1 Site details

The Piccaninnie Ponds Karst Wetlands are a rare and diverse wetland system located in the South East of the state of South Australia. The site is situated 30 kilometres south east of Mount Gambier which has a population approaching 24 000. The site is bounded by the South Australia – Victoria border to the east, the Southern Ocean to the south and privately owned cropping and grazing land to the north and west. Summary details for the nominated site are provided in Table 1.

Table 1: Site details for the Piccaninnie Ponds Karst Wetlands.

Site Name	Piccaninnie Ponds Karst Wetlands
Location in coordinates	Latitude: 38° 03' S Longitude: 140° 57' E
General location of the site	South East region of South Australia, 30 kilometres south east of Mt Gambier township.
Area	862 hectares.
Date of Ramsar site designation	21 December 2012
Ramsar/DIWA Criteria met by wetland	Ramsar criteria 1, 2, 3, 4, and 8.
Management authority for the site	The South Australian Department of Environment, Water and Natural Resources, South East Region, PO Box 1046, Mt Gambier SA 5290. (Tel: +61 -8-8735 1175; Fax +61-8-8735 1110).
Date the ECD applies	21 December 2012
Status of Description	This represents the first ECD for the site.
Date of Compilation	June 2011.
Name(s) of compiler(s)	Rhonda Butcher on behalf of DEWNR, all enquires to Melissa Herpich, Department of Environment, Water and Natural Resources, South East Region PO Box 1046, Mt Gambier SA 5290. (Tel: +61-8-8735-1205; email: Melissa.Herpich@ sa.gov.au).
References to the Ramsar Information Sheet (RIS)	Piccaninnie Ponds Karst Wetlands RIS RIS prepared June 2011.
References to the Management Plan(s)	Butcher *et al*. (2011) Ramsar Management Plan for Piccaninnie Ponds Karst Wetlands.

1.2 Statement of purpose

This ECD was prepared to support the nomination of Piccaninnie Ponds Karst Wetlands for listing as a Wetland of International Importance.

The act of designating a wetland as a Ramsar site carries with it certain obligations, including managing the site to retain its 'ecological character' and to have procedures in place to detect if any threatening processes are likely to, or have altered the 'ecological character'. Thus, understanding and describing the ‘ecological character’ of a Ramsar site is a fundamental management tool for signatories and local site managers which should form the baseline or benchmark for management planning and action, including site monitoring to detect any change in ecological character.

The Ramsar Convention has defined “ecological character” and “change in ecological character” as (Ramsar 2005):

“Ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time”

and

“…change in ecological character is the human induced adverse alteration of any ecosystem component, process and or ecosystem benefit/service.”

In order to detect change it is necessary to establish a benchmark for management and planning purposes. An ECD forms the foundation on which a site management plan and associated monitoring and evaluation activities are based. The legal framework for ensuring the ecological character of all Australian Ramsar sites is maintained is the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) (Figure 1). A Ramsar Information Sheet (RIS) is prepared at the time of designation. However the information in a RIS does not provide sufficient detail on the interactions between ecological components, processes and functions to constitute a comprehensive description of ecological character. To assist in the management of Ramsar sites in the face of insufficient detail, the Australian and state/territory governments have developed a *National Framework and Guidance for Describing the Ecological Character of Australia’s Ramsar Wetlands. Module 2 of Australian National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia* (DEWHA 2008).

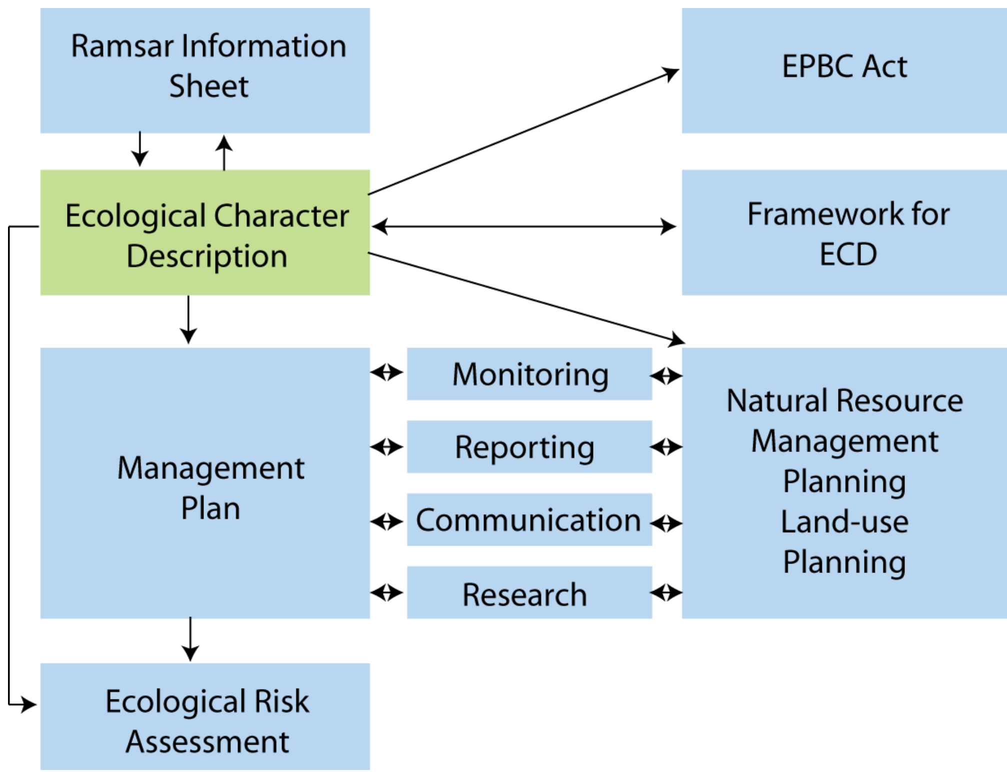


Figure 1: The ecological character description in the context of other requirements for the management of Ramsar sites (adapted from DEWHA 2008).

The framework emphasises the importance of describing and quantifying the ecosystem components, processes and benefits/services of the wetland and the relationship between them. It is also important that information is provided on the benchmarks or ecologically significant limits of acceptable change that would indicate the need for assessment to determine whether the ecological character has or is likely to change.

McGrath (2006) detailed the general aims of an ECD as follows:

1. To assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the *Environment Protection and Biodiversity Conservation Regulations* 2000 (Commonwealth):
   a) To describe and maintain the ecological character of declared Ramsar wetlands in Australia; and
   b) To formulate and implement planning that promotes:
      i) Conservation of the wetland; and
      ii) Wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.
2. To assist in fulfilling Australia's obligation under the Ramsar Convention to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has

changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.

3. To supplement the description of the ecological character contained in the RIS submitted under the Ramsar Convention for each listed wetland and, collectively, form an official record of the ecological character of the site.
4. To assist the administration of the EPBC Act, particularly:
   a) To determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act; or
   b) To assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.
5. To assist any person considering taking an action that may impact on a declared Ramsar wetland whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval.
6. To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

1.3 Relevant legislation

Effective management of the Piccaninnie Ponds Karst Wetlands requires the recognition and adoption of principles and actions identified in numerous pieces of international, national, state and regional agreements, legislation, NRM strategies and management plans.

1.3.1 International agreements

Ramsar convention

The *Convention on Wetlands of International Importance especially as Waterfowl Habitat*, otherwise known as the Ramsar Convention, was signed in Ramsar Iran in 1971 and came into force in 1975. It provides the framework for local, regional and national actions, and international cooperation, for the conservation and wise use of wetlands. Wetlands of International Importance are selected on the basis of their international significance in terms of ecology, botany, zoology, limnology and or hydrology.

Migratory bird agreements

Australia is also a signatory under the Convention on the Conservation of Migratory Species of Wild Animals (http://www.cms.int/pdf/convtxt/cms_convtxt_english.pdf) to a number of international agreements that seek to protect the habitat of migratory birds. These include:

- JAMBA - The Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment (1974) http://www.austlii.edu.au/au/other/dfat/treaties/1981/6.html ;
- CAMBA - The Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of

Migratory Birds and their Environment (1986) http://www.austlii.edu.au/au/other/dfat/treaties/1988/22.html ;
- ROKAMBA - The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment (2006); and
- Asia Pacific Migratory Waterbird Conservation Strategy 2001-2005.
- The Bonn Convention on Migratory Species - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

1.3.2 National legislation

Environment Protection and Biodiversity Conservation Act 1999 **(EPBC Act)**
The EPBC Act[1] regulates actions that will have or are likely to have a significant impact on any matter of national environmental significance, including actions that may affect the ecological character of a Ramsar wetland. The EPBC Act establishes a framework for managing Ramsar wetlands, through the Australian Ramsar Management Principles, which promote national standards of management, planning, environmental impact assessment, community involvement, and monitoring.

The EPBC Act is administered by the Australian Government Department of Sustainability, Environment, Water, Population and Communities. Some matters protected under the EPBC Act are not protected under local or state/territory legislation; for example, many migratory birds are not specifically protected under state legislation. All species listed under international treaties (Ramsar, JAMBA, CAMBA, ROKAMBA and CMS) are covered by the EPBC Act. Thus Ramsar listing of the Piccaninnie Ponds Karst Wetlands would confer additional protection to threatened species and communities under the EPBC Act.

Australian Heritage Council

The Australian Heritage Council was established under the Australian Heritage Council Act 2003 to advise the Australian Government on issues related to the protection of places of National and Commonwealth heritage. This role includes such activities as:

- Promotion of the identification, assessment, conservation and monitoring of heritage places;
- Inclusion or removal of a place on the National Heritage List or list of Overseas Places of Historic Significance to Australia; and
- Any other functions conferred on the Council by the EPBC Act.

Other important national strategies and legislation that confer protection of values associated with systems such as the Piccaninnie Ponds Karst Wetlands include (listed chronologically):

[1] The EPBC Act is accompanied by the EPBC Regulations 2000.

- National Framework for Management and Monitoring of Australia's Native Vegetation (2001) (http://www.environment.gov.au/land/publications/nvf/index.html);
- National Action Plan for Salinity & Water Quality (2000) (http://www.napswq.gov.au/publications/index.html)
- The National Strategy for the Conservation of Australia's Biological Diversity (1996) (http://www.environment.gov.au/biodiversity/publications/strategy/index.html)
- *The Native Title Act* (1993) (http://www.austlii.edu.au/au/legis/cth/consol_act/nta1993147/);
- The National Water Quality Management Strategy (1992) (http://www.environment.gov.au/water/quality/nwqms/)

1.3.3 State and regional legislation, strategies and plans

A significant body of state and regional legislation, NRM strategies and plans is relevant to or has the potential to affect the management of the Piccaninnie Ponds Karst Wetlands, including (listed chronologically):

- No Species Loss - A Nature Conservation Strategy for South Australia 2007-2017. State nature conservation strategy (2007)
- The Fisheries Management Act (2007) (http://www.austlii.edu.au/au/legis/sa/consol_act/fma2007193.txt)
- The South Australian State Natural Resources Management (NRM) Plan (2006) (http://www.nrm.sa.gov.au/SAStateNRMPlan/tabid/1356/Default.aspx)
- *Fire and Emergency Services Act* (2005) (http://www.austlii.edu.au/au/legis/sa/consol_act/faesa2005249.txt)
- The South East Natural Resources Management Plan (2004)
- *The Natural Resources Management Act (*2004) (http://www.nrm.sa.gov.au/TopNav/NRMLegislation.aspx)
- The Wetlands Strategy for South Australia (DEH & DWLBC 2003)
- NatureLinks : Implementing the WildCountry philosophy in South Australia (2002) (http://www.environment.sa.gov.au/naturelinks/)
- Petroleum Act (2000) (http://www.austlii.edu.au/au/legis/sa/consol_act/pa2000137.txt)
- Biodiversity Plan for the South East of South Australia (1999)
- *Local Government Act* (1999) (http://www.austlii.edu.au/au/legis/sa/consol_act/lga1999182.txt)
- *The Environment Protection Act* (1993) (http://www.austlii.edu.au/au/legis/sa/consol_act/epa1993284.txt)
- *The Development Act* (1993) (http://www.austlii.edu.au/au/legis/sa/consol_act/da1993141.txt)
- *The South Eastern Water Conservation and Drainage Act* (1992) (http://www.austlii.edu.au/au/legis/sa/consol_act/sewcada1992446/)
- *The Native Vegetation Act* (1991) (http://www.legislation.sa.gov.au/LZ/C/A/NATIVE%20VEGETATION%20ACT%201991.aspx)
- *The Aboriginal Heritage Act* (1988) (http://www.austlii.edu.au/au/legis/sa/consol_act/aha1988164.txt)

- *The Coast Protection Act* (1972) (http://www.austlii.edu.au/au/legis/sa/consol_act/cpa1972199.txt)
- *National Parks and Wildlife Act* (1972) http://www.austlii.edu.au/au/legis/sa/consol_act/npawa1972247/)
- *The Mining Act* (1971) (http://www.austlii.edu.au/au/legis/sa/consol_act/ma197181.txt)
- *Road Traffic Act* (1961) (http://www.legislation.sa.gov.au/LZ/C/A/ROAD%20TRAFFIC%20ACT%201961.aspx)

Important regional planning relevant to the Ramsar listing of the Piccaninnie Ponds Karst Wetlands includes the development and finalisation of water sharing plans. The system is in the area covered by the Comaum-Caroline water allocation plan (WAP) (SECWMB 2001), which is being revised, in 2012, and combined with the WAPs for Lacepede-Kongorong and Naracoorte Ranges into a single new WAP for the Lower Limestone Coast Prescribed Wells Area. Under the Draft Lower Limestone Coast WAP the site is recognised as a High Value groundwater dependent ecosystem and this will allow controls to be placed on water affecting activities within a prescribed zone around the site.

1.4 Preparing the ECD

The method used to develop the ecological character description for the Piccaninnie Ponds Karst Wetlands follows the twelve-step approach of the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008).

This ECD was developed primarily through a desktop assessment and is based on existing data and information. Although a series of visits to the site were undertaken, no new data was collected. A number of technical experts and stakeholder advisory groups were formed to provide input and comment on the ECD. Details of members of each of these and meetings held are provided in Appendix A.

1. Introduction to the description
Site details, purpose of the description, relevant legislation

2. Describe the site
Site location, climate, maps and images, tenure, criteria and wetland types

3. Identify and describe the critical components, processes, benefits and services
3.1 Identify all possible components, processes, benefits and services
3.2 Identify the critical components, processes benefits and services responsible for determining the ecological character of the site
3.3 Describe each of the critical components, processes, benefits & services

4. Develop a conceptual model of the wetland
Depict the critical components & processes of the wetland and their interactions

5. Set limits of acceptable change (LAC)
Determine LAC for critical components, processes and services

6. Identify threats to the ecological character of the site
Identify the actual or likely threats to the site

7. Describe changes to ecological character
Describe changes to the ecological character since the time of listing
Include information on the current condition of the site

8. Summarise knowledge gaps
Use information from Steps 3 - 7 to identify knowledge gaps

9. Identify site monitoring needs
Use information from Steps 3 - 8 to identify monitoring needs

10. Identify communication and education messages
Identify any communication & education messages highlighted during the development process

11. Compile the description of ecological character

12. Prepare or update the Ramsar Information Sheet
Submit as a companion document to the ecological character description

Figure 2: Twelve step process for developing an ECD (adapted from DEWHA 2008).

2 General description of the Piccaninnie Ponds Karst Wetlands

2.1 Location

The Piccaninnie Ponds Karst Wetlands are located in the South East of South Australia (Figure 3), approximately 30 kilometres south east of Mt Gambier within the South-East Coast Drainage Division. Encompassing an area of approximately 862 hectares, the system is an important remnant of an extensive system of wetlands that were once hydrologically connected to the Glenelg River Estuary via Freshwater Creek (Figure 4). The site is encompassed within the Piccaninnie Ponds Conservation Park.

The South East of South Australia is characterised as a broad coastal plain of Tertiary and Quaternary sediments with a regular series of calcareous sand ridges separated by inter dune swales, closed limestone depressions and young volcanoes at Mount Gambier. Dominant vegetation types include heathy woodlands, mallee shrublands and wet heaths in the inter dune swales. The region has relatively few major rivers and streams due to its unique geology, however there were extensive wetland areas much of which has been drained for agriculture and grazing. The only major river close to the site is the Glenelg River. There are seven wetlands of national importance in the South East of South Australia. These include inland freshwater systems such as Bool and Hacks Lagoon (Ramsar site), Deadman's Swamp, and Lake Frome; Butchers and Salt Lakes which are significant coastal salt lakes and Ewen Ponds, another karst system renowned for diving and snorkelling (Australian Natural Resources Atlas 2008).

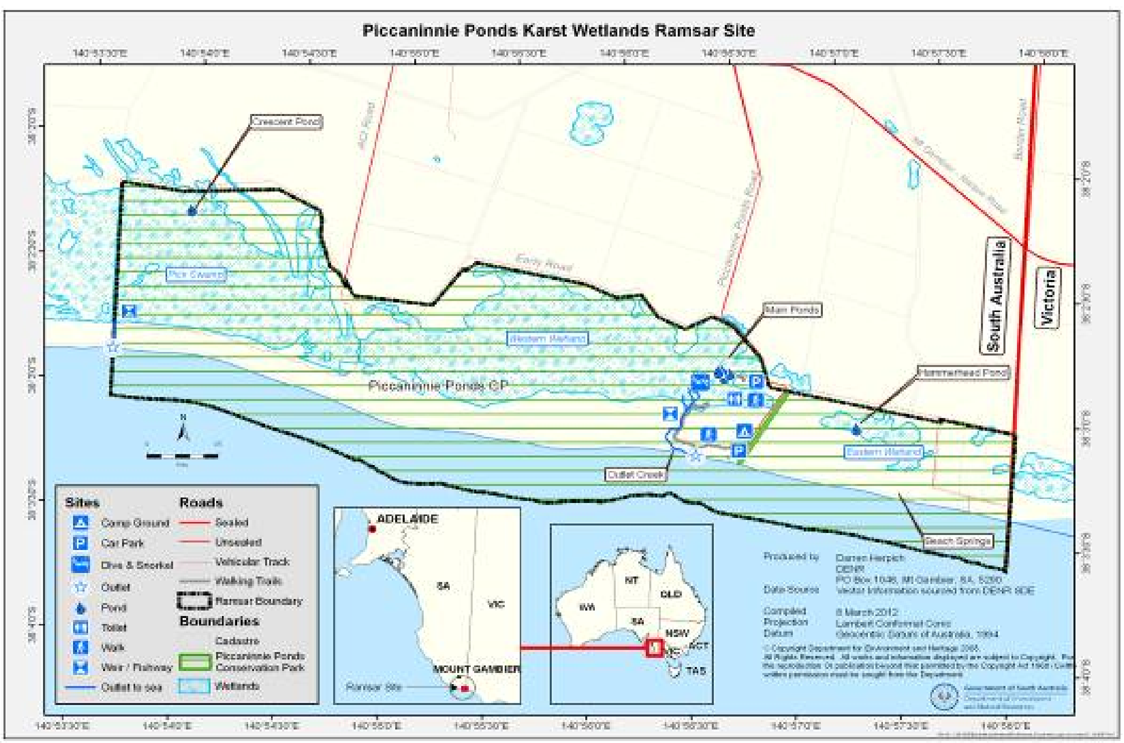


Figure 3: Site map of the Piccaninnie Ponds Karst Wetlands.

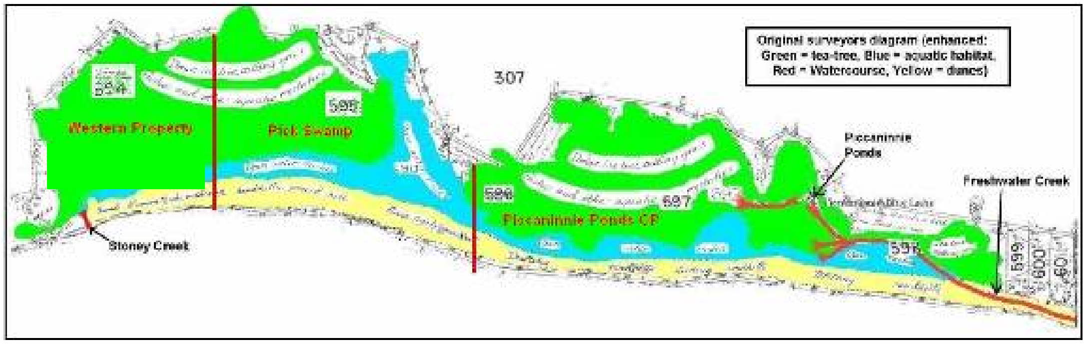


Figure 4: The 1896 surveyors map showing the approximate positions of today's property boundaries

Note that the area labelled as section 594 that has the Stoney Creek outlet is not part of the Ramsar site and that the Piccaninnie Grasslands are not labelled.

The Ramsar site includes the Piccaninnie Ponds Conservation Park which adjoins the Victorian South Australia border. The original Conservation Park was gazetted in 1976 and listed as a wetland of national importance in 1995. There are four main wetland areas within the site (Figure 5). The Piccaninnie Ponds Karst Wetlands comprises of four distinct areas:

1. Piccaninnie Main Ponds, which consists of three connected waterbodies: First Pond (10 metres deep), the Chasm (> 90 metres deep) and Turtle Pond (six metres deep). Surrounding these spring fed ponds is an area of shrub dominated swamp.
2. Western wetland lies to the west of the Piccaninnie Ponds and consists of dense closed tea-tree and paperbark shrubland over shallow dark clay on limestone soils.
3. Eastern wetland lies to the east of the Piccaninnie Ponds and includes the spring-fed Hammerhead Pond (four metres deep).
4. Pick Swamp, which lies to the extreme west of the site and includes areas of fen, marshes and sedgelands as well as the spring fed Crescent Pond (86 metres deep) on peat soils.

The site boundary matches the conservation park boundary and extends to include the adjoining beach areas to the average low tide mark.

Figure 5: Main wetland areas within the Piccaninnie Ponds Karst Wetlands.

Figure 6: Piccaninnie Ponds, First Pond (S. Clarke, DEWNR).

The Piccaninnie Ponds Karst Wetlands receives the majority of its water via an unconfined regional aquifer. Water from the extensive south east coastal plains seeps into this aquifer, and then moves underground through the Gambier Limestone in a south to south easterly direction towards the coast where it discharges throughout the zone between Port MacDonnell and the Glenelg River.

Swamps and lagoons occur in those areas where the water table intersects the surface (Department for Environment and Planning 1992). In the case of the Karst wetlands, groundwater is forced under pressure to discharge at the surface, through the ponds, where it spreads out across the land surface supporting large areas of wetland. Water is prevented from discharging to the sea by a barrier of coastal dunes, unless these are artificially or naturally breached.

2.2 Historical setting

Prior to European settlement this wetland system extended from Green Point in the west to the mouth of the Glenelg River. It supported large areas of open water, reed beds, a mobile coastal dune system, grassy open woodlands and dense thickets of Tree Everlasting (*Ozothamnus ferrugineus*), Tall Saw-sedge (*Gahnia clarkei*) and Silky Tea Tree (*Leptospermum lanigerum*). Historically the system discharged at the Glenelg River via Freshwater Creek (Figure 4). Drainage undertaken to facilitate grazing significantly reduced the extent of the wetland system. Only the area encompassed within the areas mapped as the Eastern and Western wetlands (Figure 5) remained relatively intact as a legacy of the volumes of water discharged by the Piccaninnie ponds, which resisted all attempts at drainage. Crescent Pond and a series of smaller spring outflows remained as isolated karst wetlands within a largely cleared landscape (Bachmann 2002).

In the late 1970s the habitat of Pick Swamp was still virtually contiguous with that of the Piccaninnie Ponds Conservation Park to the east. However, over the subsequent 25 years, clearance and continued drainage left the remaining wetland habitat highly isolated and vulnerable to edge effects and degradation caused by cattle grazing (Bachmann 2002).

However, despite the loss of habitat this wetland system remains the most extensive example of karst wetlands in South Australia, providing habitat for at least seven nationally threatened species, and at least 49 species of state significance. The Piccaninnie Ponds Conservation Park is listed as a wetland of national importance, and is situated within one of 15 national biodiversity 'hotspots', listed by the Australian Government in October 2003.

The Australian Government defines biodiversity hotspots as areas that support natural ecosystems that are largely intact and where native species and communities associated with these ecosystems are well represented. They are also areas with a high diversity of locally endemic species, which are species that are not found or are rarely found outside the hotspot (http://www.environment.gov.au). The remnant vegetation associations present at this site are significant as they include the largest remnant of 'coastal peat fen' in South Australia (Figure 7).

Figure 7: Fen wetland habitat at Pick Swamp. Foreground herbs and grasses: background Crescent Pond with Silky Tea Tree (*Leptospermum lanigerum*) (S. Clarke, DEWNR).

Since 2009 the South Australian Department of Environment, Water and Natural Resources has been undertaking a project aimed at restoring the extent of the Piccaninnie Ponds Karst Wetlands. This has included acquiring Pick Swamp and restoring its natural hydrological connection to the rest of the Piccaninnie Ponds Karst Wetlands, completed in 2010. Landuse within the Piccaninnie Ponds Karst Wetlands includes recreational use, with 20 000 visitors to the site annually. Cave diving is a key attraction with approximately 1500 visitors going snorkelling and or diving annually. Surrounding landuse is predominantly grazing.

2.3 Land tenure

The site comprises the entirety of the Piccaninnie Ponds Conservation Park. The initial gazettal included Sections 598 and 692 (Hundreds of Caroline) declared as Conservation park and named Piccaninnie Ponds Conservation Park, under the National Parks Act 1966 in Gazette 16/10/1969 and covered 397 hectares. Two reserve additions were made on 26/11/2010 expanding the Conservation Park. The additions included the 'Lapatha" Property (Piccaninnie Grasslands) in the north-eastern corner of the site, and Pick Swamp property on the western boundary of the site. The site now covers 862 hectares, consisting of Parcels 598, 692, 694, 695, and Allotments 1, 2, 50, 51, 52, 100, 101 and 102 in the Hundred of Caroline, County of Grey. The crown land is managed by the South Australian Government as a Conservation Park, constituted under the *National Parks and Wildlife Act 1972* (South Australia).

The original Piccaninnie Ponds Conservation Park is listed as a site of national importance in the *Directory of Important Wetlands in Australia* (Environment 2001). The criteria for which the site was listed at the national level are:

- Criterion 1: it is a good example of a wetland type occurring within a biogeographic region in Australia.
- Criterion 5: The wetland supports native plants or animal taxa or communities which are considered endangered or vulnerable at the national level.
- Criterion 6: The wetland is of outstanding historical or cultural significance.

2.4 Wetland types

There are six natural and one artificial wetland type found within the Piccaninnie Ponds Karst Wetlands under the Ramsar Convention's wetland classification system (Table 2).

By combining the floristic vegetation association data mapped by Ecological Associates (2008) and soil types (see sections 3.3.3 and 3.2.3 respectively) an approximate map of the Ramsar wetland types has been produced (Figure 8). Vegetation associations mapped by Ecological Associates (2008) have been used to estimate extent of each wetland type (see Appendix F) and are summarised in Table 2.

The wetlands can be grouped into the following broad categories:

- **Organic soil wetlands**, including peat fens, are the dominant type of wetlands in terms of areal extent and include the grassy fens and shrub swamps surrounding the main karst wetlands. This incorporates most of the Eastern and Western wetlands, and the grassy fen areas of Pick Swamp. The Ramsar type Tp has been assigned to this soil type despite the Ramsar description being on 'inorganic soils'. These wetlands occur on soils mapped as shallow dark clay loam on limestone (see section 3.2.3).

- **Inorganic soil wetlands** occur in a number of small areas and include the temporary sedge / grassy meadow near Piccaninnie Grassland and the wetlands at the bases of the dune system.

- **Karst and other subterranean hydrological systems** include the main Piccaninnie Ponds, Crescent Pond and Hammerhead Pond. Also in this category are the beach freshwater springs which are groundwater expressions.

- **Marine/coastal wetlands** include the beach area of the nominated site.

Table 2: Approximate area of Ramsar wetland types (based on combined area of floral associations as per Ecological Associates 2008 for each Ramsar wetland type – figures are rounded. See Appendix F).

Ramsar wetland type	Area (hectares) as of 2008
Inland	
Tp: Permanent freshwater marshes/pools; ponds, marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.	39
Ts: Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.	9
U: Non-forested peatlands; includes shrub or open bogs, swamps, fens.	86
W: Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.	167
Zk(b): Karst and other subterranean hydrological systems, inland	1
Marine	
E: Sand, shingle or pebble shorelines; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.	n/a
Artificial	
9: Canals and drainage channels, ditches (referred to hereafter as drains).	n/a

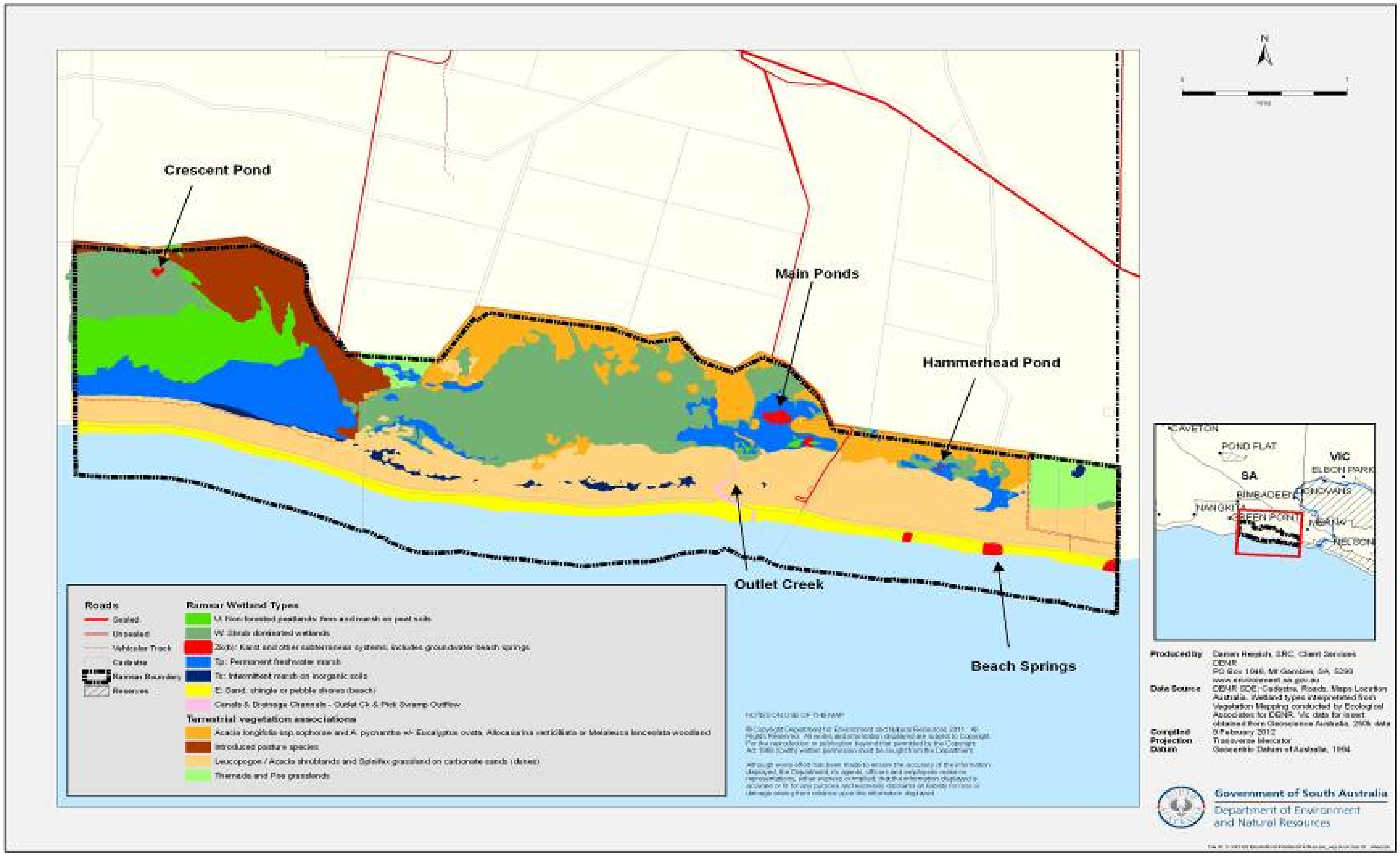


Figure 8: Ramsar wetland types for Piccaninnie Ponds Karst Wetlands.

2.4.1 Karst and other subterranean hydrological systems, Ramsar type Zk(b)

This wetland type is represented by the Piccaninnie Ponds (see Figure 6 above and Figure 9), Hammerhead Pond (Figure 10), Crescent Pond (Figure 11), a number of smaller unnamed springs and the beach springs (Figure 12). Whilst only representing a small surface area of the site this suite of karst systems is the central feature of the ecological character of the site. The continual discharge of groundwater has led to the formation of a very diverse range of vegetation associations including the formation of substantial areas of fen peatlands.

Figure 9: Piccaninnie Pond, First Pond, Ramsar type Zk(b) (2008, P. Cottingham).

Figure 10: Hammerhead Pond showing mixed sedgeland of *Typha, Baumea,* and *Triglochin* (foreground), Ramsar type Zk(b) (image supplied DEWNR).

Figure 11: Crescent Pond, Ramsar type Zk(b) (image from DEWNR).

Groundwater discharge at the beach springs causes localised changes to the water quality and also the beach substrate. At low tide the immediate area of the springs is less compacted compared to the surrounding sands, with the water bubbling up and forming slurries and constant motion of the sands. This creates craters in the beach which are quite obvious at the Piccaninnie beach reaching up to four metres in some cases (Fairweather *et al* . 2011).

Figure 12: Freshwater beach spring, Ramsar wetland type Zk(b) (2008, R. Butcher).

2.4.2 Non-forested peatlands; includes shrub or open bogs, swamps, and fens, Ramsar type U

Peat formation is significant at this site producing substantial areas of fen peatlands. Most of Pick Swamp (Figure 13 and Figure 14) is fen wetland with some areas which were previously drained and grazed being actively rehabilitated. These wetlands occur on peat soils and support a diverse array of vegetation associations. Depth of water varies across Pick Swamp and this is reflected in the variety of vegetation associations present (see section 3. 3.3).

Figure 13: Fen wetland, Ramsar type U, Pick Swamp 2008. Foreground is introduced pasture (P. Cottingham).

Figure 14: Fen wetland, Ramsar type U, Pick Swamp 2008 (R. Butcher).

2.4.3 Shrub dominated wetlands, Ramsar type W

Significant areas of the Western and Eastern wetlands and the area surrounding Crescent Pond have been assigned as shrub dominated wetlands Ramsar type W (Figure 15). The decision to assign these areas to this wetland type is based on the dominance of the shrubland, the fact that the areas have both permanent and intermittent water regimes, as well a different soil base to the peat area of Pick Swamp (except Crescent Pond - see section 3.2.3).

The Ramsar description for this type has it occurring on inorganic soils, whereas the area of concern within the site has definite areas of surface peat. The available soils mapping distinguishes between the peat soil of Pick Swamp which supports herb dominated fens and the shallow loam clay over limestone soils in the Western and Eastern wetlandswhich supports the shrublands. The presence of a dense shrubland is a distinctive feature, as is the spatially variable water regime, however it could be argued that the some areas of the shrub dominant wetlands occur on peat soils (for example the shrublands surrounding Crescent Pond) and should be classified as Ramsar type U – non forested peatlands. In the absence of fine scale mapping of soils and water regimes across this wetland type the variable water regime and dominant vegetation type have been used to assign a type. Improved mapping of soils and water regimes may assign parts of this wetland type to non-forested peatlands (Ramsar type U).

Figure 15: Shrub dominated wetland, Ramsar type W, along boardwalk to Outlet Creek, Western wetland (2008, P. Cottingham).

2.4.4 Permanent freshwater marshes/pools; ponds, marshes and swamps on inorganic soils; with emergent vegetation, Ramsar type Tp

These wetlands are groundwater fed and predominantly occur in the areas surrounding the discharge points associated with the karst wetlands (Figure 16). They are dominated by emergent and submergent species including *Typha*, *Triglochin*, sedges and grasses. They are heavily vegetated with only small areas of open water. The Ramsar classification describes this type of wetland as occurring on inorganic soils, however at Piccaninnie Ponds Karst Wetlands these wetlands are mainly found on shallow dark clay loam on limestone and can include surface peat.

Figure 16: Typha dominated marsh to the east of Main Ponds, Ramsar type Tp (2008, P. Cottingham).

2.4.5 Intermittent marshes on inorganic soils, Ramsar type Ts

This wetland type is represented by a few small areas along the base of the dune system and also in the eastern part of the site in the area referred to as Piccaninnie Grasslands (Figure 17).

Figure 17: Dry intermittent sedge/grassland marsh 'Piccaninnie Grasslands', Ramsar wetland type Ts (2008, R. Butcher).

2.4.6 Drains, Ramsar type 9

There are a number of drains throughout the site, most notably Outlet Creek (also known as Ellards Creek), but there are also a number in Pick Swamp (Figure 18). Many of the drains have been decommissioned with the return of more natural hydrological regime to the site. Outlet Creek is a significant outlet for the site as it maintains a connection to the Southern Ocean (Figure 19), an important feature for maintaining the native fish populations.

Figure 18: Drain along western boundary of Pick Swamp, 2008, Ramsar type 9 (R.Butcher).

Figure 19: Mouth of Outlet creek, Ramsar wetland type 9 (2008, R. Butcher).

2.4.7 Sand, shingle or pebble shores, Ramsar type E

The beach running along the southern edge of the site is included within the site. The sandy shoreline (Figure 20) is dotted with groundwater beach springs to the east of Outlet Creek. This area of the site supports a range of shorebirds which may be attracted by the presence of freshwater both in Outlet Creek and from the beach springs.

Figure 20: Beach within Piccaninnie Ponds Karst Wetlands, Ramsar type E (R. Butcher).

2.5 Ramsar criteria

The Ramsar criteria (Ramsar Convention 2009) for identifying wetlands of international importance are shown in Table 3.

Table 3: Criteria for identifying Wetlands of International Importance. Those criteria met by the Piccaninnie Karst Wetlands are highlighted.

Number	Basis	Description
Group A. Sites containing representative, rare or unique wetland types		
Criterion 1		A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Group B. Sites of international importance for conserving biological diversity		
Criterion 2	Species and ecological communities	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3	Species and ecological communities	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4	Species and ecological communities	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 5	Waterbirds	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion 6	Waterbirds	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
Criterion 7	Fish	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8	Fish	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
Criterion 9	Other taxa	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

An assessment against each of the Ramsar criteria for the Piccaninnie Ponds Karst Wetlands is shown below. During the development of the ecological character description a series of stakeholder meetings was held to help identify the values of the site. Part of this process included engaging local Indigenous people representing the Boandik people of South East Australia, the Traditional Owners of the site. A summary of the discussions with local Indigenous people is presented in Appendix B and highlights the historic and cultural value of the site.

Criterion 1: ***A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region*.**

The site represents an excellent example of rare wetland types within the South East Coast Drainage Division. The *Strategic Framework for the List of Wetlands of International Importance* (Ramsar Convention 2009) provides guidance for applying Ramsar criteria for identifying and designating specific wetland types such as karst and other subterranean hydrological systems as well as for peatlands.

Karst and other subterranean hydrological systems are considered unique for their hydrological importance as they often supply water for major surface wetlands and have the following principal wetland conservation values (Ramsar Convention 2009):

- Uniqueness of karst phenomena/functions and functioning;
- Inter-dependency and fragility of karst systems and their hydrological and hydrogeological characteristics;
- Uniqueness of these ecosystems and endemism of their species; and
- Importance for conserving particular taxa of fauna and flora.

Karst and other subterranean hydrological systems are also acknowledged as having high socio-economical values (Ramsar Convention 2009). Piccaninnie Ponds Karst Wetlands is internationally renowned as an exceptional cave diving site.

Peatland wetlands, including fens, are considered amongst the most vulnerable and threatened wetland types being highly susceptible to habitat loss and degradation (Ramsar Convention 2009).

Piccaninnie Ponds is one of only two karst wetlands afforded legal protection in the south east of South Australia (*National Parks and Wildlife Act* (1972)). In addition the site contains the largest remnant of coast peat fen in a karstic landscape in South Australia, the only representative of this wetland type within the South Australian reserve system (ANCA 1996). The combination of the subterranean karst wetland (Ramsar wetland type Zk(b)) and surface fen formation (Ramsar wetland type U) is notably different to other significant fen wetlands found elsewhere in the Australia reserve system, such as on Fraser Island.

In addition to the inland karst features of the site (Piccaninnie Ponds, Crescent Pond and Hammerhead Pond) and fen wetland (Pick Swamp) there are a series of beach groundwater springs along the eastern foreshore area of the site. Beach springs are poorly documented in Australia, but recent work by Fairweather *et al*. (2011) has shown that the springs located within the site are amongst the most permanent and accessible of 12 springs studied along a 210 kilometre stretch of the South Australian coastline. The beach springs are typically located in the intertidal zone of the beach and can range in size from 20 centimetres up to four metre wide craters produced from the continual flow of groundwater.

The hydrological and geomorphic combination of karst wetland, fen wetland and beach springs, all in very good condition, makes this site truly unique at the bioregion, if not national scale, thus clearly meeting this criterion.

Criterion 2: *A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.*

In the Australian context, it is recommended that this criterion should only be applied with respect to nationally threatened wetland dependent species/communities, listed under the EPBC Act or the International Union for Conservation of Nature (IUCN 2011) red list. Guidance from Ramsar (Ramsar 2005) in applying the criteria indicates that the wetland must provide habitat for the species concerned. The nationally and globally listed wetland dependent species which Piccaninnie Ponds Karst Wetlands support are shown in Table 4.

Table 4: Wetland dependent species listed under EPBC Act and IUCN (2011) red list which occur within the Piccaninnie Ponds Karst Wetlands.

Common name	Scientific name	Status
Orange-bellied parrot	*Neophema chrysogaster*	Critically endangered (IUCN & EPBC)
Australasian bittern	*Botaurus poiciloptilus*	Endangered (IUCN & EPBC)
Maroon leek-orchid	*Prasophyllum frenchii*	Endangered (EPBC)
Swamp greenhood	*Pterostylis tenuissima*	Vulnerable (EPBC)
Yarra pygmy perch	*Nannoperca obscura*	Vulnerable (IUCN & EPBC)
Dwarf galaxias	*Galaxiella pusilla*	Vulnerable (IUCN & EPBC)
Glenelg spiny freshwater crayfish	*Euastacus bispinosus*	Vulnerable (IUCN) and Endangered (EPBC)

The Australasian bittern (*Botaurus poiciloptilus*) is considered a resident at the site with regular sightings, including during the breeding season (October to January), of two pairs of birds (M. Christie, Friends of Shorebirds, pers. comm. 2007). It is believed that the species breeds at the site, and that the sightings of three or four birds may represent a breeding pair and their young (S. Clarke, DEWNR, pers. comm. 2011). The orange-bellied parrot (*Neophema chrysogaster*) regularly uses the site on its annual migration into South Australia. It is likely that Piccaninnie Ponds Karst Wetlands is a key habitat for both feeding and roosting.

The nationally endangered maroon leek-orchid (*Prasophyllum frenchii*) is found within the site occurring on seasonally inundated grassy sedgelands and is part of one of only 12 populations remaining in the wild. This species occurs in permanent swamps and meadows in south east South Australia into

Victoria. The population at Piccaninnie Ponds Karst Wetlands is part of the only known population in the Lower South East of South Australia. Whilst the plant occurs within the site, the largest part of this population is found immediately adjacent to the boundary. The population of swamp greenhood (*Pterostylis tenuissima*) which occurs within the site is the largest known population across its entire range. Data on the listed fish species found within the site are limited, but it regularly supports both the Yarra pygmy perch and dwarf galaxias (*Galaxiella pusilla*).

The Glenelg spiny freshwater crayfish (*Euastacus bispinosus*) was recorded in the site in 2009, however the size of the population within the site is not known. On 15 February 2011this species was listed as endangered under the EPBC Act. *Euastacus* crayfish are endemic to south-eastern Australia, and are characteristic of the region's aquatic fauna (TSSC 2011b).

Based on the regular occurrence of these seven listed species the site meets criterion 2.

Criterion 3: ***A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.***

Guidance from the Ramsar Convention (Ramsar Convention 2009) indicates that the application of this criterion should consider endemism and "hot-spots" of biodiversity at the bioregional scale. The site represents a unique wetland complex which provides habitat for an extensive and diverse assemblage of endangered, rare and non-threatened flora and fauna which are highly representative of pre-European biodiversity typical of the Lower Limestone Coast region of South Australia.

As established under criterion one, the karst wetland system which supports this biodiversity is rare within the bioregion and the drainage division and Piccaninnie Ponds Karst Wetlands represent the most intact example of a karst rising spring with associated wetland habitat remaining. As one of the few truly permanent freshwater wetlands in the South East Coast Drainage division, in excellent condition, the site is a significant refuge site for migratory and nomadic bird species but also a strong hold for resident aquatic species. The site falls within a national biodiversity 'hotspot' (see http://www.environment.gov.au/biodiversity/hotspots/national-hotspots.html) and the data in hand suggests this is an incredibly species-rich site. Listed species and ecological communities of conservation significance found within the Piccaninnie Ponds Karst Wetlands are presented in Appendix C –E.

The biota of the subterranean areas of karst wetlands often contain endemic and rare species. Surveys of the stygofauna of the karst system has indicated the site supports a range of undescribed species that vary from nearby populations (Leijs and Mitchell 2008), i.e. are endemic to the site having developed in isolation. Based on the available data, it is reasonable to expect that the fauna of the karst wetlands are a unique element of the regional biodiversity. Meiofauna associated with the beach springs are also likely to contribute to the unique suite of biota found at this site.

The site supports 10 of the 21 species of native freshwater fishes recorded in the South East Coast Drainage Division (47% of the freshwater fish diversity) making it hotspot for fish conservation within the drainage division (Hammer *et al*, 2007). This includes species with three different migration strategies (Hammer 2002; Hammer 2008a), a result of the unique conditions at the site including the freshwater connection to the ocean. Additionally, the site is one of the few catchments in the South East that is free of invasive pest fish species, and this enhances the value of the site for fish conservation considerably. The mosaic of wetland type and vegetation associations provide a heterogeneous environment which favours fish species which prefer well vegetated habitat, proximity to the coast and permanent water as refuge areas. Hammer (2002) describes this site as “spectacular” in “excellent condition” and a biodiversity hotspot for native fish.

For its size (862 hectares) the site supports considerable waterbird species richness compared to larger wetlands within the Lower South East region. Piccaninnie Ponds Karst Wetlands supports 79 waterbirds species with 24 migratory species compared to 66 waterbird and six migratory at Lake Frome Conservation Park (greater than 1000 hectares) (DEH 2003), and 79 waterbird and 22 migratory species at Bool and Hacks Lagoons Ramsar site (greater than 3000 hectares) (DEH 2006). Bird survey effort is concentrated with intensive survey monthly survey carried out since 2007. The species richness of all birds recorded at the site has increased as the restoration of Pick swamp has progressed with an increase from a total number of 61 species recorded in 2007 to 142 species in early 2012(Birds South East 2011). The presence of permanent fresh water at the site, when other parts of South Eastern Australia are experiencing drought, means that the site is significant refuge habitat for waterbirds.

Floristic mapping of the Piccaninnie Ponds Karst Wetlands recorded 30 floristic associations (Ecological Associates 2008) (Appendix F). Of particular note, the site supports remnant examples of significant vegetation communities including mixed tea tree (*Leptospermum lanigerum*, *Melaleuca squarrosa* and *Ozothamnus ferruginous* over *Gahnia clarkei*) and large areas of coastal peat fen. Over 250 native species of plants had been identified at this site, including 63 wetland plant species (data from supplied by DEH and South Australian Herbarium).

According to the Action Plan for Australian Butterflies (Sands and New 2002) six species of butterflies recorded from the site are of conservation significance, with three of them reliant on wetland host plants. The only recorded South Australian population of the bright-eyed brown butterfly (*Heteronympha cordace wilsoni*) occurs at the site and is considered to be of critical conservation significance (Sands and New 2002). The preferred habitat of this species is *Carex* sedgelands/wetlands in areas of high rainfall (600 millimetres) (Haywood and Natt 2006). Two species of skippers found at the site rely on saw sedges (*Gahnia*) as their host plants; the rare flame sedge-skippers (*Hesperilla idothea*) and the sedge-skipper (*Hesperilla chrysotricha*). The sedge-skipper was considered vulnerable in South Australia by Grund

(2001 cited in Sands and New 2002) but is now considered at lower risk (Sands and New 2002).

Based on the available data the site meets this criterion.

Criterion 4: ***A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.***

For this criterion, critical sites are taken to be those which are used by mobile or migratory species and support particularly high proportions of populations at particular life stages. A site can also be considered critical for non-migratory wetland species if it sustains populations in unfavourable conditions, such as providing drought refuge.

Piccaninnie Ponds Karst Wetlands provides habitat for 24 migratory waterbird species listed under international agreements (CAMBA, JAMBA, ROKAMBA or CMS) and 50 migratory or marine species under the EPBC Act. Appendix E lists the migratory bird species which have been recorded at the site. Data on frequency of occurrence is not available as yet as limited survey work has been undertaken at the site, however most of the international migratory species recorded at the site do not appear to be vagrants or one off recordings.

The site is a known winter roosting and feeding location for the critically endangered orange-bellied parrot (*Neophema chrysogaster*). The orange-bellied parrot migrates annually from its breeding grounds in Tasmania into Victoria and South Australia. It is a critically endangered species under the EPBC Act with only an estimated 150 adults remaining in the wild (Commonwealth of Australia 2005). Records have shown that Piccaninnie Ponds Karst Wetlands regularly supports one percent (Figure 21) of its population as the species moves through its wintering grounds, and it is likely that the proportion of the population that migrates into South Australia all use the site as an important resting site.

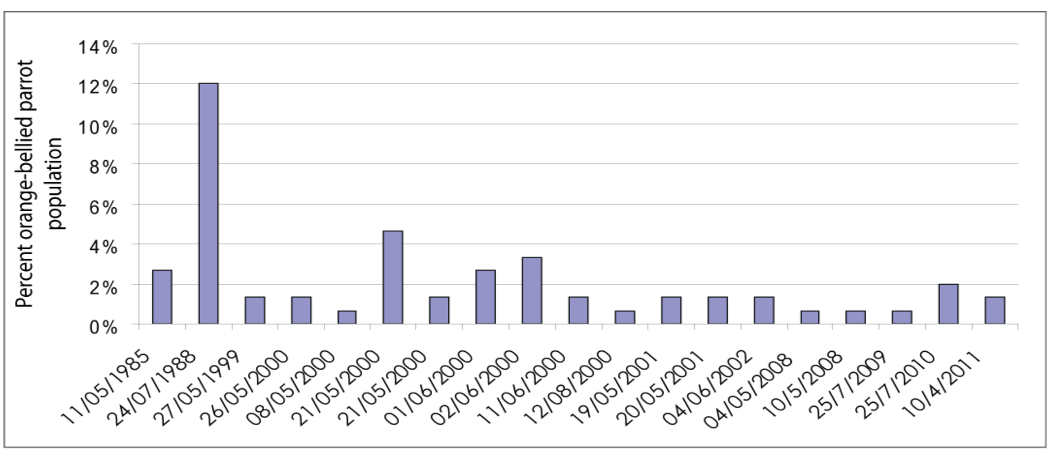


Figure 21: Percent of adult population for orange-bellied parrot recorded from Piccaninnie Ponds Karst Wetlands. Data supplied by Birds Australia July 2008 and B. Green, pers. comm. 2011. The highest record is presented for dates with multiple sightings. Uses 150 as adult population as per Commonwealth of Australia (2005).

Specific investigations into the site's importance as a drought refuge have not been undertaken, however the karst wetlands provide permanent freshwater habitat throughout the year and it has been observed that waterbird numbers increase markedly as other sites in South Eastern Australia dry out (for example during dry summer periods or extended drought). An indication of the importance of the site as providing refuge can be gauged by the number of significant species observed at the site over summer. Over summer the site has been observed to support significant migratory bird species such as Sanderling, Red necked Stint, Sharp-tailed sandpiper and Australiasian Bittern. Eleven species of waterbird have been recorded breeding at the site (Birds South East 2011).

The site is an important area for native freshwater fish, supporting 10 of the 21 species recorded for the drainage division, including the only regionally secure breeding populations of for the nationally listed Yarra pygmy perch (*Nannoperca obscura*) and Dwarf galaxias (*Galaxiella pusilla*) which are declining across other populations in the region.

The site is important for native freshwater fish species that require good quality freshwater wetland habitats with a connection to the sea to complete their lifecycles. Two catadromous species are recorded at the site. These live in freshwater systems but breed in the ocean, including the Short Finned Eel (*Anguilla australis australis*) which is a long lived species that migrates to the Coral sea to breed, with larval eels returning to the Piccaninnie Ponds Karst Wetlands as elvers to grow to adulthood (10 – 20 years) (Hammer *et al.* 2007). The Pouched lamprey (*Geotria australsi)* spawns at the site before migrating back to the sea, returning only to breed. Additionally three of the other species recorded at the site spend part of their life cycle in the sea and part in the freshwater wetland habitats of the site.

The importance of this site for supporting critical life stages of wetland dependent species including the orange-bellied parrot and a range of freshwater native fish species that complete critical life stages at the site is well documented. The site is also likely to be important for other less well documented migratory species.

Based on the unique range of habitats found at the site that support critical life stages for fish and bird species and its importance as drought refuge for migratory waterbirds in particular when much of the rest of South Eastern Australia is dry it is considered that the site meets this criterion.

Criterion 5: *A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.*

Whilst abundance data for waterbirds are limited for the site, it does not appear that the site regularly supports large aggregations of waterbirds.

The site does not meet this criterion.

Criterion 6: ***A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.***

This criterion is met if a site *regularly* supports one percent of the individuals of a population of waterbird. Regularly is defined as follows (Ramsar Convention 2009):

> **regularly** (Criteria 5 & 6) - as in supports regularly - a wetland regularly supports a population of a given size if:
>
> i) the requisite number of birds is known to have occurred in two thirds of the seasons for which adequate data are available, the total number of seasons being not less than three; or
>
> ii) the mean of the maxima of those seasons in which the site is internationally important, taken over at least five years, amounts to the required level (means based on three or four years may be quoted in provisional assessments only).
>
> In establishing long-term 'use' of a site by birds, natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus in some situations (e.g., sites of importance as drought or cold weather refuges or temporary wetlands in semi-arid or arid areas - which may be quite variable in extent between years), the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site. In these instances, a site may be of crucial importance at certain times ('ecological bottlenecks'), but hold lesser numbers at other times. In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.
>
> In some instances, however, for species occurring in very remote areas or which are particularly rare, or where there are particular constraints on national capacity to undertake surveys, areas may be considered suitable on the basis of fewer counts. For some countries or sites where there is very little information, single counts can help establish the relative importance of the site for a species.
>
> The International Waterbird Census data collated by Wetlands International is the key reference source.

The Friends of Shorebirds South East have three counts of sanderling (*Calidris alba*) from the beach area of the site which are above the one percent flyway population for this species (220 individuals). Counts of 1000 in 2005 and 400 and 2000 in 2006 were recorded (M. Christie, Friends of Shorebirds, pers. comm. 2007). Continued survey effort is required to confirm frequency of occurrence, and consistent use of the site. In the summer of 2009, 1200 birds were sighted at Greens Point, but not within the site. Local experts consider that when birds are present along the coastline that they would utilise the site, despite a lack of actual records from the site.

The site does not meet this criterion based on available data. However, this should be reassessed once additional data become available for sanderling.

Criterion 7: ***A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.***

Guidance from the Ramsar Convention (Ramsar Convention 2009) on the application of this criterion indicates that in order to meet this criterion, a site should have a high degree of endemism or biodisparity in fish communities. A site can potentially qualify based on the proportion of endemic fish species present (must be greater than 10 per cent) or by having a high degree of biodisparity in the fish community. This site does not have any species endemic to the site.

On this basis, the site does not meet this criterion.

Criterion 8: ***A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.***

Under the guidelines for this criterion coastal wetlands are identified as important as feeding and spawning grounds and nurseries, and as such support essential ecological processes for fish stocks, even if they do not necessarily harbour large adult fish populations themselves (Ramsar Convention 2009).

The Piccaninnie Ponds Karst Wetlands is an important location for sustaining populations, including spawning habitat, of Yarra pygmy perch (*Nannoperca obscura*) and dwarf galaxias (*Galaxiella pusilla*) in South Australia. Both of these species are listed as vulnerable under the EPBC Act.

Despite the relative isolation of the karst system, it supports species that spawn both within the freshwater wetlands as well as in the nearby marine environment including spotted galaxias (*Galaxias truttaceus*), climbing galaxias (*Galaxias brevipinnis*) and pouched lamprey (*Geotria australis*).

Spotted galaxias (*Galaxias truttaceus*) have only recently been found at the Piccaninnie Ponds Karst Wetlands. In South Australia this species was previously only found in the nearby Eight Mile Creek Drainage area. The Piccaninnie Ponds sighting represents the greatest numbers ever recorded in South Australia to date. This species is at the westerly limit of its range in south-eastern Australia.

This criterion is considered to be met.

Criterion 9: *A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.*

The application of this criterion relies on estimates of the total population of non-avian wetland dependent species, which for Piccaninnie Ponds Karst Wetlands would include invertebrates and amphibians. There is insufficient data on which to assess this criterion.

The site does not meet this criterion.

3 Ecosystem components and processes

3.1 Identifying critical components and processes

Ecological Character Descriptions identify, describe and where possible, quantify the critical components and processes of the site which determines its character and ultimately allow detection and monitoring of change in that character. These are the aspects of the ecology of the wetland, which, if they were to be significantly altered, would result in a significant change in the system.

DEWHA (2008) suggest the minimum components, processes, benefits and services, which should be included in an ECD are those:

- that are important determinants of the sites unique character;
- that are important for supporting the Ramsar or DIWA criteria under which the site was listed (or in this case nominated);
- for which change is reasonably likely to occur over short to medium time scales (<100 years); and/or
- that will cause significant negative consequences if change occurs.

The role that components and processes play in the provision of critical ecosystem services should also be considered in the selection of critical components and processes. The linkages between components, processes, benefits and services and the criteria under which the site was listed are illustrated conceptually in Figure 22. This simple conceptual model for the Piccaninnie Ponds Karst Wetlands site shows not only the components, processes and services that are critical to the ecological character of the site, but also the essential elements which are important in supporting the critical components, processes and services the site provides.

It is difficult to separate components (physical, chemical and biological parts) and processes (reactions and changes). For example, aspects of hydrology such as rainfall and water regime may be considered as components, while other aspects of hydrology such as groundwater flow and connectivity could be considered processes. Similarly the species composition of fish at a site may be considered a component, but breeding and migration are processes. In the context of this ECD a separation of the ecology of wetlands into nouns (components) and verbs (processes) is an artificial boundary and does not add clarity to the description. As such components and processes are largely considered together.

Each of the identified critical components and processes meet the four criteria provided by DEWHA (2008) in that they are central to the character of the site, are directly linked to the Ramsar criteria for which the site was listed, could potentially change in the next 100 years and for which change would result in negative consequences and a possible change in the ecological character of the site.

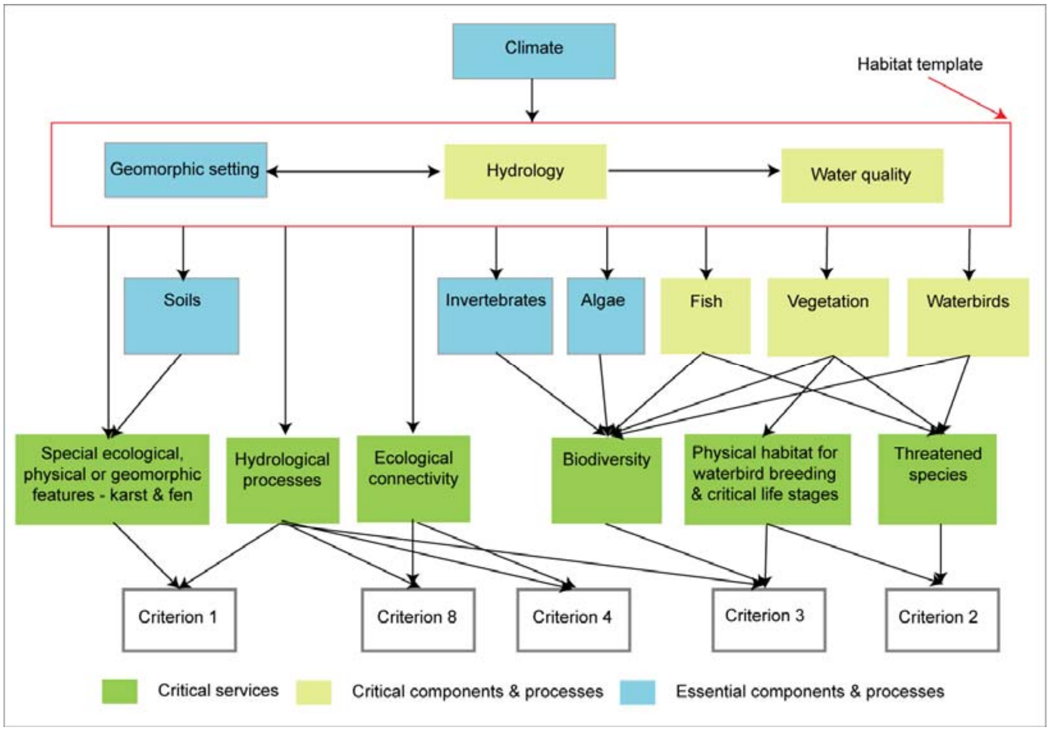


Figure 22: Simple conceptual model of critical and essential components, processes and services for Piccaninnie Ponds Karst Wetlands.

The critical components and processes for the Piccaninnie Ponds Karst Wetlands are:

- Hydrology;
- Water quality;
- Vegetation communities;
- Fish; and
- Waterbirds.

Several of the remaining components and process identified in Figure 22 are important in supporting the critical components and processes, benefits and services but are not considered critical in themselves for defining the ecological character of the site. Called essential elements, these have been identified as components which support the critical components, processes and services and are important in managing the site to maintain ecological character and some may provide early warning indicators of change. Section 3.2 provides a description of the essential elements that are important in supporting the ecological character of the site:

- Climate;
- Geomorphological setting;
- Soils;
- Algae; and
- Invertebrates.

3.2 Essential components and processes

The essential components and processes that are considered important in supporting the critical components, processes, and services of the Piccaninnie Ponds Karst Wetlands are described briefly below and summarised in Table 5. The attributes and characteristics of each of the essential components and processes of Piccaninnie Ponds Karst Wetlands are described below (section 3.2.1-3.2.5) with critical components and processes summarised in section 3.3. Ecosystem services are described in section 4.

Table 5: Summary of supporting components and processes within Piccaninnie Ponds Karst Wetlands.

Component / process	Description
Climate	Stable Mediterranean climate with warm dry summers and cool wet winters. Annual rainfall is approximately 700 millimetres per year with low interannual variation.
Geomorphic setting	One of two coastal karst regions in south east of South Australia. The formation of the karstic cavities allowed upwelling of groundwater which in turn supplies water to the surrounding wetlands. The site lies in a closed catchment with little sedimentation or erosion, with dissolution of the limestone the main geomorphic process. The main karst discharge points are Crescent Pond, Piccaninnie Ponds, Hammerhead Pond and several smaller springs. Piccaninnie Ponds is believed to have two discharge points. Fifteen beach springs have been identified along the foreshore of the site.
Soils	Six soils types are present within the site; however peat soils are a key feature of the site. Three types of peat have been identified within the immediate vicinity of the Main Ponds.
Algae	Phytoplankton growth is limited in the Main Ponds as the flushing rates and low phosphorous preclude establishment of phytoplankton communities. This in turn limits the establishment of zooplankton (Scholz 1987; Thurgate 1995). Macrophytes within the karst wetlands support significant amounts of periphyton which is believed to be important in the food webs of the karst wetlands. Epiphytic and benthic algae are distinctive features of the aquatic vegetation in the Main Ponds.
Invertebrates	Very limited data is available for the aquatic invertebrate communities of the Piccaninnie Ponds Karst Wetlands and this is considered a significant knowledge gap. Flushing rates in the Main Ponds may limit phytoplankton communities. Pick Swamp is known to support the endangered Glenelg spiny freshwater crayfish.

3.2.1 Climate

The regional climate is characterised as Mediterranean with warm, dry summers and cool, wet winters. Approximately 80 percent of the rain falls between May and October. The climate is relatively stable and relatively predictable with low inter-annual (between years) variation. The three aspects of climate that most directly affect wetland ecology are rainfall (both local and in the catchment), temperature and relative humidity as these all fundamentally affect wetland hydrology and the water budget.

Highest monthly average rainfall occurs in June, July and August (approximately 100 millimetres per month). Total annual rainfall is approximately 700 millimetres per year. The stability of rainfall is evidenced by the 10th and 90th percentiles, which range from 570 to 860 millimetres per annum (Figure 23).

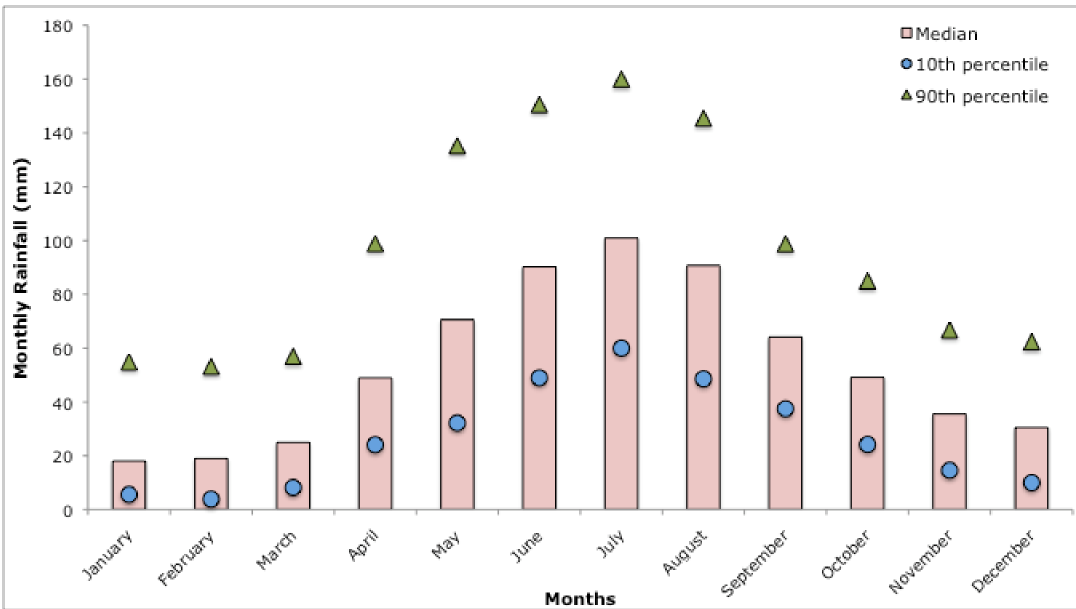


Figure 23: Average (10th and 90th percentile) monthly rainfall at Cape Northumberland (1884 – 2006; Bureau of meteorology 2007).

Temperatures are warm in summer, with maximum temperatures around 22 degrees Celsius and average minimum temperatures around 13 degrees Celsius. During winter, temperatures are cooler with maximum temperatures approximately 14 degrees Celsius and average minimum temperatures of approximately seven degrees Celsius (Figure 24).

Despite the mild temperatures and stable rainfall, annual evaporation (average of approximately 1300 millimetres) exceeds rainfall. However during the coolest and wettest months (May to August) rainfall exceeds evaporation (Figure 25).

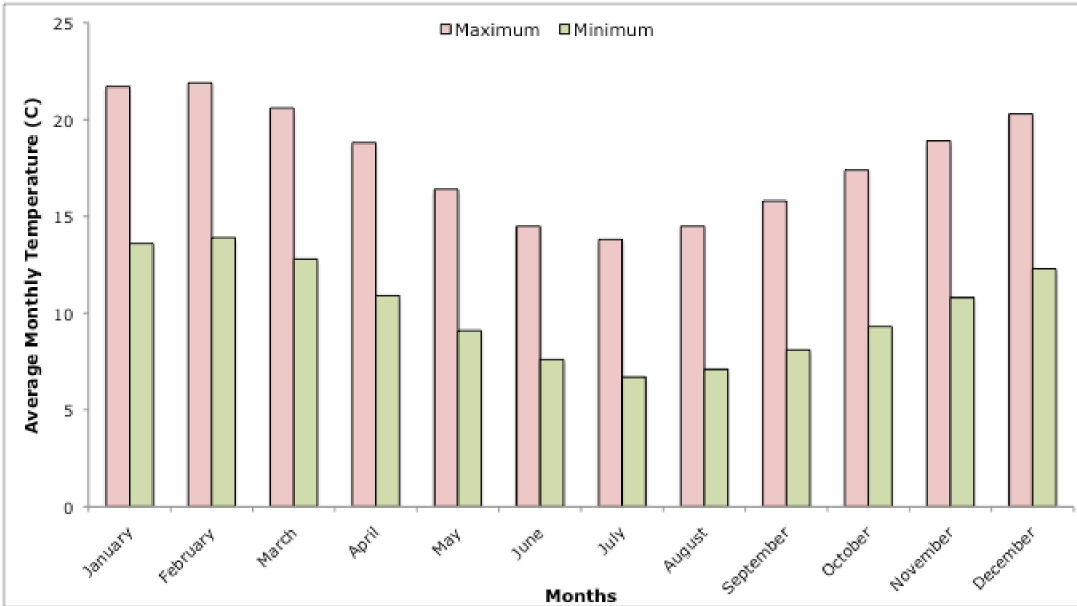


Figure 24: Average monthly minimum and maximum temperatures at Cape Northumberland (1884 – 2006; Bureau of meteorology 2007).

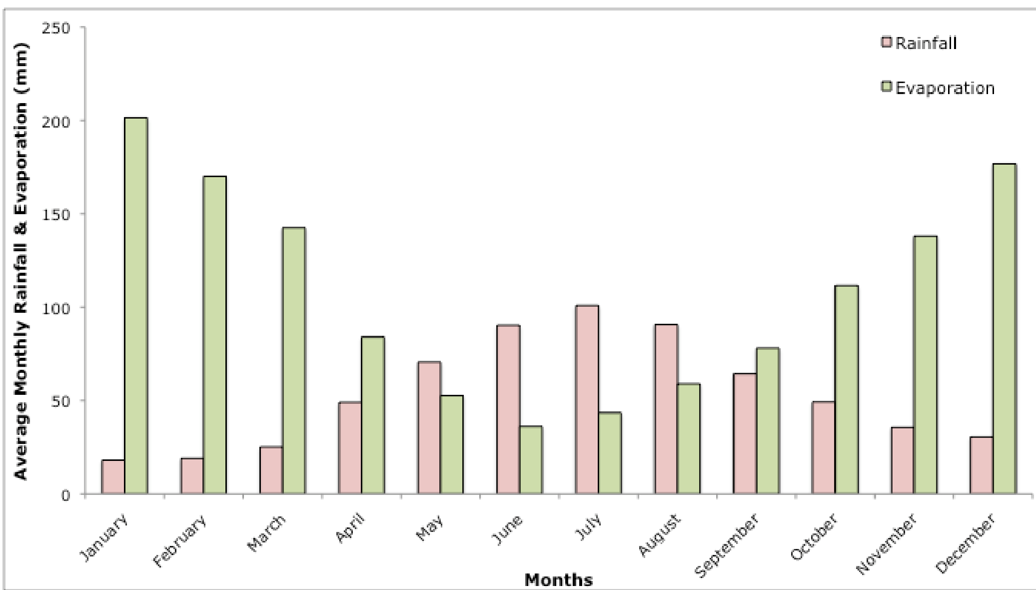


Figure 25: Average monthly rainfall and evaporation at the Mount Gambier Airport (1967 – 2006; Bureau of meteorology 2007).

3.2.2 Geomorphic setting

The Lower South East of South Australia surface geology is underlain mainly by a Tertiary marine limestone with a gentle relief and seaward gradient (Hallam and Thurgate 1992). The Lower South East lies in the Gambier Embayment, part of the Otway Sedimentary Basin which extends from the south eastern South Australia into southern Victoria. The Otway Basin was initiated in the late Jurassic with sedimentation with riverine, deltaic and shallow marine deposits occurring throughout the Cretaceous period (Hallam and Thurgate 1992).

Two phases of deposition resulted in the Dilwyn Formation and the formation of the Gambier Limestone, the two main aquifers in the South East.

Various geological processes including tectonic uplift combined with fluctuations in sea level during the Pleistocene epoch (about 1 million years ago) led to the formation of a series of calcareous sandstone dunes over the Gambier Limestone and interdunal flats which slope gently to the south-west. Dissolution of the Gambier Limestone during this period led to the formation of the karstic landscape. The dunes restrict natural surface drainage and resulted in extensive wetland development. The formation of peats in these areas occurred less than 5500 years ago (Scholz 1987).

Karst landscapes can support a range of subterranean features with the South East region being characterised by multiple karst features including enclosed depressions, caves and sinkholes. In the area of the site there are impermeable barriers within the Gambier Limestone which locally restrict underground drainage. Combined with incomplete surface drainage of the coastal areas, due to a barrier of flints shed from the Miocene limestone and the aeolian sand on the coastal dunes, this produces the swampy surface environment of the site (Scholz 1987). Two major areas of karst wetlands occur along the coast of the Lower South East; Ewens Ponds and the Ramsar site at Piccaninnie Ponds. The wetlands at these sites include karstic cavities which provide discharge points and surface water to the surrounding environment, along with beach springs, of the unconfined aquifer (SECWMB 2001).

The Piccaninnie Ponds Karst Wetlands can be broken down into four distinct areas:

1. Main Piccaninnie Ponds consisting of First Pond (10 metres deep), the Chasm (greater than 90 metres deep), and Turtle Pond (six metres deep) with surrounding swamp area (Figure 26). The Cathedral chamber located off the Chasm is believed to be a more recent formation brought about by a combination of dissolution and scouring as there is no evidence of any large scale collapses (Hallam and Thurgate 1992). Within the surrounding swamp there are a number of springs which contribute to the groundwater discharge. However the main source of water at Piccaninnie Ponds is believed to rise through the Chasm, which penetrates deep into the aquifer resulting in pressurised discharge into the surrounding wetlands (Figure 27). Discharge from the springs and surface water run off from the surrounding swamp/wetlands drain into Outlet Creek and into the sea. Recent mapping and survey work undertaken by a number of divers on the Piccaninnie Deep Diving Project for the Cave Divers Association of Australia has led to the discovery of two new areas previously unmapped. Figure 28 provides a modelled view of the main karst system.

2. Western wetland lies to the west of the Main Ponds and consists of dense closed shrubland with *Leptospermum lanigerum* and *Melaleuca squarrosa* overstorey, and coastal vegetation on peat soils (Scholz 1987).

3. Eastern wetland includes several springs which form Hammerhead Pond. This pond has a maximum depth of four metres, and its localised drainage

is all subsurface as it has been disconnected from the Main Ponds by reduced water levels. A public access road has further isolated this wetland (Scholz 1987).

4. Pick Swamp on the western side of the site includes large areas of fen wetland, marshes, sedgelands, and Crescent Pond another karst spring. The marsh and sedgelands of Pick Swamp are shallow reaching up to half a metre depth. Crescent Pond is approximately 50 metres long and 12 metres wide at its centre and has three interconnecting basins ranging in depth from four to 5.8 metres.

The unique geology and geomorphology of this karst system together with hydrology form the physical habitat template of this site and are the overriding determinants of the character of the site. The formation of the karstic cavities allowed upwelling of groundwater which in turn supplies surface water to the surrounding wetlands. This is a closed catchment with little sedimentation or erosion, with dissolution of the limestone the main geomorphic process.

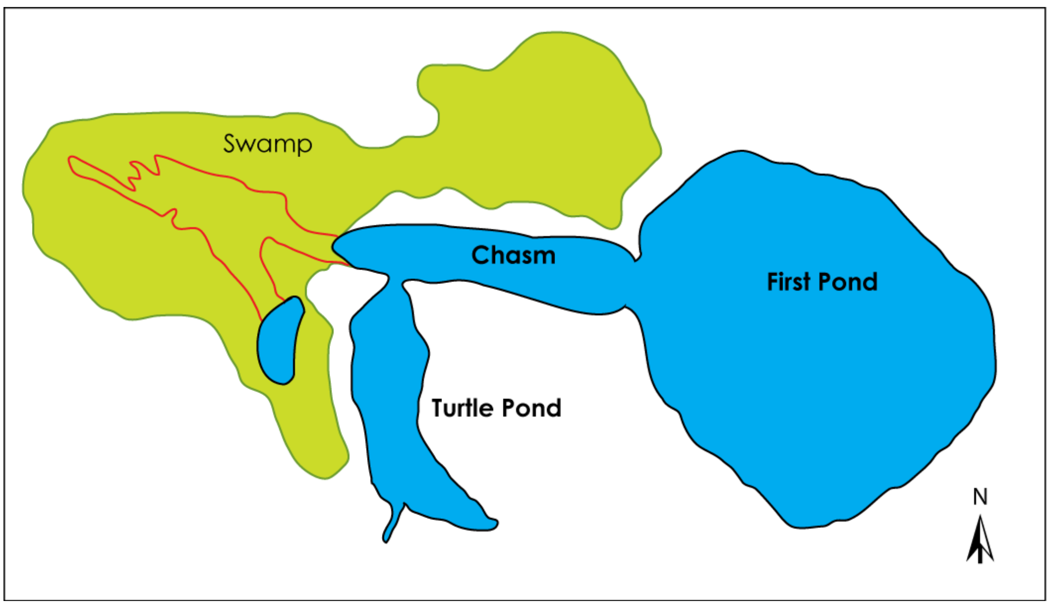


Figure 26: Plan view of Main Ponds area of Piccaninnie Ponds Karst Wetlands (adapted from Hallam and Thurgate 1992). Note that the swamp surrounding the Main Ponds is more extensive than shown here.

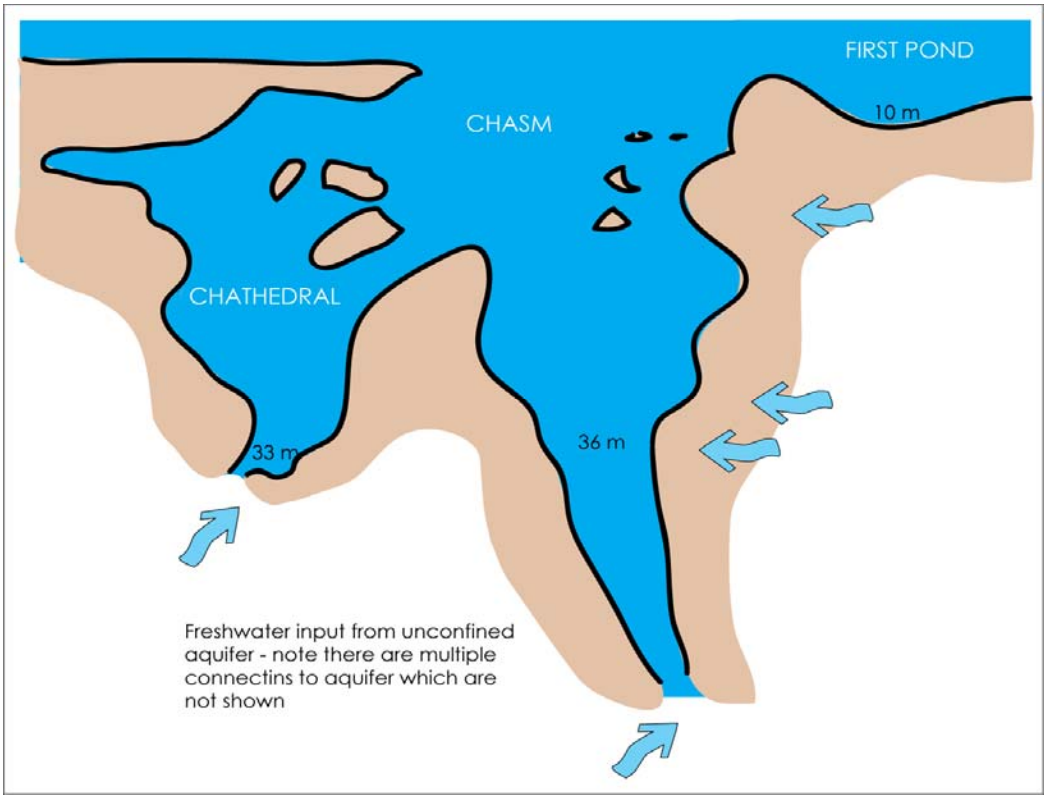


Figure 27: Stylised cross section of main karst wetlands of Piccaninnie Ponds as known up until 2008 (modified from Thurgate 1995).

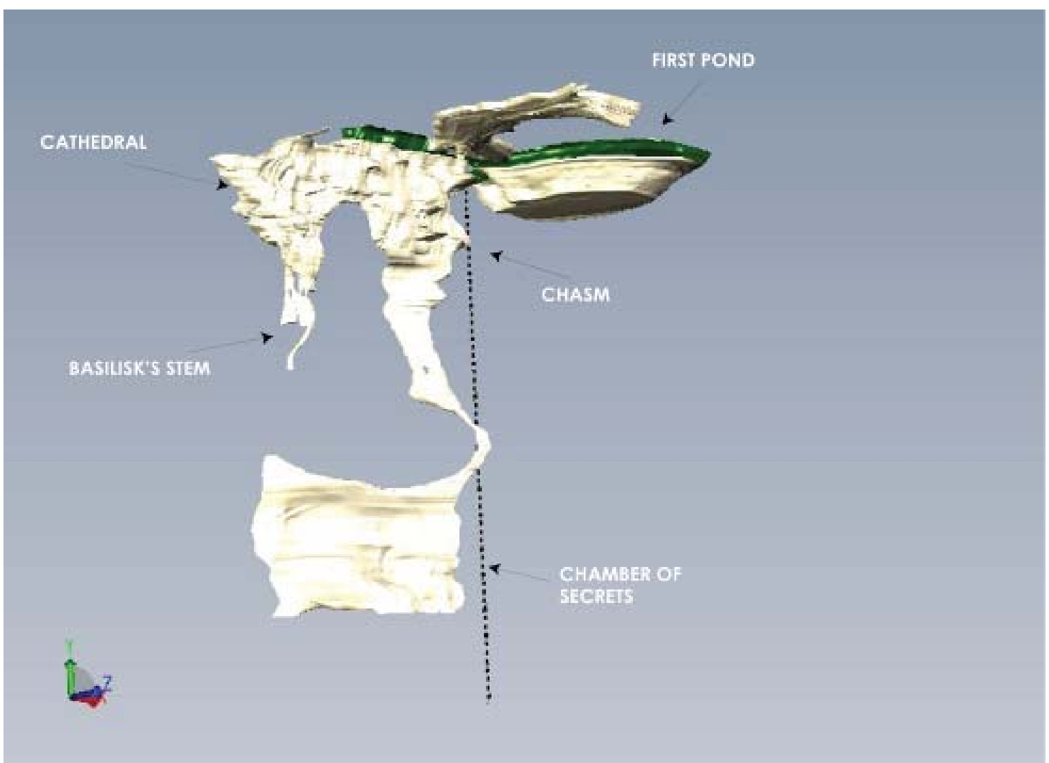


Figure 28: Model of main Piccaninnie Ponds cave system showing previously unmapped areas of the Basilisk's Stem and Chamber of Secrets. (Provided by G. Pearce, DWBLC/CDAA).

3.2.3 Soils

There are six main soil types present within the site (Figure 29) including peat, shallow red loam on limestone, shallow dark clay loam on limestone, carbonate sand and small areas of shallow sandy loam on calcrete. Bleached siliceous sands are present on the beach foreshore area (very little evident in map).

The carbonate sands of the coastal dune system comprise alkaline sand with low nutrient levels and minimal soil development. These sands are prone to drift if stabilising vegetation is removed. In small areas on the northern boundary shallow sandy loam on calcrete soils occur and this soil type is more typical of the ridges to the north of the site.

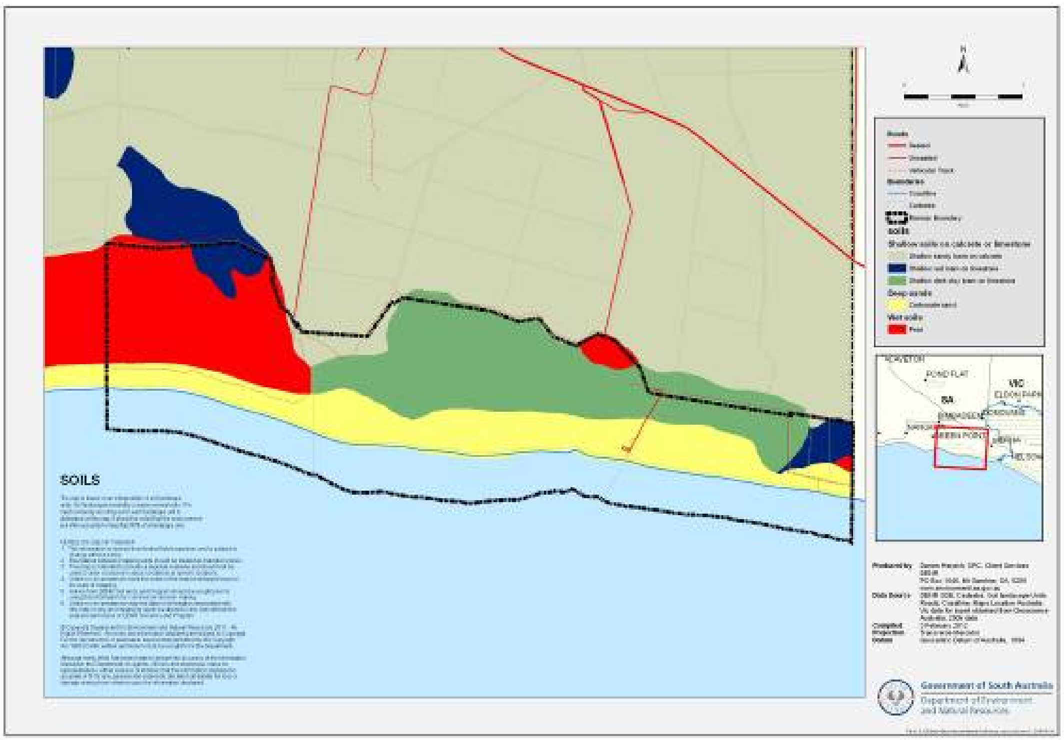


Figure 29: Soil types within Piccaninnie Ponds karst wetlands (supplied DEWNR).

Peat soils are one of the dominant features of the Piccaninnie Ponds Karst Wetlands, supporting fen wetlands in the western part of the site. Peat-based wetlands have been identified as an underrepresented wetland type in the List of Wetlands of International Importance (Ramsar Convention 2003).

Peat can be defined on the basis of depths of successive horizons (Stephens1943 cited Scholz 1987). Peat soils were recorded in the vicinity of the Main Ponds and a 'major proportion of the surrounding swamp' (Scholz 1987). Analysis of the surface peat in the vicinity of the Main Ponds showed high nutrient content compared with analysis of the water in the ponds (Scholz 1987).

Three types of peat have been found within the Piccaninnie Ponds Karst Wetlands (Grandfield 1984; Scholz 1987):

1. Badenoch Friable Peat. This peat develops from the remains of tea-tree fen vegetation (*Leptospermum* and *Melaleuca*), and is located on the better drained areas throughout the site. This is the most common type being a black friable peat comprising 85 percent organic carbon and 15 percent mineral matter.
2. Orwell Fibrous Peat. Small areas of this peat are located along the edges of the karst springs and are formed from grasslands and reedlands (*Phragmites* and *Typha*) near the edges of the springs. They are 81 percent organic carbon and 19 percent mineral content. The main area of this peat is in the Western wetland between the Main Ponds and the coastal dune.
3. Milstead Coarse Fibrous Peat. This peat occurs in small areas of poor drainage usually in association with the closed sedgeland formation of *Baumea*. It has 82 percent organic carbon and 18 percent mineral content.

The peat is generally alkaline; however some horizons of the Badenoch peat can be acidic (Grandfield 1984). Peat deposits are between 1.5 to two metres deep (Grandfield 1984) and have a high nutrient content, especially potassium and sodium (Scholz 1987), with nitrogen and phosphorus levels above nearby surface water levels (Stephens cited Scholz 1987).

The peat fen wetlands are a key characteristic of the site and their formation is intimately connected with the groundwater discharge, surface water drainage patterns and vegetation associations. They are a highly diverse ecosystem which supports numerous threatened species contributing significantly to the biodiversity value of the site.

3.2.4 Algae

There is very little information on phytoplankton community composition or biomass within the karst wetlands other than for Piccaninnie Ponds. Quantitative data on changes observed are lacking and this remains a knowledge gap with regard to setting the benchmark for the ecological character of the site.

Phytoplankton growth is limited in the Main Ponds as the flushing rates and low phosphorous preclude establishment of phytoplankton communities. This in turn limits the establishment of zooplankton (Scholz 1987; Thurgate 1995). Slower flowing areas of the ponds, such as First Pond did establish planktonic communities following rainfall events, where nutrients from the surrounding wetlands were washed into the pond.

Macrophytes in the fringing zones of the karst wetlands support significant periphyton. Periphyton can include bacteria, fungi, algae, protozoans, and other invertebrates. Also known as biofilms they can also contain a high inorganic content such as sediment. Periphyton is affected by nutrient availability, water temperature, water chemistry, hydraulics and surface conditions. They are highly variable over small distances in thickness, tenacity, surface distribution, microbial population and chemical composition. The periphyton is a major component of the food web in the karst wetlands.

The benthic zone (not defined in general, but referred to as below five metres in First Pond) of Piccaninnie Ponds is “shrouded in dense mats of a variety of macroalgae” (Thurgate 1995). In First Pond these include *Chara globularis*, *Chaetomorpha linum*, *Vaucheria*, *Porphysiphon*, and *Enteromorpha prolifera*. *Cladophora aegagrapila* grows attached to the undersides of rock ledges (Thurgate 1995). Epiphytic and benthic algae are described more in section 3.3.3 where the aquatic vegetation communities of the karst wetlands are described.

The relative importance of algae contributing to primary productivity levels within the wetland is not known. The presence of significant periphyton communities attached to the submerged macrophytes of the karst springs certainly adds to the distinctive submerged vegetation associations however their function and ecological importance with regard to supporting the vegetation association is unclear. There is likely to be distinct differences in the composition of the periphyton in the surface water wetlands compared to the karst springs. Metabolism, growth and productivity within the periphyton communities involve internal feedback loops which recycle and conserve resources within the community. Typically periphyton communities are highly efficient at utilizing captured external resources resulting in very high productivity (Wetzel 2006). The fate of the organic matter of the periphyton communities and if / how that passes to higher trophic levels within the wetlands is a knowledge gap.

3.2.5 Invertebrates

Very limited data is available for the aquatic invertebrate communities of the Piccaninnie Ponds Karst Wetlands and this is considered a significant knowledge gap with regard to setting the benchmark of the ecological character of the site.

A number of distinct invertebrate communities would be present within the site. Surface water dominated wetlands, and the surface areas of the springs will support a higher diversity of invertebrates than that found within the subterranean areas of the springs. Invertebrate communities of karst wetlands are typically simpler in structure having low populations and low diversity (QLD EPA 2006). However the karst fauna can have a higher proportion of endemic species or species adapted to the unique physical environment (for example no light, constant conditions) (QLD EPA 2006).

Scholz (1987) noted that the flushing rates within Piccaninnie Ponds limits establishment of planktonic communities, with phytoplankton based food webs being limited to areas of slow flow such as in First Pond. Most activity is expected to be in the fringing zones of the surface waters of the springs. Inputs of nutrients and sediments after rainfall events can trigger phytoplankton and zooplankton blooms in First Pond (Scholz 1987).

Hallam and Thurgate (1992) provide a brief species list of specimens collected in their survey, however methods of collection are unclear and the relative intensity or comprehensiveness of the data is unknown. Invertebrates recorded included sponges, hydra, leeches, gastropods, dytiscid beetles, aquatic moth larvae, copepods, cladocera, crabs and shrimp. Taxonomic resolution of the data is low with only a few taxa identified to species level.

Research investigating the biodiversity of South Australian groundwater is currently underway and includes sampling at Piccaninnie Ponds. The project commenced in 2007, however data is not yet available.

The site is one of several systems in South Australia which supports the Glenelg spiny freshwater crayfish (*Euastacus bispinosus*). In 2009 six adult-sub adults and three juveniles were recorded in a drain on the western edge of Pick Swamp (C. Dickson, DEWNR, pers. comm.). The species was not recorded elsewhere in the site despite a comprehensive survey (Hammer and Roberts 2008). This nationally endangered species only occurs in the Glenelg River system and a handful of fragmented coastal streams in South Australia. The South Australian population is believed to be disconnected from the Victorian population (TSSC 2011b). Further sampling for this species within the site is being undertaken in 2011.

A number of threatened Lepidoptera are found associated with sedgelands and contribute to the high biodiversity values of the site. Comprehensive surveys of terrestrial invertebrates are not available for the site.

3.3 Critical components and processes

The attributes and characteristics of each of the critical components and processes are described in the following sections. Where possible, quantitative information has been included; however, as with many ECD, there are significant knowledge gaps (see section 8). In the absence of direct data from within the site, general ecological theory has been used to help describe the component or process where appropriate.

A summary of the critical components and processes within Piccaninnie Ponds Karst Wetlands is provided in

Table 6.

Table 6: Summary of critical components and processes within Piccaninnie Ponds Karst Wetlands.

Component / process	Description
Hydrology	Continual groundwater discharge into the Main Ponds, Hammerhead Pond, Crescent Pond and several unnamed springs inundate surface areas and lead to waterlogged soils. Outlet Creek discharges to the sea and provides a connection to the marine environment for several diadromous fish species. In the Main Ponds discharge is predominantly from the Chasm with evidence of greater inflows at approximately 36 metres depth due to fractures in the limestone. Sea water intrusion occurs in the Chasm as well.
Water quality	Salinity is variable across the site. Main Ponds is consistently more saline than Outlet Creek at the weir. Nitrogen levels are high with a possible trend of gradual increase in nitrate levels over the past several decades. Nitrate levels are highest in areas with direct groundwater discharge. Phosphorous levels are low across the site. Turbidity is uniformly low in the karst wetlands, with clarity of the water a distinctive feature of the site. pH tends slightly alkaline.
Vegetation	Key associations include silky tea tree shrubland, karst aquatic communities, sedgeland, rushland and grassland and the fen and marsh aquatic communities. Diversity is high with over 30 associations mapped and 250 species identified.
Fish	Ten native fish species are recorded from the site. Historical records suggest an additional two species may have been present. No introduced species are present within the system. The species present have a range of migration strategies some of which rely on connectivity to the Southern Ocean.
Waterbirds	Supports 79 species including 24 species which are migratory. It is a key site for roosting and feeding for orange-bellied parrot during its winter migration. Shorebirds utilise the beach area and are also often encountered in Pick Swamp. There are limited records for sea birds. Diversity is high compared to larger nearby wetland complexes.

3.3.1 Hydrology

The site contains a number of groundwater discharge sites, including the three ponds that comprise Piccaninnie Ponds (First Pond, Turtle Pond and the Chasm), Crescent Pond to the west in the Pick Swamp and Hammerhead Pond to the east (Figure 30). Although there is much that is unknown about the hydrogeology of these complex systems, understanding is being improved through ongoing investigations.

Figure 30: Location of major groundwater discharge points within the Ramsar site. Beach springs not shown.

The site lies within the Lower Limestone Coast Prescribed Wells Area (Brown *et al*. 2006). Gambier Limestone forms the main, unconfined aquifer in the region. This is separated from the confined aquifer, the Dilwyn Formation, by a layer of impermeable black clays (Figure 31). The unconfined aquifer attains a depth of approximately 300 metres at the coast, but is very shallow to the north of Mount Gambier, under the Dismal Swamp (Grimes 1994).

Groundwater flows from these upland areas to the southern coast where it drains to the ocean (Figure 32). The porous nature of the Gambier limestone results in much of the groundwater flow via this porosity rather than through channels and fractures (Grimes1994).

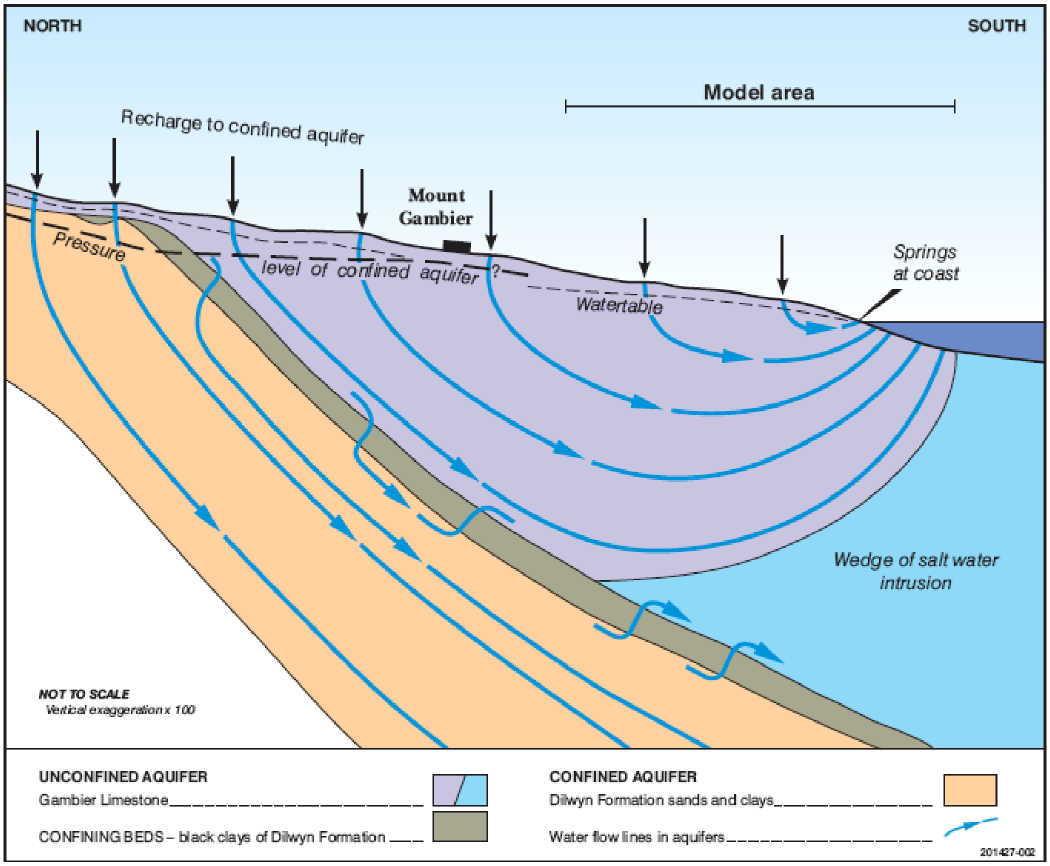


Figure 31: Hydrogeological cross section (King and Dodds 2002).

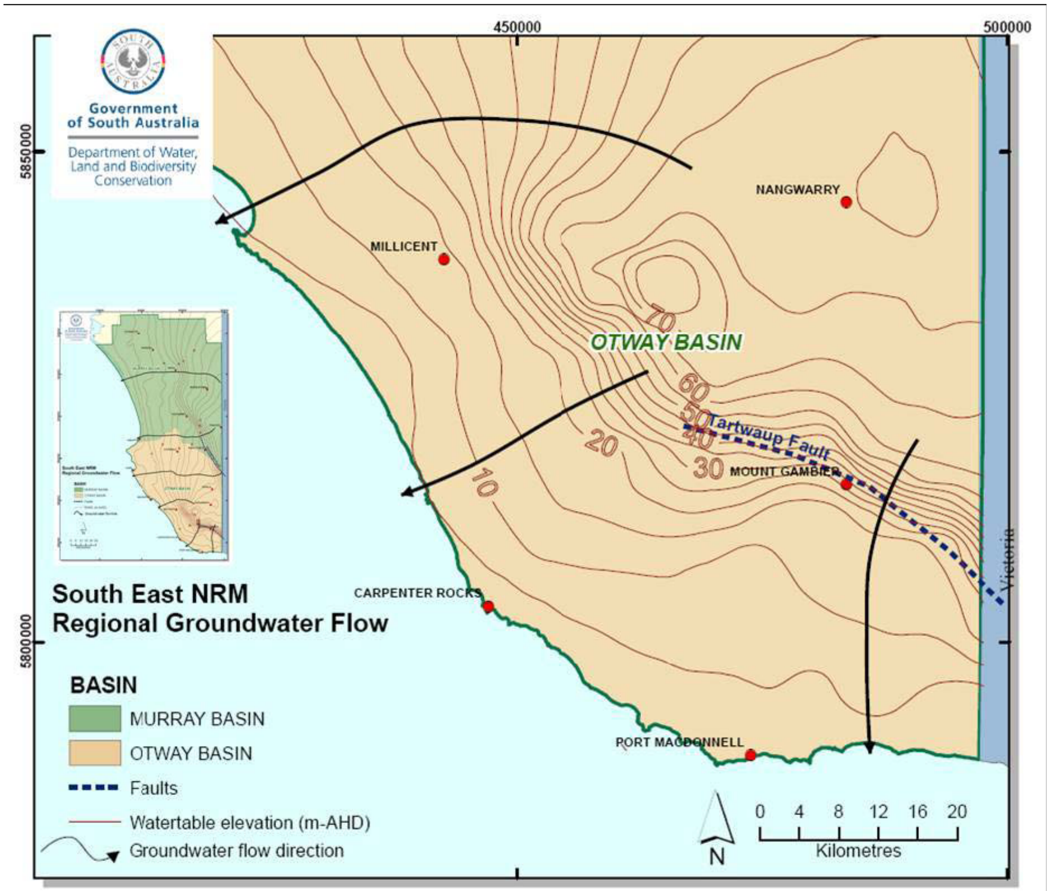


Figure 32: Regional groundwater flow in the unconfined Tertiary Limestone Aquifer in the Lower South East of South Australia (from Wood 2011).

In the area of the site, the water table is very close to the surface, and the karst spring formations act as discharge points. Groundwater is undoubtedly the dominant water source for the karst wetlands (Scholz 1990; Grimes 1994; King and Dodds 2002; Herpich 2010; Wood 2011) and the system has been classified as highly groundwater dependent (Fass and Cook 2005).

Groundwater discharges into all three ponds within the Piccaninnie Ponds system. Discharge characteristics determined by Clisby (1972 as cited by Scholz 1990) indicated that the discharge rate was highest for the Chasm at approximately 0.74 cubic metres per second (64 megalitres per day), followed by First Pond (less than 0.37 cubic metres per second) and Turtle Pond (greater than 0.12 cubic metres per second). This resulted in turnover estimates of between two and 6.6 hours for each of the ponds. Herpich (2010) used thermal imaging to show groundwater discharge within the Piccanine Ponds, based on the premise that groundwaters are warmer than receiving waters (Figure 33). The warmest areas are the Chasm and Turtle Pond clearly indicating discharge into these areas. First Pond is thought to have several discharge points as well (Herpich 2010).

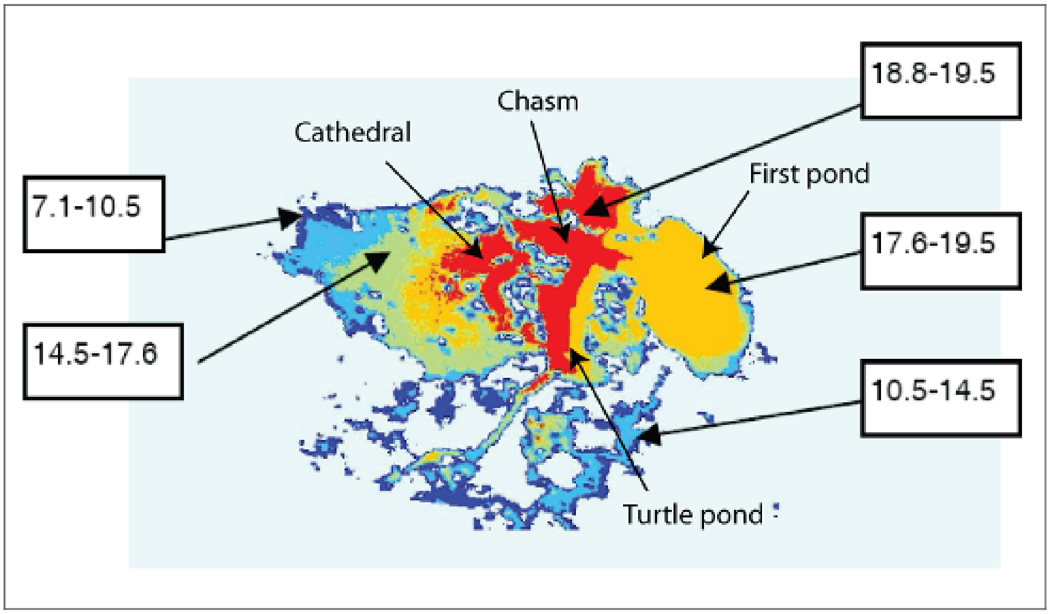


Figure 33: Thermal image of Piccaninnie Ponds, blue is colder water, red warmer indicating groundwater discharge (modified from Herpich 2010).

Wood (2011) further investigated groundwater discharge into Piccaninnie Ponds using a hydrochemical approach finding that discharge was likely to be coming from the entire sequence of the open limestone face of the Chasm rather than specific locations. Higher discharge zones are associated with fracturing of the limestone, such as occurs at 36 metres depth in the Chasm (Figure 34).

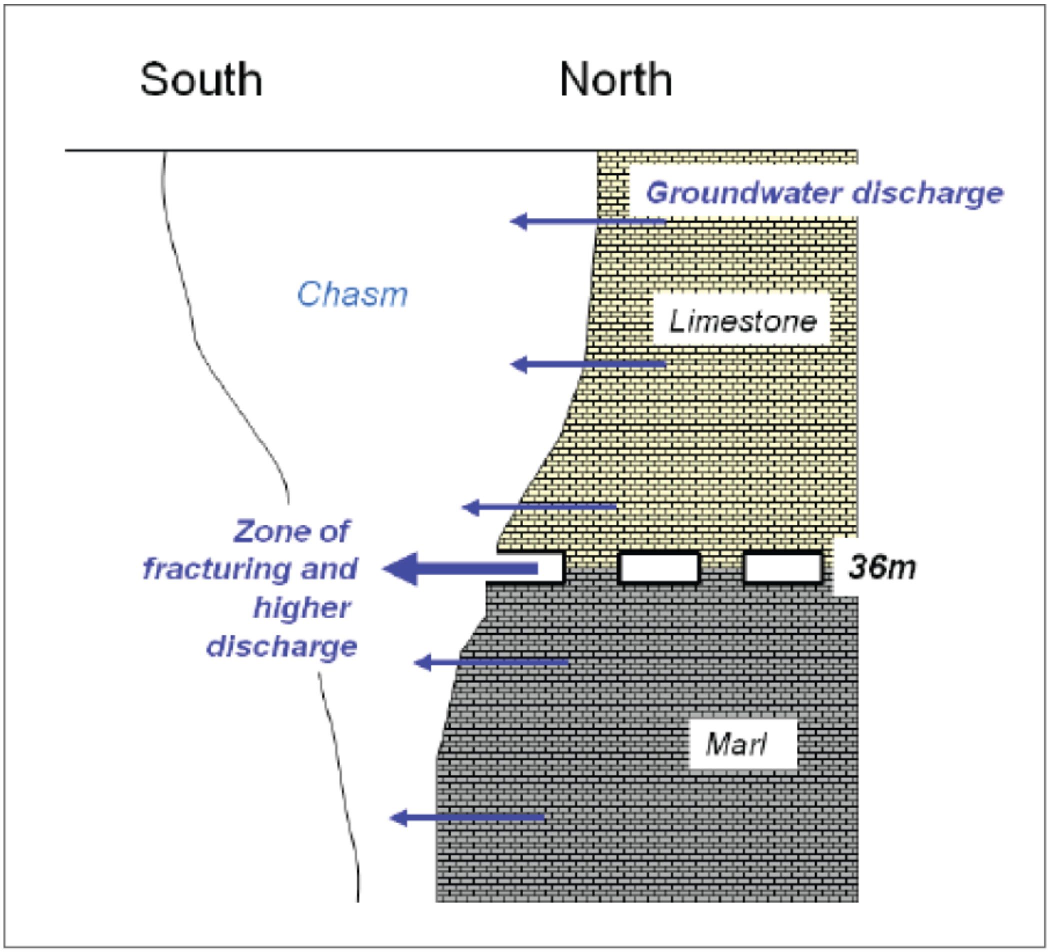


Figure 34: Conceptual model of groundwater discharge into the Chasm (from Wood 2011).

Pick Swamp is fed by continuous groundwater discharge from Crescent Pond and seasonal discharge from Piccaninnie Ponds and Western wetland area (Wood 2011). Pick Swamp hydrology is also influenced by local rainfall and evaporation.

The reliance of the karst-springs on the surficial aquifer as a primary water source makes them vulnerable to changes in the water table from local activities. The Gambier Limestone aquifer is used for irrigation in the area, with some evidence of reduced water tables over recent years (Brown *et al*. 2006). The results from Outlet Creek (which drains the Piccaninnie Ponds system) show a decrease in discharge over the past decade from average daily discharge of between 60 and 80 megalitres per day in the 1970s and 1980s to between 30 and 50 megalitres per day since 2005 (Figure 35).

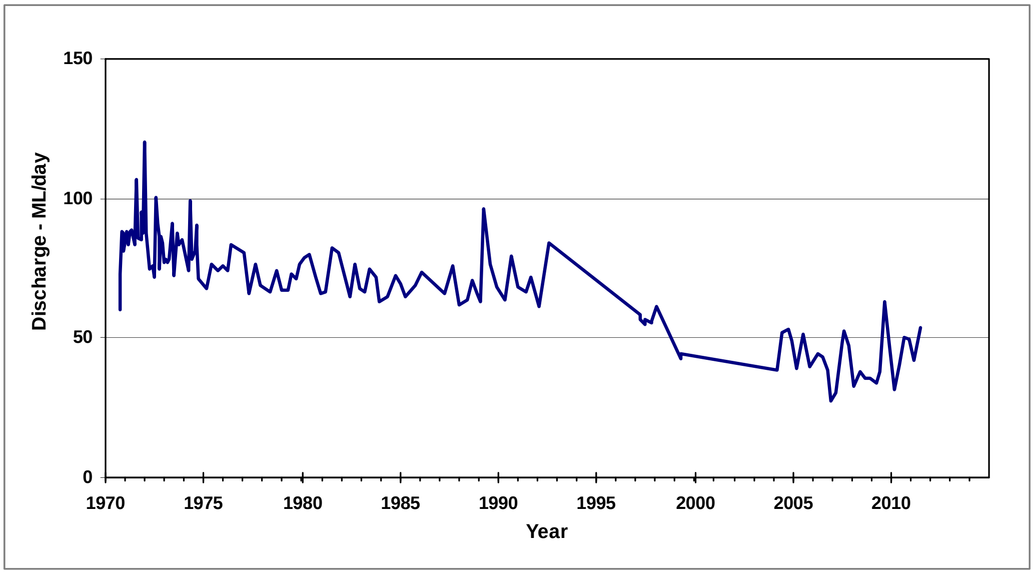


Figure 35: Mean daily discharge (megalitres per day) from Outlet Creek (data supplied by DfW).

Natural drainage channels are largely absent over much of the region. However, there has been extensive modification to surface water drainage in the past 30 years (Clarke 2007). The area that is now comprised of the Piccaninnie Ponds Conservation area, Pick Swamp and adjoining farm land, was once a continuous wetland complex with large areas of surface water (Figure 36). Originally a natural drainage channel, Freshwater Creek, drained the system eastward into the Glenelg estuary. In 1906 the course of the creek changed as it broke through a depression in the dunes and flowed out to the sea approximately 1.2 kilometres west of the Glenelg River (Scholz 1987). Sometime in the period 1917-1945 the Western wetland became separated from the Main Ponds, and a drain was subsequently cut through the dunes from the Main Ponds (Scholz 1987). Freshwater Creek stopped flowing around 1958, potentially as a result of choking by drifting sand (Scholz 1987).

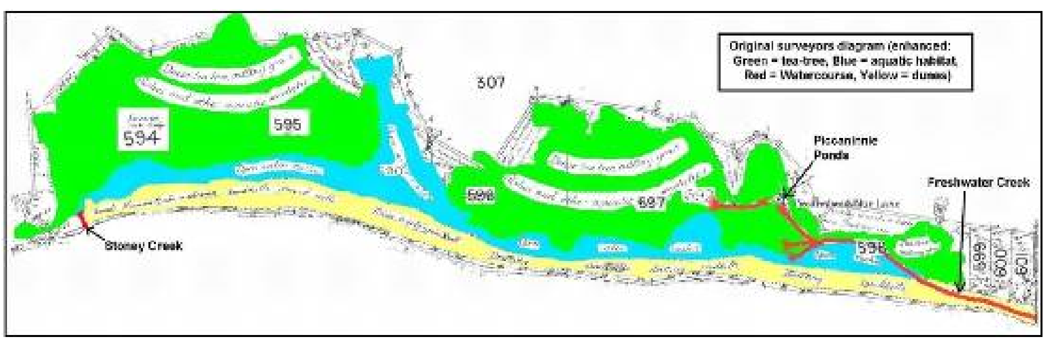


Figure 36: Original hydrological connectivity of the Pick Swamp and Piccaninnie Ponds wetlands (reproduced from Clarke 2007).

The position of Freshwater Creek and the current drainage channel, Outlet Creek, which cuts, through the dunes to discharge water into the ocean can be seen in (Figure 36 and Figure 30) above. During the 1970s a large number of drainage channels were added to Pick Swamp, resulting in much of this area being converted to terrestrial environments and used for agricultural purposes (Clarke 2007). The resulting changes reversed the direction of flow between the two wetlands with surface flow during winter westwards from Piccaninnie Ponds into the Pick Swamp area. A drain captured this water and diverted it to the sea (Clarke 2007). A significant investment has been made to restore the historical timing and frequency of inundation of the Pick swamp portion of the site. With the construction of a weir, fishway and levee completed in 2010, the depth of water held in Pick Swamp has increased significantly and water now flows seasonally from Piccaninnie into Pick Swamp where it can be released through a regulated structure to the sea. During the restoration program approximately 3 kms of drains were decommissioned. The restoration works have resulted in surface water levels, and hence wetland habitat, across the Piccaninnie Ramsar site steadily increasing since restoration commenced in 2006, even during periods of lower than average rainfall. Figure 37 shows the original drains with proposed blocks and control structures which are now in place.

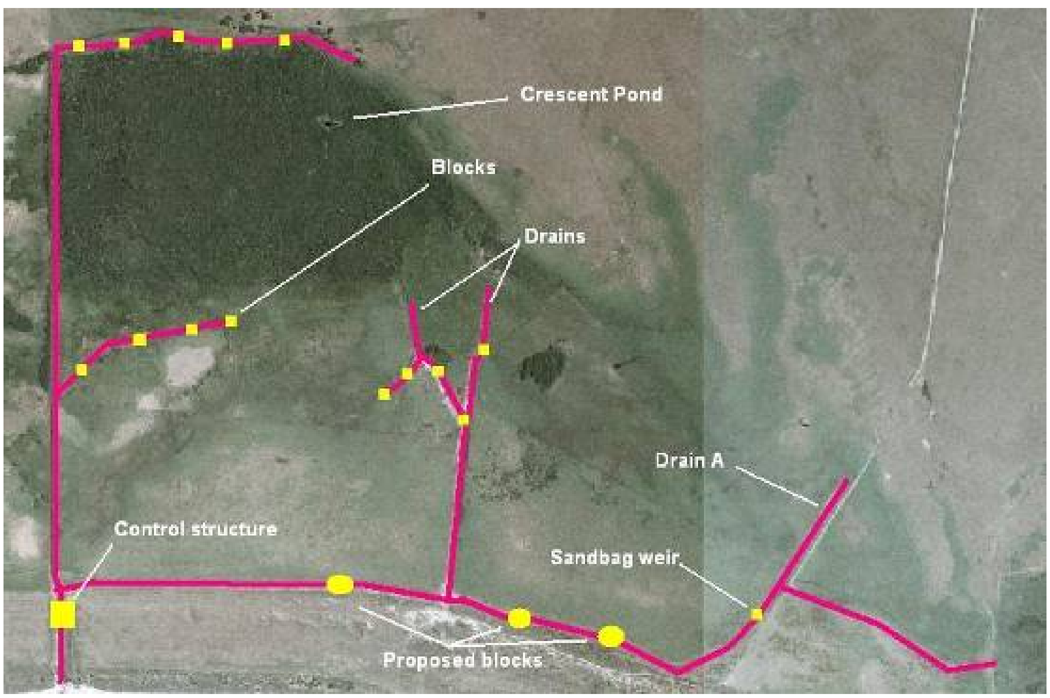


Figure 37: Drains and drain blocks in Pick Swamp (reproduced from Clarke 2007).

Hydrology is a major driver of all wetland systems and the wetlands of the nominated Ramsar site are no exception. The groundwater discharge is critical to the duration, depth and frequency of inundation across the site, resulting in the mosaic of wetland habitat observed, the establishment of peatlands and presence of a diverse array of biota.

3.3.2 Water quality

The dominance of the surficial groundwater aquifer as a water source for the system makes the wetland vulnerable to inflows of nutrients and other chemicals from surrounding landuse activities. Water quality is considered a critical component of the ecological character of the wetland system; in particular the groundwater quality (salinity, nutrient concentrations, and clarity) is pivotal to supporting the submergent macrophyte and algal associations within the karst springs. The alkaline nature of the groundwater is also important for the formation of peat, leading to the development of fen wetlands.

Salinity

The flow of groundwater from the land towards the sea helps to maintain freshwater conditions at the site. Seawater incursion occurs at depth, as both the predicted and surveyed data indicate that the saltwater-freshwater interface is at a depth of 120 to150 metres in the region of the Ramsar site (King and Dodds 2002). Two depth profiles of salinity for the bore CAR011, which is approximately 250 metres east of Piccaninnie Ponds, are available (Figure 38 and Figure 39). The first profile, taken in summer 2001(King and Dodds 2002), indicates:

- 0 to 114 metres: consistent salinity of approximately1500 milligrams per litre.
- 114 to 120 metres: salinity increases gradually to approximately 3000 milligrams per litre.
- 120 to 123 metres: sharp increase in the salinity from 3000 to 17 000 milligrams per litre.
- 123 to the end of hole at 140 metres: salinity increases gradually to 20 000 milligrams per litre.

The second profile was taken in June 2008, along with a salinity profile of the Chasm (Woods 2011). This profile identifies an increase in salinity at approximately 36 metres depth, which Wood (2011) attributed to a change in the hydrostratigraphy of the Tertiary Limestone Aquifer (TLA). The change in salinity in the Chasm is not as abrupt of that of the bore and suggests that the groundwater discharge into the Chasm at this depth may be due to fractures in the limestone face of the Chasm (see section 3.3.1 above). Increased salinity at 80 to 100 metres in bore CAR011 is related to a shift from marl to limestone. This is not reflected in the sample from the Chasm, which may indicate reduced or no discharge at this point from the lower TLA. Alternatively this may represent sampling error (Wood 2011).

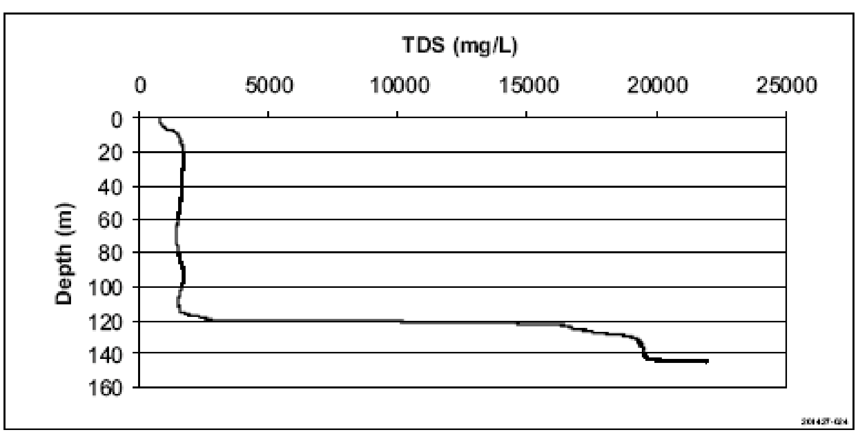


Figure 38: Salinity profile, total dissolved solids, Jan/Feb 2001, from bore (CAR011) on coast adjacent to Piccaninnie Ponds (King and Dodds 2002).

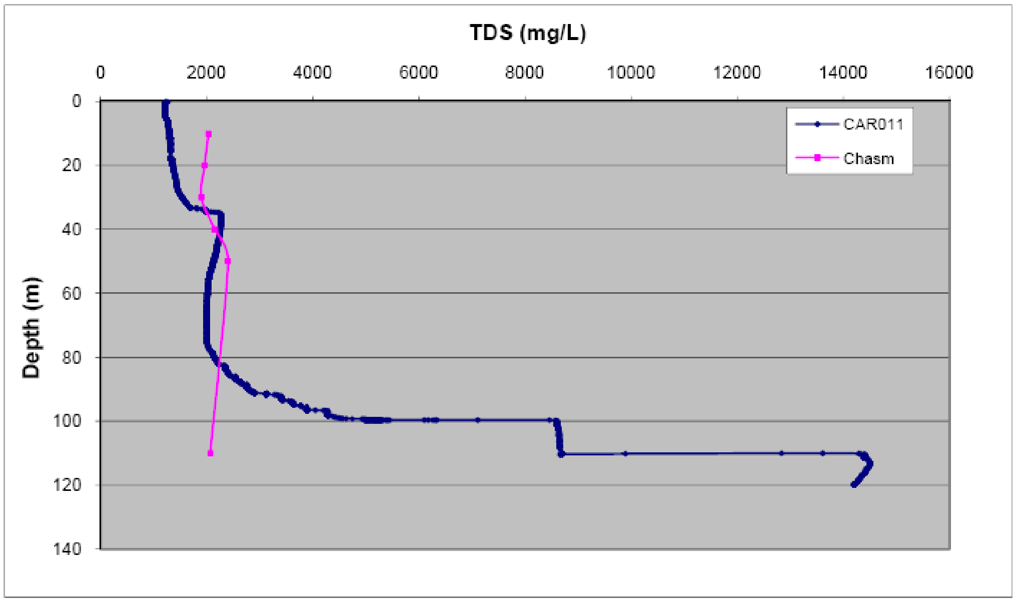


Figure 39: Salinity profile, total dissolved solids, June 2008 in the Chasm and CAR011 (from Wood 2011).

The effect of seawater on the salinity within the Ponds themselves is not well documented. Fass and Cook (2005) indicated that chloride concentrations were higher than expected, but did not suggest a source. Scholz (1987; 1990), however, found that the ionic dominants in groundwater and the Chasm were different. Water in the aquifer had a lower salinity (390 milligrams per litre) than that in the Chasm (1770 milligrams per litre). Scholz (1990) suggested that a subterranean contribution of seawater into the ponds, via the Chasm would account for this four to five fold difference in salinity (Figure 40).

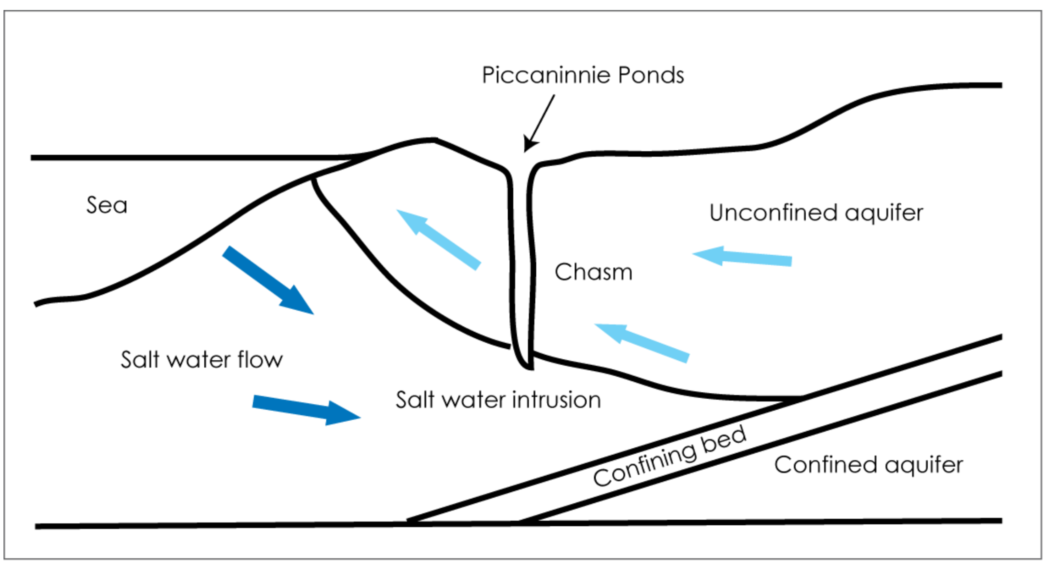


Figure 40: Possible water sources for Piccaninnie Ponds showing salt water intrusion into the unconfined aquifer (after Scholz 1987).

Fass and Cook (2005) and Fairweather (unpublished) recorded salinities in Piccaninnie Ponds during 2004 to 2007 that were similar to those recorded by Scholz (1990) 15 years prior (1000 to 2000 milligrams per litre). Similar readings (1260 milligrams per litre) were also taken by Hammer *et al*. (2000) in December 1999 in Piccaninnie Ponds (1260 milligrams per litre) and lower salinity in Hammerhead Pond (460 milligrams per litre). Scholz (1990) noted that there were seasonal fluctuations in salinity within the ponds, with higher concentrations in winter and lower in summer. He suggested that salt accumulation in the surrounding catchment over summer was washed into the ponds in the first winter rains, resulting in increased salinity. A similar trend of salinities in the order of 1300 to 1500 milligrams per litre recorded in February 2008, and approximately 2000 milligrams per litre in June 2008 (DFW unpublished data).

Surface water salinity is spatially variable across the site, reflecting different levels of groundwater discharge and rates of evaporation. Monthly surface water salinity for Piccaninnie Ponds at the pontoon on First Pond and the weir from July 2008 to March 2011 broadly follow the seasonal pattern reported by Scholz (1990). Salinity at Pick Swamp is somewhat different to that observed in Piccaninnie Ponds, reflecting the greater role of evaporation in this part of the site (Figure 41). It also shows the lower salinity at the weir indicating inputs of fresher water, probably from additional springs (Clisby 1972; Wood 2011). The seasonal pattern of higher salinity in the Main Ponds in the wetter months remains unexplained. Wood's (2011) findings did not support the theory proposed by Scholz (1990) that seasonal changes in salinity in the Main Ponds is attributable to greater surface water inflows carrying higher concentrations of salts in wetter months. Wood (2011) found virtually no change in stable isotope composition of the surface waters, which would be expected if surface runoff was contributing to salinity patterns.

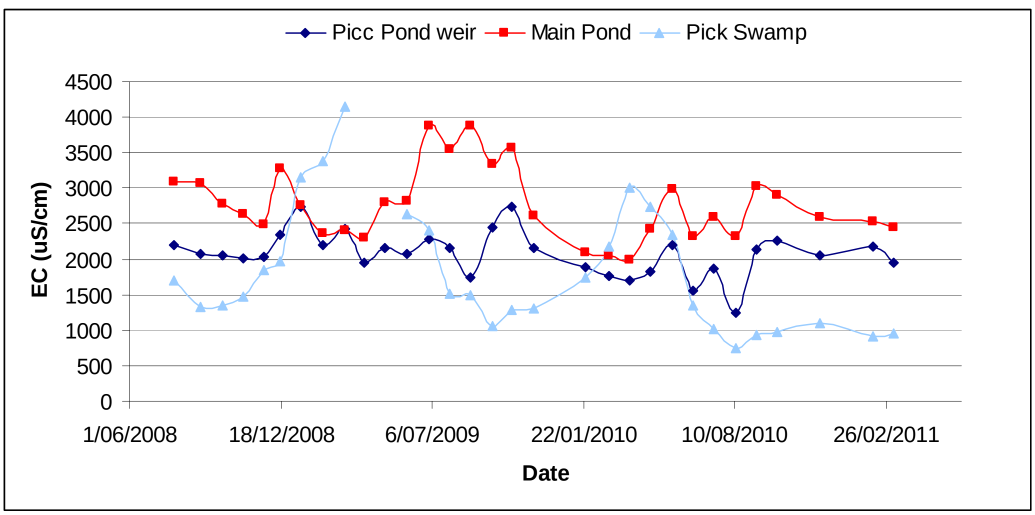


Figure 41: Surface water salinity for Main Pond, Piccaninnie Ponds weir and Pick Swamp July 2008 to March 2011(data supplied DEWNR).

The ionic concentrations measured by Scholz (1990) in June/July 1987 are similar to those collected by Fass and Cook (2005) in November 2004 and February 2005 (Table 7). Scholz (1990) also found that water quality was similar across space and time within the Piccaninnie Ponds during his studies in the 1980s.

Table 7: Concentrations of ions (milligrams per litre) recorded at Piccaninnie Ponds

Ion	June / July (Scholz 1990)	November 2004	February 2005
		Fass and Cook (2005)	
Cations			
Na	461	510	390
Mg	128	72	59
Ca	89	90	85
K	1.2	18	14
Anions			
Cl	956	1200	690
HCO3	137	198	182
SO4	No data	132	89

The salinity regime can have a significant effect on the flora and fauna and hence the ecological character of a wetland. Salinity changes may affect aquatic organisms in two ways (ANZECC 2000):

- direct toxicity through physiological changes (particularly osmoregulation) — both increases and decreases in salinity can have adverse effects;
- indirectly by modifying the species composition of the ecosystem and affecting species that provide food or refuge.

The salinity tolerances of a few key plant and fish species of Piccaninnie Ponds are provided in

Table 8. While some of these species may be able to tolerate large fluctuations in salinity (particularly species that are adapted to estuarine conditions) others (such as milfoil *Myriophyllum propinquum*) are strictly freshwater species that will not survive large increases in salinity.

Table 8: Salinity tolerances for a number of species recorded at Piccaninnie Ponds Karst Wetlands.

Species	Salinity tolerance (milligrams per litre)	Reference
Spotted galaxias	Fresh to 34 000	Merrick and Schmida 1984
Common galaxias	< 1000 to 49 000	Kuiter *et al*. 1996
Small-mouthed hardyhead	2000 – 120 000	Hart *et al*. 1989
Yarra pygmy perch	Fresh to brackish	Chessman and Williams 1975
Sago pond weed (*Potamogeton pectinatis*)	1000 - 6000	Brock and Lane 1983
Water milfoil (*Myriophyllum propinquum)*	< 4000	Brock 1981
Phragmites australis	< 10 000	Lissner and Schierup 1997
Triglochin procerum	< 6000	Warrick and Bailey 1997

Nutrients

Scholz (1990) found no spatial or temporal variation in nutrient concentrations within Piccaninnie Ponds in 1987 (Table 9). Oxidised nitrogen (nitrate plus nitrite) of 6.5 milligrams per litre was recorded in Piccaninnie Ponds in December 1999 (Hammer *et al*. 2000). Fass and Cook (2005) recorded nitrate concentrations of 11 – 17 milligrams per litre in 2004 – 2005. This represents an order of magnitude increase in nitrate from 1987 concentrations. Nitrogen concentrations would be expected to be higher compared to phosphorous as nitrogen (as NOx) remains in solution to a far greater extent than phosphorous. Phosphorous is likely to be retained in the soil profile as water infiltrates to groundwater.

Table 9: Nutrient concentrations at Piccaninnie Ponds June/July 1987 (Scholz 1990).

Species	Concentration
Nitrate	0.74 milligrams per litre
Nitrite	1.1 micrograms per litre
Total Nitrogen	2.46 milligrams per litre
Phosphate	10.7 micrograms per litre
Total Phosphorus	16.0 micrograms per litre

However, more recent data (supplied by P. Fairweather; Flinders University) indicates that total inorganic nitrogen levels within Piccaninnie Ponds are generally between one and three milligrams per litre (December 2005 to December 2007), with a maximum recording of 5.7 milligrams per litre (Fairweather *et al*. 2011). These data also indicates that the nitrogen is mostly (60 – 100%) in dissolved, inorganic form and available for immediate uptake by plants and algae (Figure 42). Monitoring of nitrate and phosphate from July 2008 to March 2011 for Pick Swamp, Main Pond and the Piccaninnie weir show much higher nitrate in the ponds than at Pick Swamp (Figure 43) and higher readings than that of Fairweather *et al*. (2011). All sites had relatively stable and low recordings for phosphate (Figure 44).

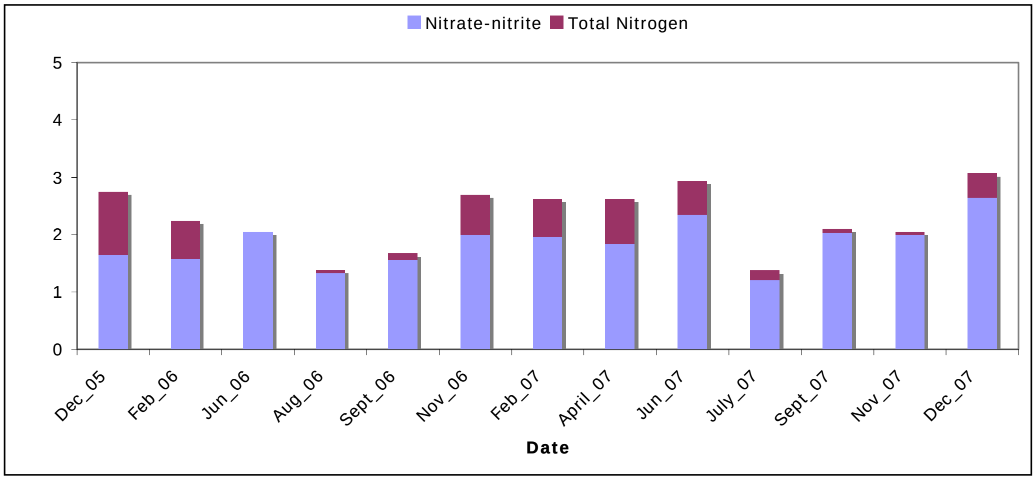


Figure 42: Nitrate–nitrite and total nitrogen concentrations (milligrams per litre) in Piccaninnie Ponds December 2005 to December 2007 (P. Fairweather, unpublished).

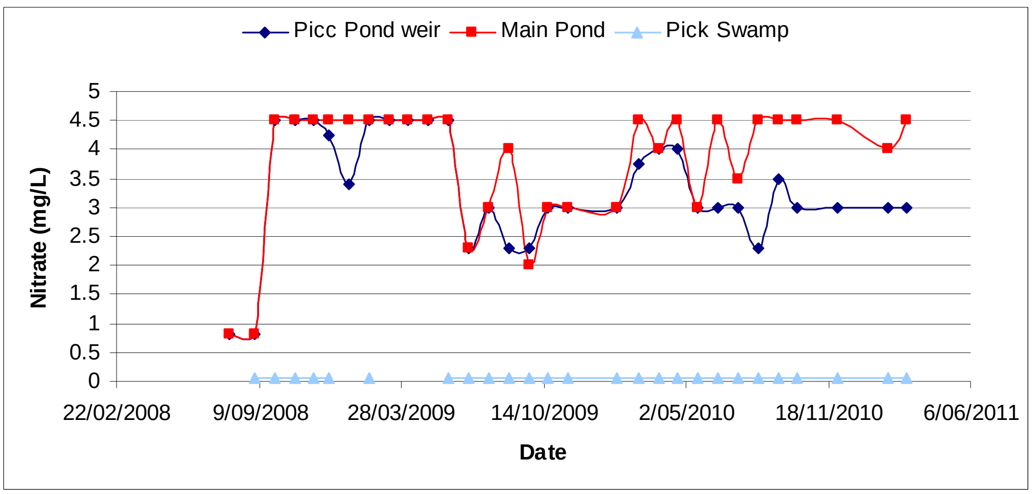


Figure 43: Nitrate concentrations at Piccaninnie Pond weir, Main Pond and Pick Swamp July 2008 – March 2011(data supplied DEWNR).

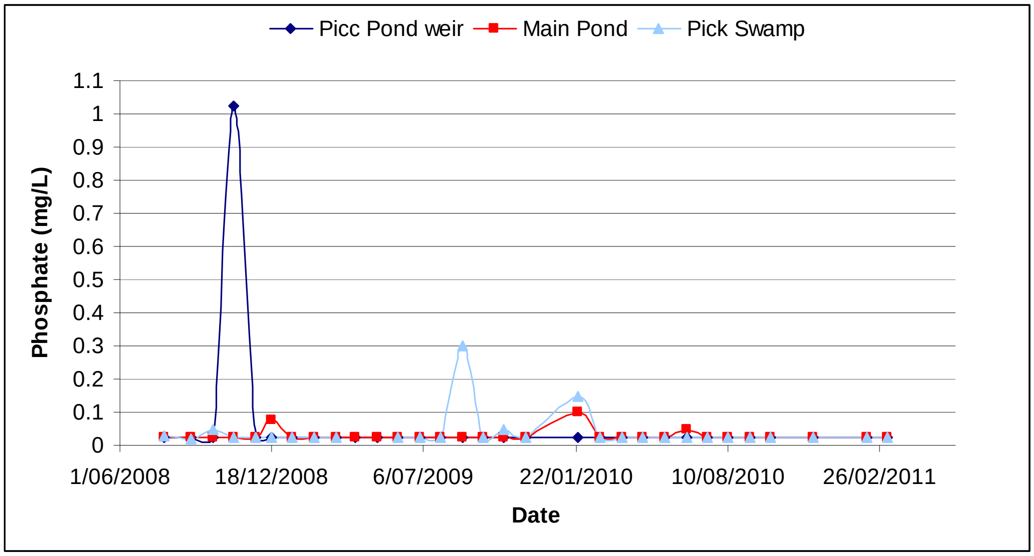


Figure 44: Phosphate concentrations at Piccaninnie Pond weir, Main Pond and Pick Swamp July 2008 – March 2011(data supplied DEWNR).

Turbidity and light penetration

Piccaninnie Ponds are characterised by their low turbidity and high water clarity. Scholz (1987) postulated that the flushing rates in the Main Ponds play a significant role in maintaining water clarity. Increased turbidity associated with rainfall events have been noted in First Pond, however the levels are only raised for short periods and a return to pre-event levels usually occur in a matter of four to five days. Associated with rainfall events are an influx of nutrients, which can lead to blooms in phytoplankton and zooplankton communities. Such events lead to an increase in turbidity and the formation of a brown surface layer in First Pond (Scholz 1987). Surface water monitoring at Piccaninnie Ponds from July 2008 to March 2011 have consistently recorded less than 10 nephelometric turbidity units. Pick Swamp is more variable with readings up to 25 nephelometric turbidity units (DEWNR unpublished data). Such low turbidity levels are not likely to be light limiting.

pH

The ponds are slightly alkaline with pH between 7.1 and 7.5 and are reportedly stable both spatially and temporally (Scholz 1990; Fass and Cook 2005). The bicarbonate from the limestone aquifer discharge is likely to be responsible for this. Hammer *et al*. (2000) recorded higher pH (pH 8) in December 1999. However, there is insufficient information to determine any trends. Surface water monitoring by DEWNR (unpublished data) at different locations across the site indicate pH is slightly more alkaline in Pick Swamp than in the ponds, mostly ranging between 7 to 9 between 2008 and 2010, with slightly more acidic conditions recorded in 2010 across the site (Figure 45).

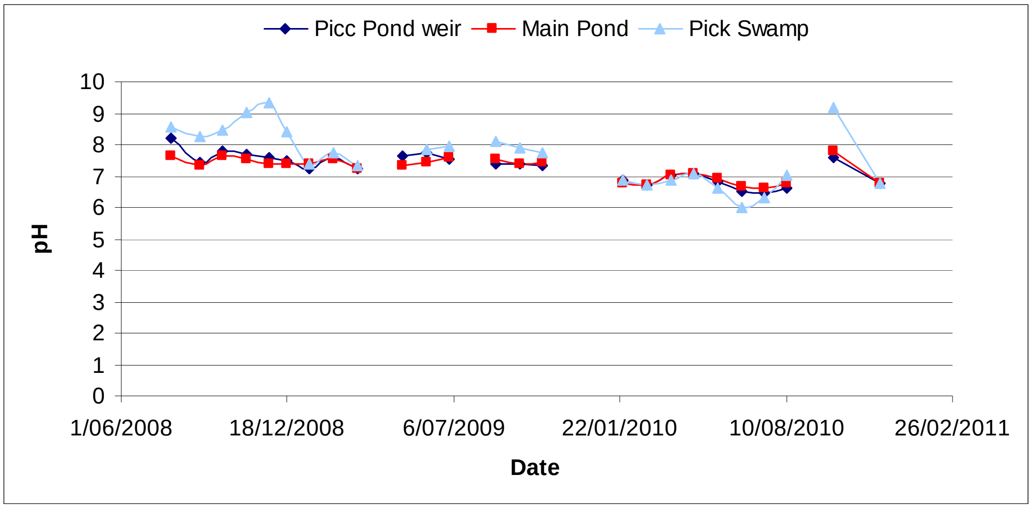


Figure 45: pH at Piccaninnie Pond weir, Main Pond and Pick Swamp July 2008 – December 2010 (data supplied DEWNR).

3.3.3 Vegetation associations

Over 250 native plant species have been recorded from within the Piccaninnie Ponds Karst Wetlands (including terrestrial and wetland dependent species) (data supplied by DEWNR Mt Gambier). Recent floristic mapping of the site identified 30 vegetation associations (see Appendix F). Some of these associations are considered successional stages, in a transitional state due to the changing hydrological regime at Pick Swamp. These vegetation associations have been placed into five broad groupings which correspond to major habitat types within the site (

Table 10). Terrestrial (for example dune vegetation and pasture associations) and some transitional associations are not considered critical components relevant to the meeting the criterion for which the site is nominated and are not discussed in detail.

The distribution of each of the 30 vegetation associations in each of the main areas of the Piccaninnie Ponds Karst Wetlands is shown in Figure 46 - Figure 48.

Table 10: Summary of broad vegetation groups/habitat types, vegetation associations and Ramsar wetland type. Excludes Ramsar type E.

Habitat type	Vegetation association (Ecological Associates 2008)	Dominant species (not necessarily in order of dominance)	Ramsar Wetland type
Aquatic community - karst	X	Mixed submergent species (*Triglochin, Myriophyllum, Runnunculus, Nasturtium, Potamogeton*) with characteristic fringing zone of emergent species (*Typha, Phragmites, Eleocharis, Baumea, Juncus, Schoenus, Cyperus*). Benthic algae and macroalgal zone present in Main Ponds, replacing the submergents at five metres. Dominant taxa include *Chara*, *Chaetomorpha*, *Vaucheria, Porphysiphon, Entermorpha, Monostoma, Siroyr, Cladophora, Oscillatoris* and *Distichophyllum*.	**Zk(b)** - Karst
Aquatic community – fen & marsh	A, B, D, G, H, I, J, L	Mixed submergent and emergent species, herbs, grasses and sedges. *Triglochin procerum*, *Eleocharis acuta Juncus kraussii*, *Typha domingensis, Epilobium billardierianum ssp.,Baumea arthrophylla, Gahnia trifida*	**U** - fen **Tp** – permanent marsh **9** - drains
Silky tea tree tall shrubland	N, P, AB, POW	*Leptospermum lanigerum, Melaleuca squarrosa, Ozothamnus ferrugineus* with some *Leucopogon parviflorus* and *Acacia.*	**W** – shrubland
Sedgelands, rushlands and grasslands	F, O, Q, W, Z, AD, AC	Dominated by four main genera: *Gahnia*, *Baumea*, *Typha*, and *Phragmites*. Species include: *Gahnia trifida, Ozothamunus ferrugineus, Leptospermum lanigerum, Baumea arthrophylla, Baumea juncea, Typha domingensis, Juncus kraussii,i Phragmites australis, Cladium procerum, Melaleuca squarossa*	**Ts** – seasonally inundated sedgeland **Tp** – permanent marsh
Leucopogon shrubland	SE00271	*Leucopogon parviflorus, Acacia longifolia ssp. sophorae, Olearia axillaris*	n/a

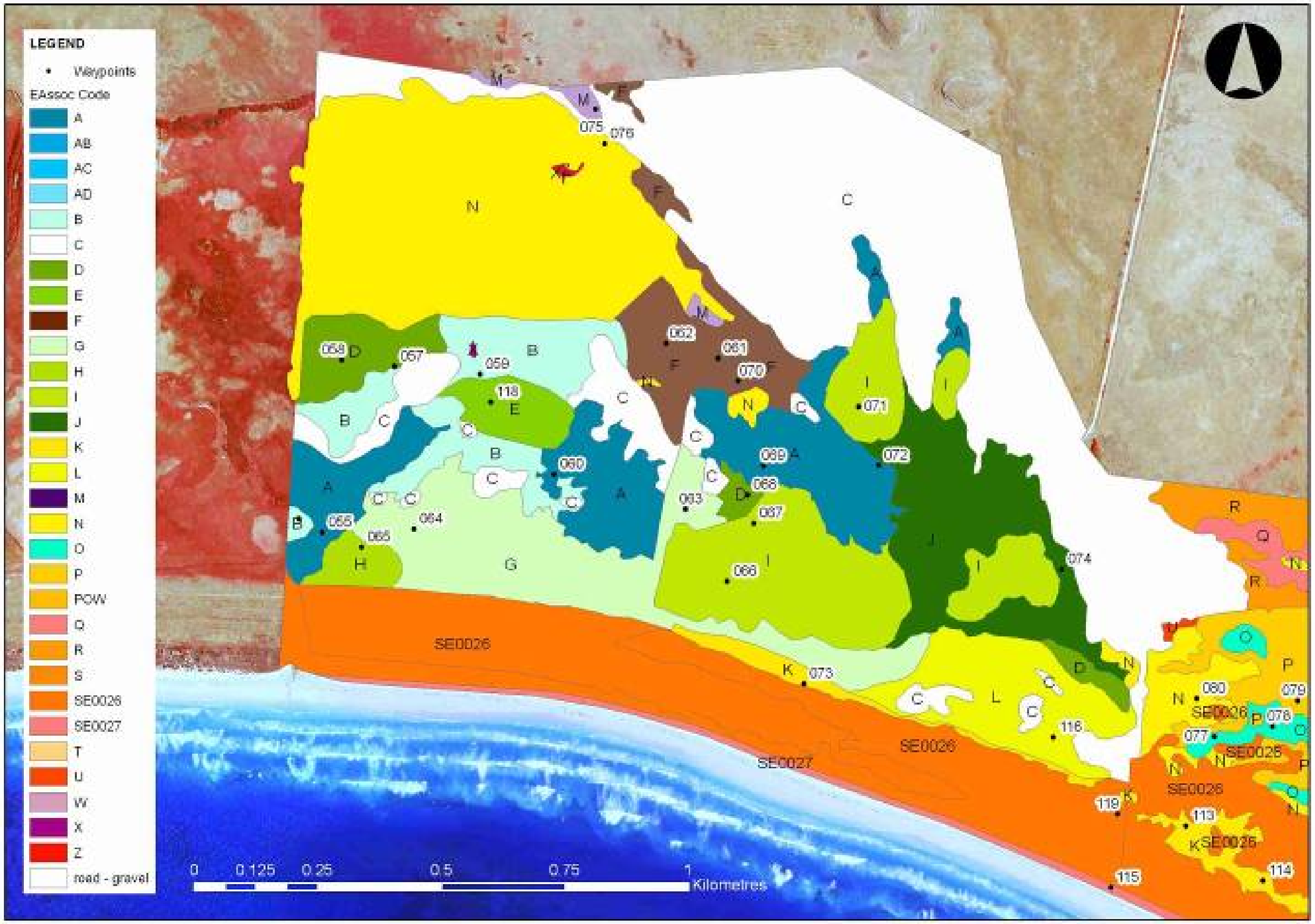


Figure 46: Floristic mapping July 2008 of Pick Swamp area of Piccaninnie Ponds Karst Wetlands showing groundtruth waypoints (Ecological Associates 2008). Description of each vegetation association is presented in Appendix F.

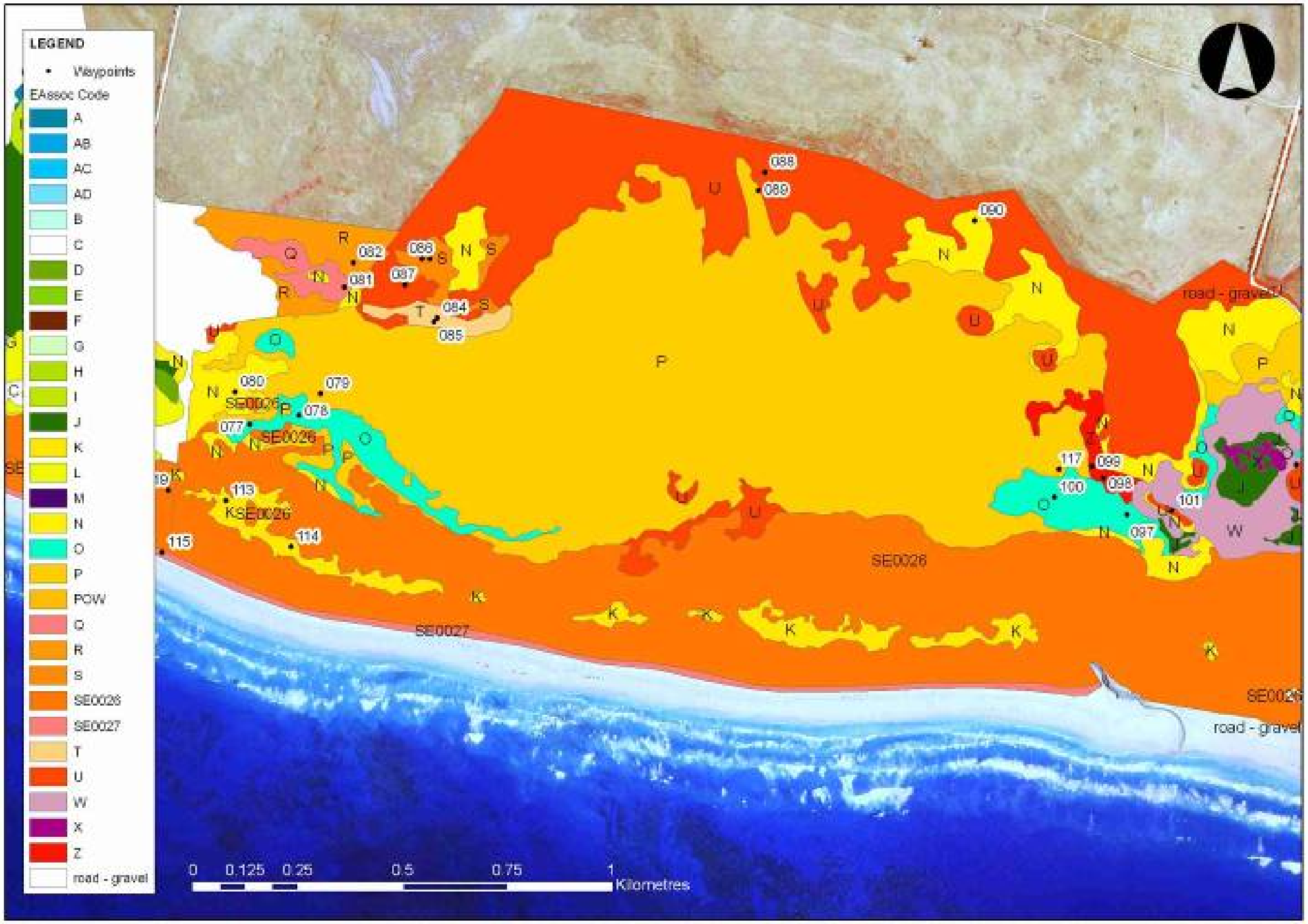


Figure 47: Floristic mapping July 2008 of Main Ponds and Western wetland area of Piccaninnie Ponds Karst Wetlands showing groundtruth waypoints (Ecological Associates 2008). Description of each vegetation association is presented in Appendix F.

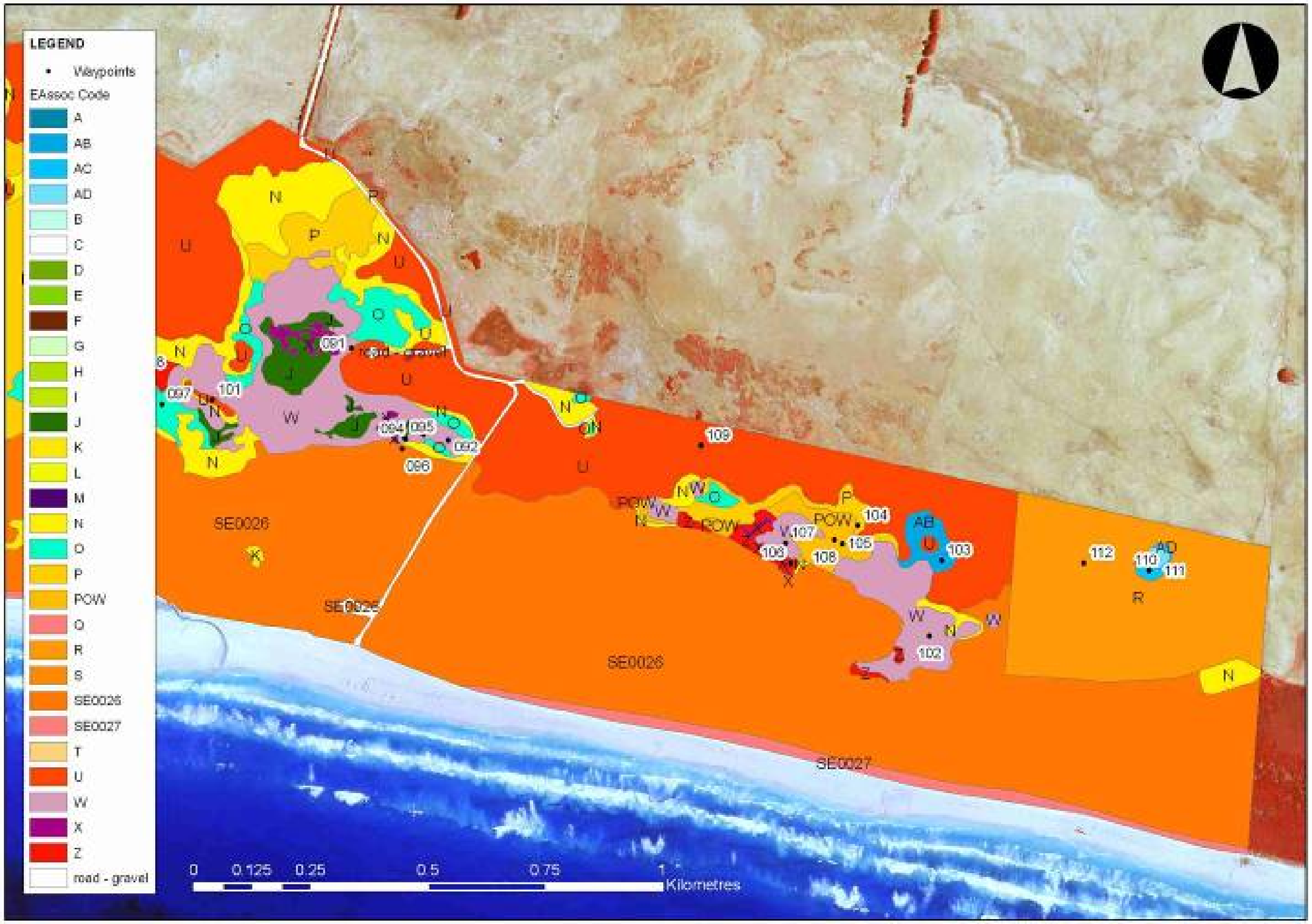


Figure 48: Floristic mapping July 2008 of Western wetland and Hammerhead Pond area of Piccaninnie Ponds Karst Wetlands showing groundtruth waypoints (Ecological Associates 2008). Description of each vegetation association is presented in Appendix F.

Aquatic community – karst

This vegetation association is a very distinctive feature of the site; however it is poorly documented due to limited accessibility (Ecological Associates 2008). Scholz (1987) and Thurgate (1995) described the zonation seen in the Piccaninnie Main Ponds which includes the following associations:

> **Fringing emergent zone**: this zone is dominated by grasses (*Phragmites australis* – common reed), sedges and rushes (e.g. *Typha domingensis*). Shallower areas of open water are dominated by emergent water ribbon (*Triglochin procerum*) and sea tassel (*Ruppia polycarpa*). Other genera recorded from this zone include *Agrostis, Baumea, Juncus, Schoenus, Cyperus, Selliera* and *Samolus* (Kraehenbeul 1964 cited Scholz 1987).
>
> **Submergent macrophyte zone**: the depth to which this zone extends varies between the Main Ponds as does the species composition. In First Pond river buttercup (*Ranunculus inundatus*) and watercress (*Nasturtium officinale* – introduced species) occurs on the slopes, but rarely on the level areas where sago pondweed (*Potamogeton pectinatus*) is dominant. The submergent macrophyte zone extends to a depth of five metres in First Pond. The slopes of Turtle Pond are dominated by *Lepilaena cylindrocarpa* with *Lilaeopsis polyantha*, water milfoil (*Myriophyllum propinquum*), sea tassel, and sago pondweed on the upper slopes. The Chasm is dominated by watermilfoil and sago pondweed. Floating ivy leaf duckweed (*Lemna trisulca*) is found in this association in the Chasm. The water milfoil extends to seven metres and the sago pondweed to 15 metres in the Chasm. In general there is an abrupt change in macrophytes at six to five metres depth in the Main Ponds with the change attributed to a shift from peat soils to silt (Scholz 1987; Thurgate 1995). Epiphytic algae are also present on much of the submerged macrophytes.
>
> **Benthic algae and macroalgae zone**: This zone replaces the submerged macrophyte zone at five metres in First Pond and is dominated by *Chara globularis, Chaetomorpha linum, Vaucheria, Porphysiphon*, and *Enteromorpha prolifera*. *Cladophora aegagropila* is found on the underside of rock ledges. The channel between Turtle Pond and the Chasm supports a number of macroalgae in summer including *Monostoma, Spiroyra, Cladophora glomerata* and others (Thurgate 1995). In the Chasm the macroalgae *Oscillatoris* and the moss *Distichophyllum microcarpum* are dominant in the zone below 15 metres.

Information for Crescent and Hammerhead Ponds is lacking, but it is expected that similar zonation is present at these wetlands. The general pattern of zonation seen in the Main Ponds is shown in Figure 49.

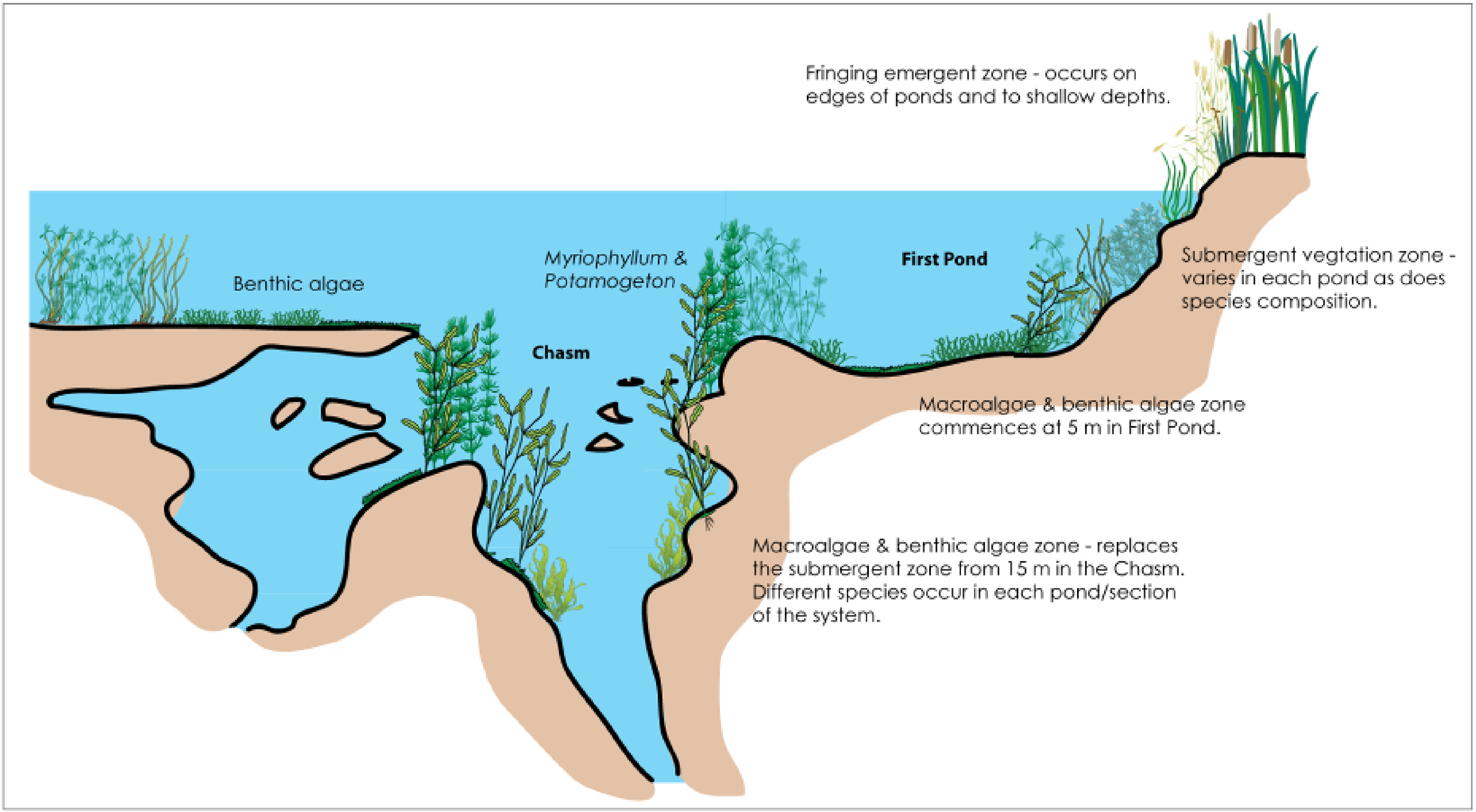


Figure 49: Vegetation zones within Main Ponds – based on distribution patterns described by Scholz (1987) and Thurgate (1995).

The relative importance of this habitat for fauna of the karst systems is not known as virtually no work has been done on assessing the faunal communities of the karst springs, particularly in the deeper sections of the system. This habitat does however constitute a key component of the ecological character of the site as the extensive aquatic plant growth is a unique feature of the karst wetlands, linked to the clarity of the groundwater. The water clarity and extensive plant growth are a major attraction for cave divers, thus contributing to the cultural services provided by the site.

Aquatic community – fen and marsh

Little formal information is available other than species lists for this habitat type. Mixed submergent and emergent species, herbs, grasses and sedges make up the vegetation associations that fall under this grouping. There are also a number of transition associations, those that are shifting from predominantly pasture and terrestrial species to wetland dominated associations. The majority of this grouping of vegetation associations is found in the west of the site, in Pick Swamp. The variation in hydrological regime, due to restoration actions, is reflected in the diverse range of vegetation associations within this area (see Figure 50 to Figure 52).

The fen and marsh vegetation associations of Pick Swamp provide important habitat for native fish species, and numerous waterfowl.

Figure 50: Example of fen area on water logged soils in Pick Swamp. Floristic description emergent ± *Eleocharis acutus*, ± *Juncus kraussii*, ± **Festuca arundinacea*, ± **Rumex* sp. sedges over *Cotula coronopifolia*, ± *Crassula helmsii* low forbland (from Ecological Associates 2008).

Figure 51: Transition zone Pick Swamp, recently inundated. Floristic description: *Juncus kraussii*, *Eleocharis acuta*, ± *Gahnia trifida* mid open sedgeland over ± *Graminae sp., ± *Crassula helmsii*, ± *Ranunculus amphitrichus*, ± **Rumex* sp. grasses (from Ecological Associates 2008).

Figure 52: Aquatic marsh, Pick Swamp. Floristic description: *Triglochin procerum*, ± *Eleocharis acuta*, ± *Leptocarpus brownii* tall open aquatic bed over *Crassula helmsii*, ± *Ranunculus amphitrichus*, ± *Myriophyllum salsugineum* aquatics (from Ecological Associates 2008).

Silky tea tree tall shrubland

This shrubland is relatively common throughout the nominated site. The overstorey is dominated by silky tea tree (*Leptospermum lanigerum)* of varying density from closed to open formation. Bottlebrush tea tree *(Melaleuca squarrosa*) occurs in some areas. Robust willow herb (*Epilobium billardierianum* ssp. *billardierianum)* and biddy-biddy (*Acaena novae-zelandiae*) contribute to the understorey. Found predominantly on loam soils, although located on peat soils in Pick Swamp (Foulkes and Heard 2003). An example of this association is shown in Figure 53.

This vegetation association provides critical habitat for many of the threatened species for which the site was listed. Bachmann (2002) describes the remnant silky tea tree on Pick Swamp as 'virtually unrivalled' in supporting threatened species. Threatened species found associated with the tea tree shrubland include the maroon leek-orchid (*Prasophyllum frenchii*), swamp greenhood (*Pterostylis tenuissima*) and late helmet orchid (*Corybas* sp. aff. *diemenicus*), Yarra pygmy perch (*Nannoperca obscura*), dwarf galaxias (*Galaxiella pusilla*), orange-bellied parrot (*Neophema chrysogaster*), rufous bristlebird (*Dasyornis broadbenti*), swamp antechinus (*Antechinus minimus*) and swamp skink (*Egernia coventryi*) (Bachmann 2002; Duncan *et al*. 2007).

Figure 53: Example of Silky Tea Tree Tall Shrubland. Floristic association *Leptospermum lanigerum*, *Melaleuca squarrosa*, ± *Ozothamnus ferrugineus*, ± *Leucopogon parviflorus*, ± *Acacia longifolia* ssp. *sophorae* tall closed shrubland over *Gahnia trifida*, ± *Gahnia clarkei* sedges over *Eleocharis gracilis*, ± *Baumea juncea*, ± *Samolus repens* sedges (image from Ecological Associates 2008).

Sedgelands, rushlands and grasslands

Sedgelands include associations dominated by *Gahnia*, *Baumea*, and *Typha* (although *Typha* is not a true sedge) among others (for example *Carex, Eleocharis*). Rushlands are dominated by species from the family Juncaceae. *Phragmites* is a grass and typically fringes deeper water areas. Each type is found in specific areas of the site and is closely related to the hydrological regime and local topography.

Several areas of *Gahnia trifida* are found in Pick Swamp in association with tall shrubland. This association is considered a transitional habitat with the climax association likely to be silky tea tree tall shrubland (Ecological Associates 2008). Tall sedge grass *(Gahnia clarkei)* is often associated with the silky tea tree (see Figure 53 above) and bottlebrush tea tree shrublands, but extends into sedgelands in parts of the Western wetland and immediately south of Crescent Pond. *Gahnia* sedgeland is one of the favoured habitats of the southern emu wren (*Stipiturus malachurus*) and swamp antechinus (*Antechinus minimus maritimus*) (Bachmann and van Weenen 2001).

Baumea sedgelands occur in the Western and Eastern wetland, around the Main Ponds and Hammerhead Pond.

Narrow leafed cumbungi (*Typha domingensis*) occurs as dense stands in a number of places throughout the Piccaninnie Ponds Karst Wetlands. *Typha domingensis* is a robust emergent aquatic herb which can reach up to two metres in height. It prefers still to slow flowing water up to two metres deep and can be a strong competitor. In the Western wetland area around Hammerhead Pond there are significant areas of this sedgeland (see Figure 54).

Dense stands of common reed in association with *Typha* and other emergent species are also found throughout the site, particularly fringing the karst wetlands in the Main Ponds and in the Western wetland.

Sedgelands and rushlands provide critical habitat for the Australasian bittern, threatened Lepidoptera and other fauna. The sedgelands and grasslands also contribute significantly to the formation of peat soils throughout the site.

Figure 54: Example of sedgelands. Floristic association *Baumea arthrophylla*, *Baumea juncea*, ± *Typha domingensis* sedgeland over ± *Triglochin procerum* aquatics (from Ecological Associates 2008).

***Leucopogon* shrubland**

This vegetation association constitutes most of the dryland vegetation associated with the dune system. However this association extends into the Western wetland area, in particular, and contains areas subject to inundation. This habitat consists of dense tall coastal shrubland, dominated by *Leucopogon parviflorus* and coastal wattle (*Acacia longifolia* var. *sophorae*) with coastal daisy (*Olearia axillaris*) and *Myoporum insulare* scattered throughout. Since the 1950s, it has been noted that the density of coastal wattle has increased (see section 7).

The orange-bellied parrot has been observed roosting in this habitat type within the site. However, as this vegetation association is not considered wetland dependent it is not considered critical to the ecological character of the site.

3.3.4 Fish

Fish habitat at the Piccaninnie Ponds Karst Wetlands is predominantly freshwater with a permanent connection to the sea, and a small estuarine environment. Historically the outflow from the Piccaninnie system flowed to the east into the Glenelg River estuary. Currently, however, the Piccaninnie Outlet Creek flows south through the dune system out to sea, maintaining a limited connection with the marine environment. Even so there are records of diadromous species using the Piccaninnie Outlet Creek as migratory route. Diadromous species are those which use both freshwater and marine areas at some time in their life cycle, these include Anadromous, Catadromous and Amphidromous fish, as described below. Most migrations are for feeding or breeding with fish being classified in the following groups (adapted from Hammer 2008a):

- **Anadromous** fish live in the sea mostly, but migrate to breed in fresh water.
- **Catadromous** fish live in fresh water; migrate to breed in the sea.
- **Amphidromous** fish migrate between fresh and salt water during some part of life cycle, but not for breeding.
- **Obligate freshwater** fish complete their life cycle in freshwater only, may or may not undergo migration.

The conservation status of the fish species from Piccaninnie Ponds Karst Wetlands is presented in Appendix C. A brief summary of the species recorded, their habitat preference, migration type and location within the Piccaninnie Ponds Karst Wetlands is shown in Table 11 with greater detail presented in Appendix D.

Table 11: Summary of fish species recorded at Piccaninnie Ponds Karst Wetlands.

Common name	Species	Habitat preference and location within site	Migration
Climbing Galaxias	*Galaxias brevipinnis*	Vegetation and flowing water are the key habitat requirements. Breeds during autumn and winter, laying eggs among vegetation on the stream edge above normal flow levels. The marine component of the life cycle is possibly facultative, and not well understood in South Australia. Found in Outlet Creek.	Amphidromous – adults live in fresh water but larvae may be washed out to sea for several months before returning inland.
Congolli	*Pseudaphritis urvillii*	Found in streams and estuaries. Inhabits slow-flowing water around log snags, under over-hanging banks or among leaf litter. Adult fish migrate downstream to spawn in weedy estuaries from late April to August. Predatory feeding on invertebrates and fishes. Found in Piccaninnie Ponds, Outlet Creek.	Catadromous
Dwarf galaxias	*Galaxiella pusilla*	Occurs among vegetation along the edge of still or slow-running waters including swamps, drainage ditches and backwaters of creeks. Adults live in both ephemeral and permanent habitats. A short-lived fish, reaching maturity in the first year of life and perishing shortly after spawning. Silky tea tree swamp surrounding Crescent Pond, and Pick Swamp.	Obligate freshwater
Pouched lamprey	*Geotria australis*	Typically found in mud burrows in upper reaches of coastal streams for the first four years of life, and then they	Anadromous

Common name	Species	Habitat preference and location within site	Migration
		migrate back to the sea. Adults inhabit the sea for an undetermined period and are parasitic on other fishes. They migrate upstream and spawn in freshwater. Found in Piccaninnie Ponds.	
Short finned eel	*Anguilla australis australis*	Found in streams lakes and swamps. Feeds on fishes, invertebrates, aquatic plants, and terrestrial and aquatic insects. Long lived species which migrate to near the Coral sea to breed. Larval eels return as elvers. Found in Piccaninnie Ponds, Outlet Creek.	Catadromous
Small-mouthed hardyhead	*Atherinosoma microstoma*	Normally associated with estuaries but also found in brackish lakes and slow flowing habitats adjacent to marine environments. Occurs on the edges of systems and prefers sits with aquatic vegetation. Annual species breeding in spring and early summer. Found in Piccaninnie Ponds, Pick Swamp and Western wetland	Amphidromous
Southern pygmy perch	*Nannoperca australis*	Prefers vegetated margins in still or gently flowing water. Found in Piccaninnie Ponds, Hammerhead Pond, Pick Swamp drain, Crescent Pond and Outlet Creek.	Obligate freshwater
Spotted galaxias	*Galaxias truttaceous*	Prefers covered areas along banks/ margins of pools. Larvae have a marine phase, returning inland as whitebait in spring. Feeds mainly on aquatic and terrestrial insects. Found in Outlet Creek, Crescent Pond and Pick Swamp.	Amphidromous
Variegated pygmy perch	*Nannoperca variegata*	Prefers fast flowing streams over wetlands, with clear water. Feeds on aquatic invertebrates. Historic record for Piccaninnie Ponds.	Obligate freshwater
Yarra pygmy perch	*Nannoperca obscura*	Prefers permanent water with abundant aquatic vegetation. Occurs in creeks and lakes, usually among aquatic weeds. Feeds on aquatic invertebrates. Found in Crescent Pond.	Obligate freshwater

Hammer (2002) describes the Lower South East karst region as a biodiversity hotspot for native fish, supporting both a high number of species and threatened taxa. Wetlands in the Piccaninnie Ponds Karst Wetlands are considered in excellent condition for fish, with no exotic species having been recorded at this site.

Species of note include dwarf galaxias, Yarra pygmy perch, spotted galaxias, climbing galaxias, and pouched lamprey. The dwarf galaxias is endemic to south-eastern Australia with populations in Victoria, South Australia and the far north of Tasmania (Saddlier *et al*. 2010). Dwarf galaxias, as with many of the other species found within the site, particularly Yarra pygmy perch, have a strong preference for highly vegetated habitat, a notable feature of the site. Dwarf galaxias are highly susceptible to habitat loss and are thought to have suffered considerable reduction in historic range. This species is highly adaptive and able to take advantage of ephemeral habitats, drainage lines and harsh environments (Hammer 2002).

Yarra pygmy perch are listed under the EPBC Act as vulnerable. Recent collections from Crescent Pond represent a new record for the area. This species has also exhibited a decline from its historic range, with only nine known localities from four areas in the South East of South Australia. These sites are highly fragmented and considered remnants from a once more extensive range of permanent wetlands (Hammer 2002).

Spotted galaxias have been recorded from the Piccaninnie Ponds Karst Wetlands in Outlet Creek (Hammer 2008a). Although relatively widespread in Victoria, this and another population in the nearby Eight Mile Creek Drainage area are the only two known South Australian locations, representing the westerly limit of this species distribution. The Piccaninnie Ponds sighting consisted of the greatest numbers ever recorded in South Australia, and prior to its recording this species was believed to be heading for local extinction (Hammer 2002).

Grayling (*Prototroctes maraena*) were recorded from Piccaninnie Ponds during the 1980s, but are thought to be transient species and are potentially locally extinct (Hammer 2002). Variegated pygmy perch (*Nannoperca variegata*) have also been recorded from the site but the record has not been verified (Hammer *et al*. 2007).

3.3.5 Waterbirds

Australian waterbirds are highly mobile, exhibiting opportunistic behaviour and occurrence (Jaensch 2002) with habitat resources and availability driving waterbird abundances. The movements of waterbirds are considered to be largely unpredictable and complex (Kingsford and Norman 2002) with the nomadic nature of many Australian waterbirds believed to have evolved in response to Australia’s variable climate (Scott 1997). The most predictable movements are seen in those species which migrate annually to the Northern Hemisphere and/or New Zealand.

Only birds that are considered wetland dependent are included in the ecological character description of the Piccaninnie Ponds Karst Wetlands, and so this excludes terrestrial birds recorded in adjacent landscapes. Consistent with the Ramsar Convention, a broad definition of “wetland dependent” has been adopted. Wetland dependant in this context is defined as birds that are associated with habitats and vegetation that are considered to require periods of inundation. Wetland dependency may apply only to certain life stages for some species.

Piccaninnie Ponds Karst Wetlands supports waterfowl, migratory shorebirds, and several sea birds all of which contribute to significance of the site for waterbirds.

The range of wetland types found at the Piccaninnie Ponds Karst Wetlands supports a considerable diversity of waterbirds and wetland dependent species. A total of 79 wetland associated bird species have been recorded within the site (

Table 12; Appendix E). These include species which are resident throughout the year, as well as transient species such as migratory shorebirds that use the Piccaninnie beach seasonally. This list includes 25 migratory species that are listed under international migratory agreements CAMBA (20), JAMBA (20), ROKAMBA (15) and BONN (16) as well as an additional 26 Australian species that are listed as migratory or marine under the EPBC Act. Eleven species of waterbird breed at the site, including brolga, hooded plover (*Thinornis rubricollis*), Australian shelduck (*Tadorna tadornoides*), black swan (*Cygnus atratus*), masked lapwing (*Vanellus miles*), magpie goose (*Anseranas semipalmata*), great cormorant (*Phalacrocorax carbo*), Pacific black duck (*Anas superciliosa*), musk duck (*Bizura lobata*) and Australasian bittern (see section 4.2.3).

Table 12: Wetland dependent birds recorded within the Piccaninnie Ponds Karst Wetlands.

Waterbird group	Typical feeding and foraging information	Number of species
Waterfowl	Shallow or deeper open water foragers. Vegetarian (black swan) or omnivorous with diet including leaves, seeds and invertebrates.	12
Grebes	Deeper open waters feeding mainly on fish.	3
Pelicans, cormorants, darters	Deeper open waters feeding mainly on fish.	4
Heron, ibis, egrets	Shallow water or mudflats. Feeding mainly on animals (fish and invertebrates).	12
Crakes, rails, water hens, coots	Coots in open water; others in shallow water within range of cover. Omnivores.	8
Shorebirds	Shallow water mudflats and beach foreshore. Feeding mainly on animals (invertebrates and fish).	23
Gulls, terns	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats.	9
Sea birds	Birds that live their lives predominantly in the open ocean, coming to shore only to nest, feed mainly on fish. Includes shearwaters, petrels and penguins.	2
Hawks, eagles	Shallow or deeper open water feeding on fish and occasionally waterbirds and carrion.	2
Wetland associated	Wetland vegetation dependant.	4
Total		**79**

It should be noted that because waterbirds are highly mobile, some with continental or international ranges of occurrence, and because many are secretive or easily overlooked within dense aggregations, lists of species recorded at a particular site are rarely complete and tend to increase over time. In 2007-2008 several species were recorded with numbers between 300--1000 individuals including grey teal, chestnut teal, hardhead, straw-necked Ibis, Eurasian coot, sharp-tailed sandpiper, whiskered tern and red-necked stints. A further seven species were recorded with abundances between 100-300 individuals (Australasian shoveler, Australian shelduck, hoary headed grebe, Australian white ibis, black-winged stilts, Pacific black duck, and black swan).

Monthly counts of waterbirds have been collected since May 2007 to June 2011 for Pick Swamp and reveal a relatively consistent number of species of waterbird present within this part of the site (Figure 55). On average annual counts are in the order of 48 species, with some interannual variation.

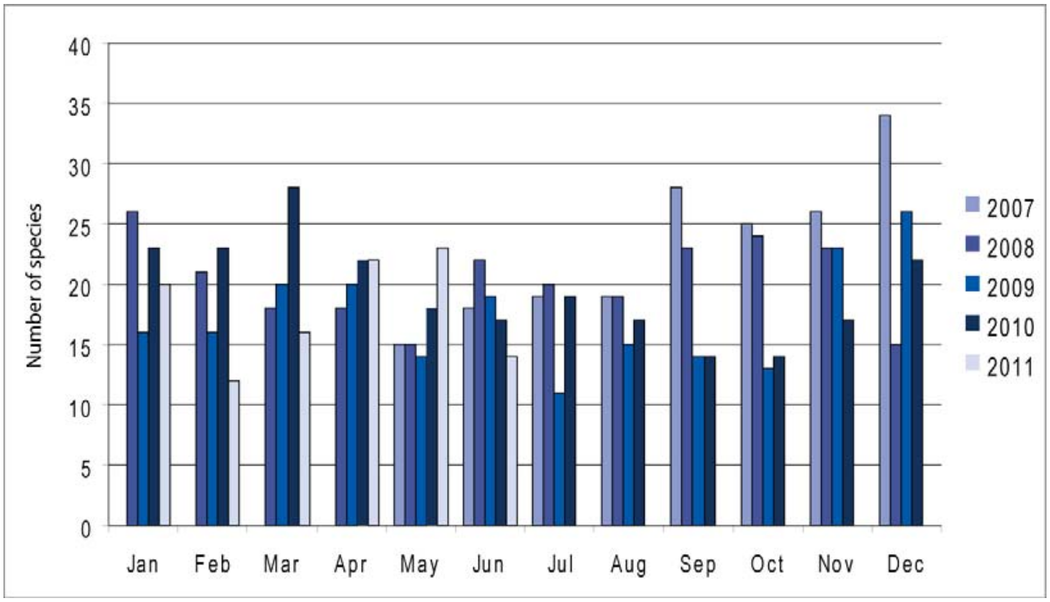


Figure 55: Waterbird species richness from May 2007 to June 2011 (data from Birds South East 2011).

The site does not support large numbers of individuals, with only 15 species having counts of 100 to 300, and of those fifteen only the black swan, hardhead and Pacific black duck having more than two large counts. Nine species have had counts between 300 to 1000 and whiskered tern and sharp-tailed sandpiper have each had a single count over 1000. Most records are for counts less than 100 individuals for each species (Birds South East 2011).

As the site is coastal and includes a beach area with a permanent source of freshwater (Outlet Creek and beach springs) the site supports 23 species of shorebird. This includes the hooded plover (*Thinornis rubricollis*), which uses the beach areas of the site, having been sighted roosting and breeding on the upper zones of the beach (Clarke 2007). Whilst no longer listed under the EPBC Act many still consider this species to be of high conservation significance. Despite the beach area being relatively small the site periodically supports more than one percent of sanderling. Records for seabirds are limited and this group of waterbirds is very likely underestimated here.

The site is recognised as part of an Important Bird Area which extends from Discovery Bay in Victoria to Piccaninnie Ponds (Birds Australia 2007), being important for Australasian bittern, hooded plover, orange-bellied parrot and two terrestrial species.

4 Ecosystem services

4.1 Overview of benefits and services

Ecosystem benefits and services are defined under the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems (Ramsar Convention 2005). This includes benefits that directly affect people such as the provision of food or water resources as well as indirect ecological benefits.

The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) defines four main categories of ecosystem services:

1. **Provisioning services** - the products obtained from the ecosystem such as food, fuel and fresh water;
2. **Regulating services** – the benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation;
3. **Cultural services** – the benefits people obtain through spiritual enrichment, recreation, education and aesthetics; and
4. **Supporting services** – the services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time.

The key ecosystem benefits and services of the Piccaninnie Ponds Karst Wetlands are outlined in Table 13 .

Table 13: Ecosystem services and benefits provided by Piccaninnie Ponds Karst Wetlands.

Category	Description
Provisioning services - products obtained from the ecosystem such as food, fuel and fresh water	
Indigenous food and resources	The Boandik people of South East are the Traditional Owners of the site having used the site for food and resources including eels, fish, bush tucker, and eel smoking trees. Middens are located on the site.
Regulating services - benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation	
Maintenance of hydrological regimes	Groundwater discharge from the karst springs provides surface water to surrounding areas creating peat fen wetlands, and areas of permanent water.
Hazard reduction - reduced risk of fire	Presence of permanent surface water and wet soils reduces risk of wildfire.
Incidental regulating services	Erosion control, pollution control and detoxification, climate regulation, biological control of pests and diseases potentially occur at the site, however they are incidental and not considered of major importance. There is limited information on each of these services for the nominated site.
Cultural services - benefits people obtain through spiritual enrichment, recreation, education and aesthetics	

Category	Description
Recreation and tourism	International cave diving and snorkelling site.
	Recreational fishing on the beach.
	Passive recreational activities such as nature observation, bushwalking around the karst wetlands, as well as along the beach, although there is limited access for some of the site.
Spiritual and inspirational	The site has inspirational, aesthetic and existence values at regional, state and national levels.
Scientific and educational	Scientific reference area/site – remnant wetland type and vegetation associations. Has the potential to provide a window into the past through fossil pollen record in peat fen wetland.
	Research and education opportunities particularly relating to groundwater dependent ecosystems and karstic landscapes.
	Long term monitoring site.
Supporting services - services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time	
Special ecological, physical or geomorphic features	Supports a unique combination of rising spring karst wetlands, groundwater beach springs and peatland fen wetlands.
Physical habitat which supports waterbirds and critical life stages of biota	Wetlands support 79 species of waterbirds including migratory species. Diversity in habitat provides supports a range of feeding guilds. The site is important as a roosting and feeding site for orange-bellied parrot and other migratory species.
Biodiversity	The wetland has high biodiversity values, including high species richness, high habitat diversity, and supports threatened species and biota representative of the bioregion. The site supports a diverse fish population, with no exotic species present. Overall the site lies within one of 15 national biodiversity hotspots.
Supports priority wetland species	Supports 20 migratory waterbirds listed under various international treaties.
Soil formation	Accumulation of organic matter in waterlogged conditions leading to formation of coastal peat fen. Strongly interconnected with groundwater discharge from the karst springs.
Nutrient cycling	Carbon sequestration – data deficient but plausible – linked to peat formation.
Ecological connectivity	Supports a range of diadromous and obligate freshwater native fish with the connection to the sea via Outlet Creek being critical to sustain the diversity of fish species at the site.

Similar to the process for identifying critical components and processes the critical ecosystem services and benefits have been identified in relation to the reasons the site is nominated as a wetland of international significance (see section 4.2 below). However, as there are no criteria for listing that relate to cultural and economic services, and the site is culturally significant to both Indigenous and non-Indigenous communities, a brief description of the cultural and economic services provided by the site is presented below.

Recreation and Tourism

Piccaninnie Ponds Karst Wetlands, in conjunction with nearby Ewens Ponds, are internationally renowned cave diving locations, due to exceptional water clarity. The site has a public visitation of 20 000 people a year who come to enjoy the unique vegetation, walk and fish on the pristine beaches, and dive in the deep subterranean caves formed over thousands of years by the upwelling of groundwater through the limestone.

The beach area of the site is used for recreational fishing; however no fishing occurs within the freshwater wetlands. Passive recreation activities include nature observation, bushwalking and bird watching.

Indigenous values

The unique karst system has significant Indigenous values as well as providing inspirational and aesthetic values. The Boandik and local Indigenous people of the South East have a strong connection with the site recognising the key importance of the groundwater discharge, and an appreciation that cultural economy is intrinsically linked with wetland health. The Piccaninnie Ponds Karst Wetlands provided a number of resources and foods to the Boandik, with middens and evidence of occupation remaining today. The site was considered a very good place to live providing an abundance of food and resources for the old people.

4.2 Identifying critical services and benefits

The critical ecological ecosystem services and benefits of the Piccaninnie Ponds Karst Wetlands have been identified using criteria specified in the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands. Module 2 of Australian National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia* (DEWHA 2008):

1. are important determinants of the site's unique character;
2. are important for supporting the Ramsar or DIWA criteria under which the site was listed;
3. for which change is reasonably likely to occur over short or medium time scales (less than 100 years); and/or
4. that will cause significant negative consequences if change occurs.

Using these criteria it was considered that six ecosystem services could be considered 'critical'; these are:

- Regulating service: Maintenance and regulation of hydrological cycles and regimes.
- Supporting service: Special ecological, physical or geomorphic features.
- Supporting service: Provides physical habitat for waterbird breeding and feeding and critical life stages.
- Supporting service: Threatened species.
- Supporting service: Biodiversity.
- Supporting service: Ecological connectivity.

With respect to threatened species, only those for which the site comprises important habitat were considered to meet all four of the DEWHA (2008) criteria for determining critical components processes and services. As such the threatened species that are identified as critical to the ecological character of the site are:

- Australasian bittern.
- Orange-bellied parrot.
- Dwarf galaxias.
- Yarra pygmy perch.
- Maroon-leek orchid.

4.2.1 Maintenance and regulation of hydrological cycles and regimes

Continuous upwelling of fresh groundwater into the karst wetlands provides a permanent freshwater habitat which supports diverse aquatic flora and fauna. The site acts as a drought refuge, with the presence of permanent open water considered a critical feature of the site. Flows into the karst wetlands are in part caused by a barrier at the coastal dunes which prevents groundwater flowing into the sea, and forces the upwelling. The dunes also form a barrier to surface water flows, leading to ponding along the base of the dune system Overspill from the karst wetlands into the surrounding landscape has combined with the impeded surface drainage and decaying vegetation to lead to the formation of extensive peat soils and fen wetlands.

4.2.2 Special ecological, physical or geomorphic features – unique wetland types: karst and fen

The unique nature of the karst and fen wetlands of the site underpins the character of the site. The formation of the cavities was predominantly from dissolution of the limestone with the bedrock largely intact. The Piccaninnie Ponds karst wetlands originally formed as dry surface depressions (dolines) where rainwater seeped into the joints of the limestone which were gradually widened by dissolution. One crack would have widened faster than others leading to the development of a void and subsidence of the surrounding land (Hallam and Thurgate 1992). When the rate of dissolution is greater than accumulation of insoluble material in the depression the master joint will deepen creating a funnel. Pressurised groundwater was forced up into the dolines via the master joints leading to the creation of the chasms through a combination of continued dissolution and scouring from the upwelling groundwater. Turtle and First ponds are basin dolines and the Chasm is a funnel doline. In geomorphological evolution the Cathedral is a late addition to the complex system (Hallam and Thurgate 1992). The formation of the Piccaninnie Ponds is illustrated in Figure 56.

Hydrological and geomorphological processes are the key drivers of the formation of the site. The continual expression of the groundwater into the surrounding landscape as overspill from the karst springs, combined with vegetation decay led to the formation of peat soils and the creation of a substantial fen wetland system. The Piccaninnie Ponds Karst Wetlands is the largest remaining coastal fen system in South Australia. Fen wetlands are rare within Australia and highly prone to fragmentation and loss through drainage.

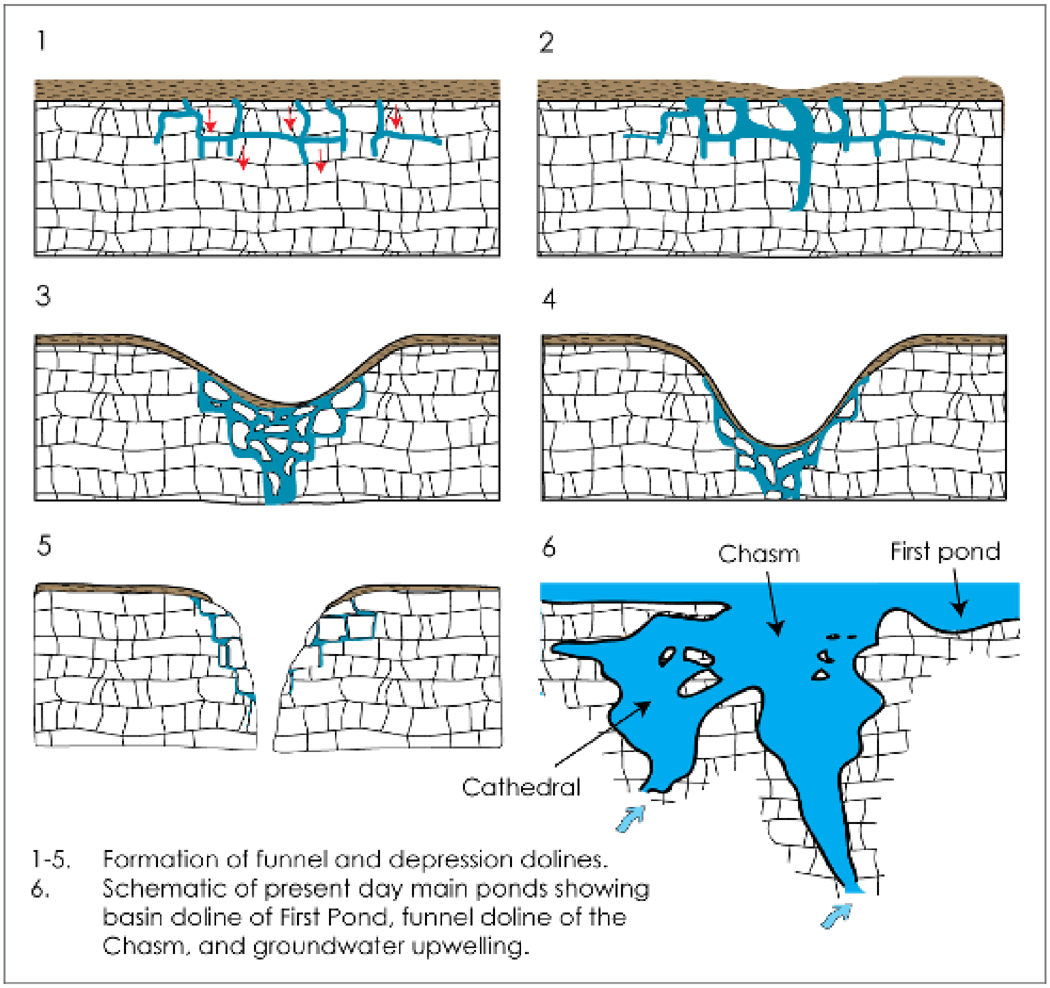


Figure 56: Formation of karst wetlands at Piccaninnie Ponds (after Hallam and Thurgate 1992) and present day Main Ponds system.

Peat formation requires two primary processes, a positive water balance and organic material accumulation (Mitsch and Gosselink 2000). Peat is created when there is an accumulation of carbon as primary productivity exceeds decomposition with the dead organic matter accumulating (Batzer and Sharitz 2006; Rydin *et al*. 2006). Water logged conditions leads to low oxygen and reducing conditions thus slowing the decomposition of organic material and leading to peat deposition overtime (Rydin *et al*. 2006).

Peat can be created under a range of hydrological and physical conditions, with two common types widely recognised; bogs and fen. Fens are formed where mineral rich groundwater flows are sustained to the plant rooting zone, and support a range of vegetation types including grasses, sedges, reeds, shrubs and trees (Batzer and Sharitz 2006). The alkaline nature of fens and the fact that their primary water source is groundwater, with some surface and rainfall inputs, distinguishes them from bogs which are dominated by surface water inputs. The major area of peat soils is found within Pick Swamp with a smaller area on the northern edge of Piccaninnie Ponds.

The peatlands at the site are topogenous in nature, in that they have developed in topographical depressions with the main water source being from regional groundwater (Batzer and Sharitz 2006). At this point in time there is no specific information regarding how the fen wetlands formed within the Piccaninnie Ponds Karst Wetlands, other than the peat is believed to have formed over the previous 5,500 years and that different vegetation associations have led to the formation of different peat types (see below). Some generalities can be made about the fen wetland formation, and how this, in turn, may influence the ecological character of the Piccaninnie Ponds system.

In general fens are more alkaline and nutrient rich than bogs as their main water source is mineral rich groundwater with some surface and rainfall inputs. Initially fens start as basins dominated with open water. Water flow into and through the basin is a critical element in the formation of peat/fens. Water quality/chemistry is the other key determinant of the formation of peat and the eventual vegetation the fen wetland will support.

A hypothesised initial and current state of fen development is presented in Figure 57. At the beginning of the fen formation peat deposition would have been slow and likely restricted to the edges of the wetlands. Open water habitat would have dominated the wetland. Over time, (estimated as 5,500 years for Piccaninnie Ponds) peat deposition would continue, extending beyond the edges of the wetland and ultimately affecting the topography of the wetland area. At the well established phase the peat accumulation can now influence patterns of surface water movement.

It is possible to classify the fens further according to water chemistry, hydrological, and topographical origins, as there are a number of different classification systems available (e.g. see Mitsch and Gosselink 2000 for discussion of various systems). Section 3.2.3 list three types of peat identified within the site each being associated with different vegetation associations. Different plants will decay at different rates thus giving rise to different types of peat. However limited details regarding these aspects of the fens of Piccaninnie Ponds Karst Wetlands are available and this remains a knowledge gap.

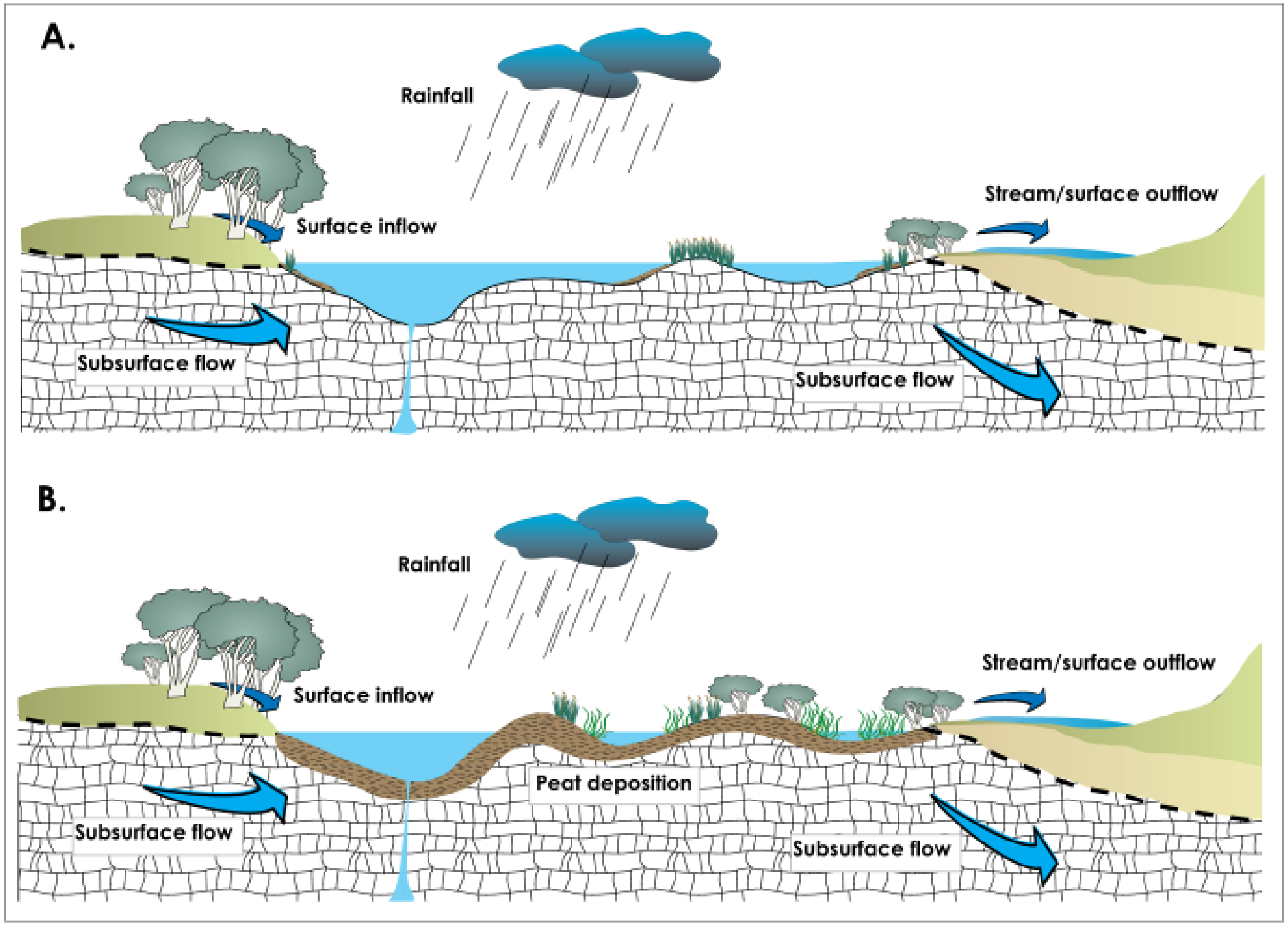


Figure 57: General conceptual model of fen formation. A. Wetland area dominated by open water with initial peat deposition on edges of wetland. B. Substantial peat deposition with reduced open water areas. Establishment of new vegetation associations, herb, grass and sedge dominated. Peat deposition now influences surface water movement.

4.2.3 Provides physical habitat for waterbird breeding and feeding and critical life stages

Piccaninnie Ponds Karst Wetlands provides a range of habitats that support wetland birds in terms of feeding and breeding. The site is also important in supporting critical life stages of waterbirds and fish. The extent, condition and use of habitat types have not been assessed across the Piccaninnie Ponds Karst Wetlands. What is known, or can be deduced through ecological principles about habitat types within the system are described in Table 14.

Table 14: Predicted wetland habitat usage within the Piccaninnie Ponds Karst Wetlands.

Habitat	Description	Key fauna and flora
Karst spring wetlands	Permanent open water with relatively constant water quality.	Fish, macroinvertebrates, some waterbirds. Provides spawning grounds for fish. Supports aquatic macrophytes and algal associations.
Peat wetlands – fens/ sedgeland, rushland and grassland wetlands	Submergent and emergent herbs grasses, reeds, rushes and sedges. May change seasonally with intermittent wetlands supporting different successional stages.	Australasian bittern and other waterbirds. Invertebrates, frogs and waterbirds. Provide foraging and possibly nesting sites for some waterbirds.
Shrubland wetlands	Extensive stands with varying composition, includes Silky tea tree shrublands.	Key threatened species including orchids, fish and other plants. Important roosting area for orange-bellied parrot. Important for swamp antechinus.
Drains and Outlet Creek	Includes Outlet Creek and drains in Pick Swamp.	Fish, aquatic plants. Important migratory corridors and areas of deeper water for fish.
Beach	Beach area forms the southern boundary of the site and includes the mouth of Outlet Creek and beach springs	Shorebirds feeding and roosting site. Foraging site for orange-bellied parrot.

<u>Waterbird breeding</u>

Eleven species of waterbirds have been recorded breeding from the site. This number may rise as the restoration of the hydrological regime at Pick Swamp continues. Waterbirds that breed within the site utilise different habitats for foraging, roosting and breeding and a network of different habitat types is required to meet all of their needs.

Waterbirds breed in response to season, flooding and for some species rainfall, with both availability of nesting habitat as well as food resources influencing when breeding commences. There is evidence to suggest that waterbird breeding occurs when food resources are at a maximum (Kingsford and Norman 2002). Once breeding has commenced, many Australian waterbirds require surface water to remain in and around nesting sites until offspring are independent feeders (Jaensch 2002). The breeding stimuli for each species are provided in Table 15.

Table 15: Main breeding stimuli for the waterbirds which breed within Piccaninnie Ponds Karst Wetlands.

Breeding stimuli	Common name
Flooding	Black swan, brolga.
Flooding, season	Australian shelduck, Pacific black duck.
Season, flooding	Purple swamphen.
Season	Musk duck, Australasian bittern, hooded plover.
Rainfall, season	Magpie goose.
Anytime	Masked lapwing, great cormorant.

Breeding stimuli for black swans and brolga is flooding, and their breeding on site is likely a response to the changed water regime within Pick Swamp since restoration activities commenced. Australasian bittern are resident at the site and breeding has been recorded in 2009 (Birds South East 2011). This species is believed to breed on site annually but due to its cryptic nature confirmation of breeding is difficult to achieve.

Hooded plovers prefer sandy ocean beaches, especially those that are broad and flat, with a wide wave-wash zone for feeding, much beach-washed seaweed, and creek mouths or inlet entrances with large flat areas of sand and some storm wrack. Breeding usually occurs from August to March on the high side of beaches strewn with beach-washed seaweed, in the narrow strip between the high-water mark and the base of the fore-dunes. The nest is a scrape in the sand near debris, making it vulnerable to predators and beach disturbance. Hooded plovers display high nest site fidelity and nest solitarily, with nests often being anywhere between two to five kilometres apart (http://www.environment.gov.au/biodiversity/threatened/publications/action/birds2000/pubs/hooded-pl-e.pdf).

Australian shelduck breed in shallow fresh/brackish lakes, lagoons, and marshes with short grasslands and with scattered trees. In winter they move onto large water bodies, estuaries and sheltered coasts. Masked lapwings breed on dryland areas around the wetlands of Pick Swamp.

Prior to 2009, Bool and Hacks Lagoon Ramsar site north of Mount Gambier was believed to be the only location at which magpie geese breed in South Australia. However, monthly survey data has reported small numbers of birds breeding at Pick Swamp for the past three years (Birds South East, 2011).

Great cormorants are sociable birds which usually form colonies when breeding. Breeding can occur at any time depending on food supply. Both sexes build the nest, which is a large structure of sticks placed in a low tree or on the ground. Both parents also incubate the eggs and care for the young. Only one record of breeding has been made for this species in 2009 at Pick Ponds (Birds South East, 2011). Musk duck have also only been recorded breeding at the site once. This species tends to prefer deep water habitats.

Pacific black duck usually prefers to breed on deep permanent heavily vegetated wetlands, but will also use open water and wet paddocks. Nests are established either on the ground, in tree holes or in the old nests of other birds. Purple swamphen have been recorded breeding at Pick Swamp for the past three seasons (Birds South East 2011).

Waterbird feeding

Waterbirds exhibit a range of foraging and feeding strategies, which ultimately affect how they use wetlands. As a result different species are able to use the same areas by feeding on different resources (Kingsford and Norman 2002). Bill shape and size is often related to diet, and closely related species can use different habitats but eat the same or different prey. Diet requirements affect the behaviour and patterns of habitat use; for example, it is typical to see herbivorous species feeding for extended periods, as their food is harder to digest.

Ducks, swans, geese, grebes, coots and waterhens encompass a range of feeding strategies and foraging and roosting habitats but most are herbivores partial to heavily vegetation inland wetlands. Whilst the site does support a number of waterbirds whose diet is wholly or mostly comprised of fish, many of the fish eating waterbirds require deep water for diving and plunging and may not be using the site as a principal feeding area. Fish eating waterbirds include the terns, cormorants and darters. Pursuit divers such as terns require open water expanses and may be using the ocean as their primary feeding grounds.

Ardeidae and Threskiornithidae (herons, egrets, spoonbills and ibis) are often referred to as large waders, and typically feed in shallow water (usually less than 15 centimetres). There are 23 species of shorebirds recorded from the site, and as stated above, based on recent data, these are not abundant within the site. Foraging and feeding strategies of some of the waterbird species found within the site are provided in

Table 16; further information is presented in Appendix G.

Table 16: Foraging habitat and feeding behaviour of several species found within Piccaninnie Ponds Karst Wetlands. Information based on Marchant and Higgins (1990) and Simpson and Day (1996).

Species	Foraging habitat and behaviour
Australian grebe, *Tachybaptus novaehollandiae*	Foraging habitat includes open water but also among vegetation. They feed mainly by diving but also swimming with head and neck immersed and swinging from side to side, floating in one position, peering through carpets of surface vegetation, stealing in crouched pose upon insects perched on floating vegetation, snatching insects from substrate. They feed on fish, snails and wide variety of aquatic invertebrates. It's likely they have a preference for free swimming prey.
Australian wood duck, *Chenonetta jubata*	They feed mainly grazing on land, are sociable with family parties joining flocks, usually of less than 100 birds. They usually graze on waterside areas, mainly at night. They eat green grasses, herbs, sedges plus some aquatic plants in winter. Very few seeds eaten.
Australian shelduck, *Tadorna tadornoides*	Mainly found grazing on land, also dabbling, head-dipping and scything on water. Crepuscular (evening and morning) feeding pattern. The diet is poorly known, but appears to include a range of vegetation and invertebrates (molluscs, mussels, crustaceans, cladocerans, and insects).
Black swan, *Cygnus atratus*	Prefer large open expanses of water, fresh through to saline with abundant vegetation. Dabbles on surface, upends. Grazes pasture or flooded fields. Basically vegetarian, mainly eating submerged aquatic plants, algae and pondweeds.
Great cormorant, *Phalacrocorax carbo*	Prefers large open areas of water and lakes and major rivers, less common on temporary systems or small systems. Requires trees, branches or stumps for perching. Feeds on fish, crustaceans, frogs and aquatic invertebrates. Feeds by capturing prey in shallow underwater dives, which often last for more than a minute.
Grey teal, *Anas gracilis*	Often feed in small to large flocks, eating plants, seeds as well as invertebrates. Exhibit a range of feeding methods including dabbling, upend and feed from the bottom, or grazing from the surface.
Little pied cormorant, *Microcarbo melanoleucos*	Feed on a wide variety of aquatic animals, including invertebrates and fish, with freshwater crayfish/yabbies being a preferred food item. Feeding mode includes deep underwater dives with both feet kicking outward in unison. Other crustaceans are also taken, with shrimps being a large part of their diet in cooler months.
Masked lapwing, *Vanellus miles*	Feed on terrestrial insects and their larvae, and earthworms. Most food is obtained from just below the surface of the ground, but some may also be taken above the surface. Birds are normally seen feeding alone, in pairs or in small groups.
Pacific black duck, *Anas superciliosa*	Predominantly vegetarian, eating seeds of aquatic and fringe vegetation, and other plants. Some animal material is taken including bivalve molluscs, aquatic insects, and freshwater crayfish. They mainly feed nocturnally.
Yellow-billed spoonbill, *Platalea flavipes*	Diet is predominantly invertebrates. Foraging occurs in shallow mud using the vibration detectors in its bill to detect movement of prey in the mud.

Migratory waterbirds

Twenty five migratory waterbird species have been recorded from the site, with a further 26 nomadic Australian species (listed as migratory within Australia under the EPBC Act). Migratory shorebirds in Australia are a part of the Asia-Pacific flyway. They migrate from breeding grounds in the Arctic Circle to non-breeding grounds in Australia and New Zealand, covering the journey of many thousands of kilometres in a single year. Habitat preferences of some of the migratory shorebirds are shown in Table 17. Since 2006 surveys of waterbirds at the Piccaninnie Ponds Karst Wetlands by Birds South East have indicated that 60 percent of the migratory species were utilising the wetlands and 40 percent the beach (Birds South East ,2011). More survey work is required to establish clear patterns of habitat use over time.

Table 17: Habitat preferences for some of the migratory shorebirds supported by the Piccaninnie Ponds Karst Wetlands.

Shorebird	Breeding Area	Preferred Habitat in Australia
Common greenshank	Arctic circle, Siberia	Wide variety of inland and sheltered coastal wetlands - mudflats, saltmarshes, mangroves
Curlew sandpiper	Arctic Tundra	Intertidal mudflats of sheltered coastal areas, coastal lakes, estuaries, bays and occasionally inland wetlands.
Double-banded plover	New Zealand	Littoral, estuarine and fresh or saline terrestrial wetlands, grasslands and pasture.
Red-capped plover	Mongolia, China	Inland - grasslands, roost on beaches or muddy margins of terrestrial wetlands.
Red-necked stint	Northern Siberia, Alaska	Mostly coastal sheltered inlets and estuaries with intertidal mudflats - occasionally on ocean beaches, commonly on inland lakes.
Ruddy turnstone	Northern Siberia, Alaska	Wide variety of habitats - generally mudflats or rocky coastline – rarely inland waters.
Sanderling	High arctic regions – Alaska, Greenland, Russia	Mostly open sandy beaches.
Sharp-tailed sandpiper	NE Siberia	Muddy edges of shallow fresh or brackish water. Common on both intertidal and inland waters.

The orange-bellied parrot utilises the site as a part of its winter migration into South Australia. It has been recorded in a number of habitats in the site including the beach area, grassland surrounding Pick Swamp and shrubland in the Western wetland.

4.2.4 Supports threatened species

Piccaninnie Ponds Karst Wetlands support seven nationally or internationally threatened species, five of which are considered critical to the ecological character of the site. A combination of components and processes within the site combine to support these species. The ecological requirements are in some cases poorly understood; however a summary of known information is presented in Table 18.

Table 18: Summary of ecological requirements for threatened species occurring at Piccaninnie Ponds Karst Wetlands.

Australasian Bittern (*Botaurus poiciloptilus*)	
Maintenance of taxa	Inhabits inland wetlands, and occasionally, estuarine wetlands, generally where there is permanent water. Prefers wetlands with dense vegetation, including sedges, rushes and reeds. Freshwater is generally preferred, although saltmarsh vegetation in estuaries and flooded grasslands are also used by the species.
Regeneration & reproduction	Little information available regarding breeding. Breed from October to February. Nests built approximately 30cm above water level from reeds or rushes.
Yarra Pygmy Perch (*Nannoperca obscura*)	
Maintenance of taxa	Inhabits slow flowing streams and wetlands with large amounts of aquatic and surrounding vegetation. Usually found in small groups, often mixed with Southern Pygmy Perch. Will utilise drains as well.
Regeneration & reproduction	It breeds in spring, at water temperatures between 16 and 24°C.
Dwarf Galaxias (*Galaxias pusilla*)	
Maintenance of taxa	Live in slow flowing freshwater habitats in the shallows and along the margins of wetlands, drains, backwaters of streams that are overgrown with aquatic macrophytes. They may also occur in temporary waters that dry in summer but remain connected to a permanent water supply. They are capable of aestivating for several months in mud and or yabby burrows if the wetland dries.
Regeneration & reproduction	Spawning occurs around August, with eggs deposited on aquatic plants, stones and leaves. Eggs hatch after approximately three weeks and are mature after approximately one year. Adults die after spawning.
Orange-bellied Parrot (*Neophema chrysogaster*)	
Maintenance of taxa	Uses the site as a winter roosting and feeding ground during its winter migration into South Australia. Utilises the beach, shrublands and pasture areas of Pick Swamp.
Regeneration & reproduction	Not relevant to Piccaninnie Ponds Karst Wetlands
Maroon Leek-orchid (*Prasophyllum frenchii*)	
Maintenance of taxa	Perennial terrestrial orchid that emerges annually from an underground tuber. Grows in variety of grassland or grassy woodland habitats. Plants grow in damp soil, which is usually well drained. In Piccaninnie Ponds the orchid grows in seasonally wet/inundated grassy-sedgelands that occur over limestone pavements.
Regeneration & reproduction	Flowers between late October and December. Produces a single slender flowering spike bearing 20-60 small flowers. Flower spike to 60 cm tall. Reverts to dormancy in late February as an underground tuber, when the life-cycle is complete. Seed capsules may be produced and can be seen for several more months.
Swamp Greenhood (*Pterostylis tenuissima*)	
Maintenance of taxa	Grows exclusively in tall dense closed shrublands dominated by *Leptospermum lanigerum* in alkaline peat soils.
Regeneration & reproduction	Appears to be reproductively opportunistic, having been observed flowering during all months of the year.

Glenelg Spiny Crayfish (*Euastacus bispinosus*)	
Maintenance of taxa	Found in cool, flowing freshwater streams or drains with high water quality
Regeneration & reproduction	Mating occurs in May/June then females carry eggs for 6 months and then the hatched larvae for a further month.

The Australasian bittern (*Botaurus poiciloptilus*)(Figure 58) has been recorded at the site eleven times in a five year period (2003-2008 Birds SE data) and is considered a resident species with records every year at Pick Swamp from 2007 to 2011. The Australasian bittern has very specific habitat preferences preferring shallow, vegetated freshwater or brackish wetlands with a mixture of short and tall emergent sedges/rushes and is highly susceptible to habitat loss (BirdLife International 2006; TSSC 2011a).

Although there is some evidence that it will utilise ephemeral wetlands permanent systems are preferred. The loss of drought refuges may also have an impact on this species with the loss of permanent wetlands/drought refuges in South Australia postulated as a possible reason for decline in that state (BirdLife International 2006). The current Australian population is thought to be in the order of 250 to 800 birds, with the majority being found within the south-eastern sub population (TSSC 2011a). The Australian area of occupancy is in decline and is estimated as being approximately1150 square kilometres (TSSC 2011a).

Figure 58: Australasian bittern (*Botaurus poiciloptilus*) (Ian Montgomery, Birdway).

The site is considered important roosting site as it regularly supports one percent or more of the adult population of the critically endangered orange-bellied parrot (OBP) (*Neophema chrysogaster*) (Figure 59). The OBP is also listed under Appendix 2 under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as a species threatened with extinction (Commonwealth of Australia 2005).

Figure 59: Orange-bellied parrot (*Neophema chrysogaster*) (Ian Montgomery, Birdway).

Data from Birds Australia show that in the period 1985-2008 there were at least 17 OBP sightings at the Piccaninnie Ponds Karst Wetlands (Birds South East 2011). Considering the low numbers remaining in the wild this represents a significant record of usage for the site. This species uses salt marshes, coastal dunes, pastures, shrublands, estuaries, islands, beaches and moorlands typically within 10 kilometres of the coast as habitat during the winter migration in South Australia and Victoria (Commonwealth of Australia 2005). At the Piccaninnie Ponds Karst Wetlands sightings have been made on the edge of the marshes in Pick Swamp, the beach at Piccaninnie Ponds Conservation Park between the beach access track and Outlet Creek and various locations extending along the beach to the Victorian border, and on various tracks and roads throughout the site (in flight) (R. Green, Birds South East, pers. comm. 2007). The site is considered an important roosting site for the species.

4.2.5 Biodiversity

Piccaninnie Ponds Karst Wetlands supports a diverse assemblage of endangered, rare and non-threatened flora and fauna which are highly representative of pre-European biodiversity typical of the Lower Limestone Coast region of South Australia. The site falls within a recognised national biodiversity 'hotspot' and even though complete survey data are not available, the data in hand suggests this is an incredibly rich site. Listed species and communities of conservation significance found within the Piccaninnie Ponds Karst Wetlands are presented in Appendices C -E.

The biota of the subterranean areas of karst wetlands often contain endemic and rare species, however the fauna of the Piccaninnie Ponds system is not documented and constitutes a significant knowledge gap. It is expected that the fauna of the karst wetlands will contribute a unique element to the regional biodiversity. Meiofauna associated with the beach springs are also likely to contribute to the unique suite of biota found at this site.

For its size (862 hectares) the site supports a rich waterbird assemblage with 79 species recorded to date. It is likely that this number is an under estimate, especially with regards to the number of sea birds that may use the site. Nearby Lake Frome, a larger coastal Conservation Park supports only 66 waterbird and six migratory (DEH 2003). Bool and Hacks Lagoon Ramsar site has a similar number of species with 79 waterbird and 22 migratory species (greater than 3000 hectares) (DEH 2006). The site also supports 79 dryland bird species (Birds South East 2011).

The site supports 10 native fish species and includes species with three different migration strategies (Hammer 2002; Hammer 2008a). The lack of introduced fish species in the Piccaninnie Ponds Karst Wetlands enhances the value of this site considerably. Hammer (2002) describes this site as "spectacular" in "excellent condition" and a biodiversity hotspot for native fish.

Over 250 native species of plants had been identified at this site, including 63 wetland plant species (data from supplied by DEH and South Australian Herbarium).

Invertebrate surveys are incomplete; however six species of butterflies recorded from the site are of conservation significance, with three of them reliant on wetland host plants (Sands and New 2002).

The critical components and processes which support this service are geomorphic setting and hydrology. These create the habitat diversity and results in diverse food resources.

4.2.6 Ecological connectivity

Seven of the ten native fish species supported by Piccaninnie Ponds Karst Wetlands are diadromous (see section 3.3.4), migrating between the freshwater wetlands and the marine environment at some stage of their life cycle. The upwelling groundwater and subsequent overflow into Outlet Creek maintains the hydrological connection with the sea, thus sustaining this service. The hydrological connectivity, permanent water source, dense vegetation and good water quality are all key habitat features that support the fish populations within the Piccaninnie Ponds Karst Wetlands. However without the connection to the sea, the fish diversity could be significantly reduced.

4.3 Ecological character conceptual models

Documenting the ecological character of a site requires an understanding of how components, processes and services interact: how the unique combination present at a site determines the ecological character of the site. Wetlands are dynamic and complex ecosystems and documenting how they work at the fine scale is a daunting task, often beyond the limits of the data in hand. In order to aid describing the ecological character of the site a number of character conceptual models, specific to the site, have been developed. These models show the components, processes and services which contribute to the ecological character of the site. The models are simple models and do not attempt to show every interaction.

Wetlands are generally appreciated for what can be seen – the flora and fauna of the site and in many cases the listing of sites as Wetlands of International Importance reflects this (for example wetlands which support spectacular aggregations of waterbirds). For the Piccaninnie Ponds Karst Wetlands the drivers of the site's ecological character are the geomorphic setting and hydrological regime which produce the physical habitat template. These in turn support, and in some cases are influenced by key species and communities (threatened species, fish, vegetation associations and waterbirds).

Several models have already been presented in the previous sections, for example models for karst and fen formation (see Figure 56and Figure 57 above). Presented below are two models which detail the relationship between the critical components, processes and services of the site. The first is a reproduction of Figure 23 which is an overarching model which provides a simple outline of the linkages between components, processes, services and the Ramsar criteria for which the site was listed (Figure 60).

The second model is representative of Main Ponds, the fen wetlands of Pick Swamp and Crescent Pond, Outlet Creek and the connection to the Southern Ocean (Figure 61). The critical features of this site are the karst and fen wetlands which are sustained by the constant groundwater discharge. Discharge occurs at a number of named karst wetlands as well as a number of small unnamed springs located throughout the Western and Eastern wetlands. The coastal dunes act as a barrier to surface water drainage with ponding occurring along the base of the dunes creating waterlogged conditions and the development of peatland fens.

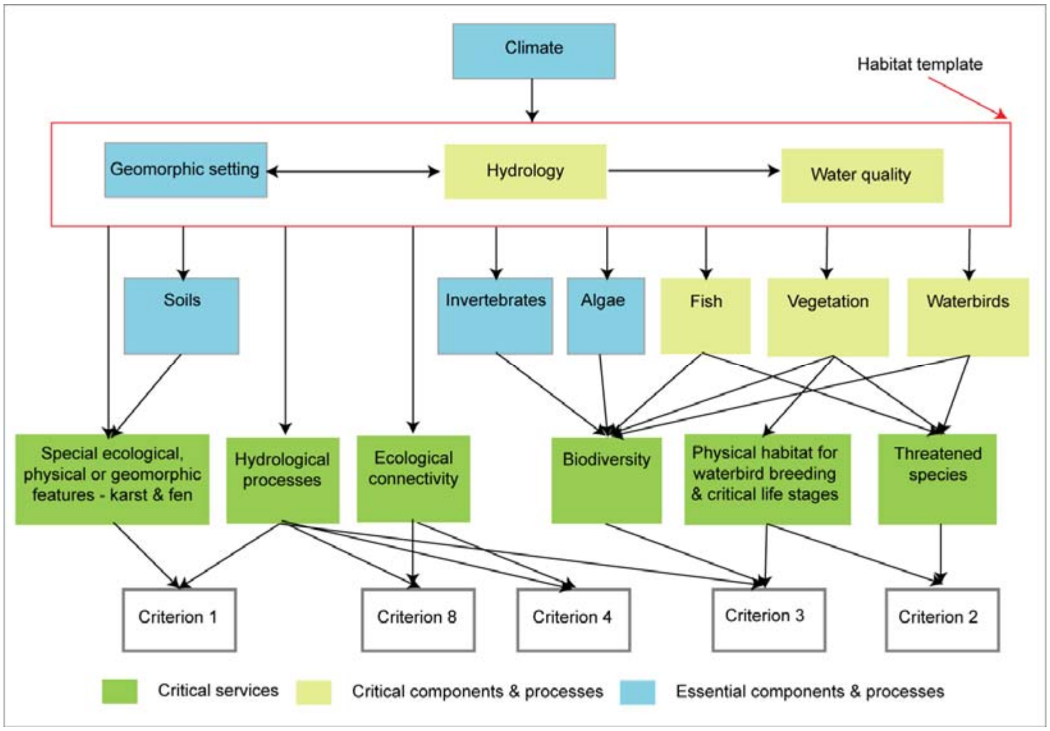
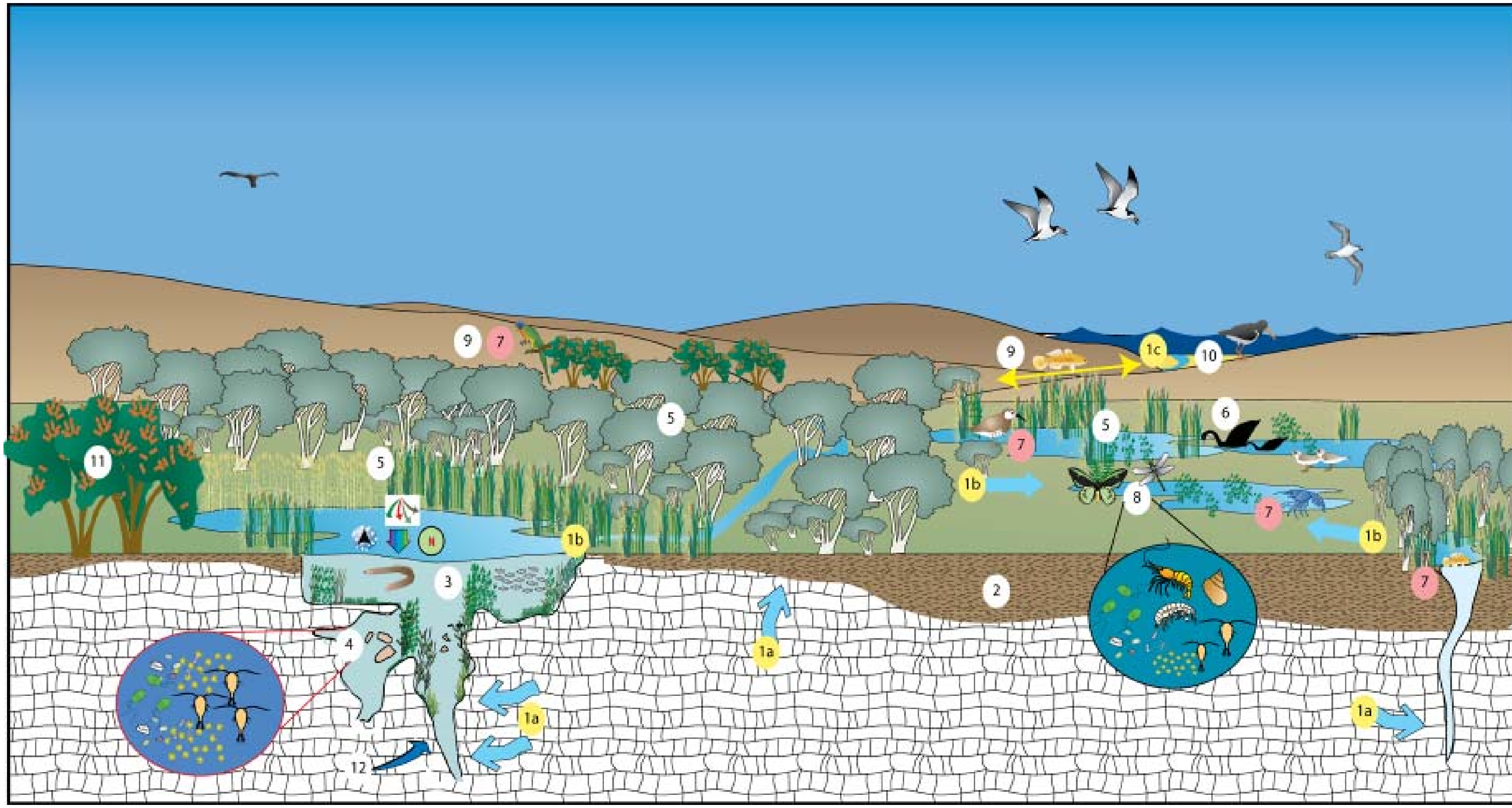


Figure 60: Simple conceptual model of critical and essential components, processes and services of Piccaninnie Ponds Karst Wetlands.

The site has high biodiversity values and is important for supporting critical life stages for several species, notably the orange-bellied parrot and several native fish species. Twenty five migratory waterbirds utilise the site with 79 species of waterbird recorded at the site. Despite being a small site of only 862 hectares, the range of vegetation associations present is quite high with over 30 associations and 250 plant species identified. The inclusion of the beach habitat provides another distinctive area to the site which supports a different suite of taxa to that of the karst and fen areas. The freshwater groundwater beach springs and Outlet Creek provide constant freshwater along this coastal strip.

Overall the combination of geomorphic features, hydrological regime, peatland fens, and connectivity with the marine environment provide a truly unique wetland complex.



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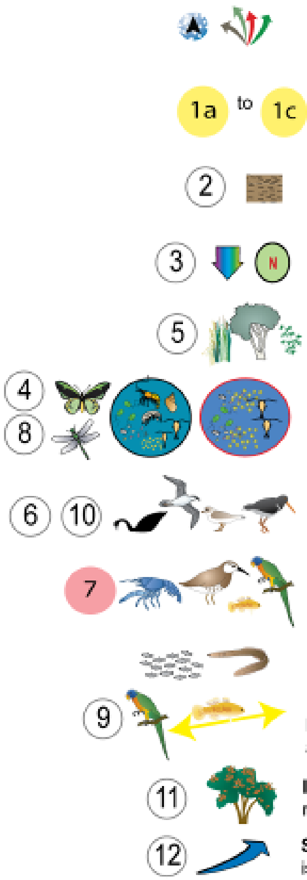
Components, processes, and services.



Water quality. Water is fresh, however electrical conductivity is temporally and spatially variable across the site. Turbidity levels in karst wetlands are very low with light penetration to great depths. Sediments, dissolved nutrients and allochthonous material are transported into karst wetlands via over land flows.

Hydrology/ Special ecological, physical or geomorphic features - Karst. Groundwater discharge occurs at several karst wetlands including Piccaninnie Ponds, Hammer-head Pond and Crescent Pond (1a). In the Chasm of the Main Ponds discharge is along the face of the limestone, but is greatest at approximately 36 meters where fractures in the limestone allow greater inflow. Groundwater is discharged into Outlet Creek and also spills into the surrounding wetlands (1b) inundating areas of shrub dominated wetlands and the peat fens of Pick Swamp. Flows are continually discharged to the sea via Outlet Creek (1c). Contributes to meeting criterion 1.

Special ecological, physical or geomorphic features - Fen wetlands. The continual groundwater discharge has resulted in waterlogging of soils and the formation of peat. Peat soils are a distinctive feature of the site, with the fen marshes of the site supporting high biodiversity values; contributing to meeting criteria 1 and 3.

Karst wetlands - vegetation and water quality. The unique aquatic plant community of the karst wetlands are due to the water clarity and quality with plant growth to depths beyond 15 metres in the Main Ponds. Groundwater discharge has high nitrogen and low phosphorous. Epiphytic algal growth on macrophytes is a distinctive feature of the wetlands.

Vegetation. Large areas of the site support dense shrub dominated wetlands - Western and Eastern wetlands as well as surrounding Crescent Pond - includes silky tea tree shrubland. Sedge, rush and grasslands are also important vegetation associations present within the site. These contribute to the critical ecosystem service, **Physical habitat for waterbirds**.

Supports biodiversity The animal community of the karst wetlands are not well known other than for the fish. It is expected that the invertebrate karst community contains some unique species. The invertebrate communities, both aquatic and terrestiral (i.e Lepidoptera) of the fen and marsh areas will also contribute to the biodiversity value of the site. Contributes to criterion 3.

Waterbirds. Supports a diverse array of waterbirds: 79 species, with 11 breeding on site. Records include 23 shorebirds and two sea birds with 25 species covered under various treaties such as JAMBA and CAMBA. The beach along the southern border of the site is an important area for species such as hooded plover and sanderling. Contributes to meeting criterion 3 and 4.

Supports threatened species. Seven nationally listed species. Contributes to meeting criterion 2.

Fish. Ten species of fish are supported within the site including several threatened species. Several species are diadromous and migrate between freshwater and the ocean to complete various stages of their life cycle. Several which have a strong preference for site heavily vegetated. Contributes to meeting criterion 4 and 8.

Ecological connectivity Several species rely on the connection of Outlet Creek to the ocean to complete their life cycles. The orange-bellied parrot uses the site as a roosting and feeding ground during its winter migrations. Contributes to meeting criterion 4 and 8.

Invasive species. Coastal wattle has invaded much of the original wetland area following drainage works in the past. It is hope restoring a more natural hydrological regime will reverse this trend.

Saline water intrusion. Saline water intrusion occurs deep in the Chasm, however mixing and rates of groundwater discharge from the upper levels of the TLA ensure the water is predominantly fresh.

Figure 61: Conceptual model of critical components, processes and services of Piccaninnie Ponds Karst Wetlands.

5 Limits of Acceptable Change

5.1 Process for setting Limits of Acceptable Change (LAC)

Limits of Acceptable Change are defined by Phillips (2006) as:

"…the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland. This may include population measures, hectares covered by a particular wetland type, the range of certain water quality parameter, etc. The inference is that if the particular measure or parameter moves outside the 'limits of acceptable change' this may indicate a change in ecological character that could lead to a reduction or loss of the values for which the site was Ramsar listed. In most cases, change is considered in a negative context, leading to a reduction in the values for which a site was listed".

Limits of Acceptable Change and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that LAC should be beyond the levels of natural variation. Setting limits in consideration with natural variability is an important, but complex concept. Wetlands are complex systems and there is both spatial and temporal variability associated with all components and processes. Defining this variability such that trends away from "natural" can be reliably detected is far from straight forward.

Hale and Butcher (2008) considered that it is not sufficient to simply define the extreme measures of a given parameter and to set LAC beyond those extremes. What is required is a method of detecting change in pattern and setting limits that indicate a distinct shift from natural variability (be that positive or negative). This may mean accounting for changes in the frequency and magnitude of extreme events, changes in the temporal or seasonal patterns and changes in spatial variability as well as changes in the mean or median conditions.

It should be noted that LAC are not synonymous with management values or "trigger levels" and do not necessarily indicate a change in ecological character. Rather, the LAC described here will be used to determine whether preliminary assessment is required to evaluate whether there has been or is likely to be a potential change in ecological character. The site management plan should include management triggers that relate to the LAC, thereby enabling early intervention should a change in ecological character become known or likely. Detecting change with sufficient time to instigate management actions to prevent an irrevocable change in ecological character is the role of the wetland management plan and not the Ecological Character Description.

In summary, Limits of Acceptable Change are a tool by which ecological change can be measured. However, Ecological Character Descriptions are not management plans and LAC do not constitute a management regime for the Ramsar site.

Exceeding or not meeting LAC does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting LAC may require investigation to determine whether there has been a change in ecological character.

While the best available information has been used to prepare this Ecological Character Description and define LAC for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The LAC may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.

Users should exercise their own skill and care with respect to their use of the information in this Ecological Character Description and carefully evaluate the suitability of the information for their own purposes.

Limits of Acceptable Change can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

5.2 LAC for Piccaninnie Ponds Karst Wetlands

Limits of Acceptable Change have been set for the site based on conditions at the time of nomination (2011). It is preferable to use site specific information to statistically determine LAC. However, in the absence of sufficient site specific data, LAC are based on recognised standards or information in the scientific literature that are relevant to the site. In these cases, the source of the information upon which the LAC has been determined is provided. For Piccaninnie Ponds Karst Wetlands there is limited site specific data for most of the critical components, processes and services, therefore qualitative LAC based on the precautionary principle are recommended and will require careful review with increased information gained from future monitoring. In addition some LAC will require long timeframes in which to characterise variation of the components, process or service.

The Piccaninnie Ponds Karst Wetlands site was nominated under conditions of altered hydrology for part of the site: Pick Swamp. This section of the site is actively being rehabilitated; as such the hydrological regime may change in this part of the site in the future. While LAC should be set for conditions at the time of listing, it is not the intent to ensure that poor condition / health is maintained. Obligations for member nations under the Ramsar Convention are to “protect and *enhance*” wetlands. However, LAC are not synonymous with management targets and should not be used to set ideal future benchmarks or targets. As such, LAC for hydrology have been set as conditions at the time of listing on the understanding that any negative change will need to be investigated to determine whether there has been a change in character.

All identified critical components, processes and services require a LAC to be set (DEWHA 2008). However, due to the interrelated nature of components, processes and services a single LAC can account for multiple components, process and services. For example, the LAC which address hydrology often account for several other critical processes and services, such as supporting a diversity of wetland types and physical habitat for waterbirds, biodiversity and ecological connectivity. This is because hydrology is a key determinant of many aspects of the ecological character of a site and a change in hydrology would lead to a loss of related services. In order to limit repetition in the LAC for Piccaninnie Ponds Karst Wetlands, a hierarchical approach has been adopted where LAC have been set for components or processes, which in this case has also covered critical services.

The columns in Table 19 contain the following information:

Component / Process/ Service	The component or processes for which the LAC is a direct measure.
Baseline / supporting evidence	Relevant baseline information (relevant to the time of listing) and any additional supporting evidence from the scientific literature and / or local knowledge.
Limit of Acceptable Change	The LAC stated as it is to be assessed against.
Confidence level	The degree to which the authors are confident that the LAC represents the point at which a change in character has occurred. Assigned as follows: **High** – Quantitative site specific data; good understanding linking the indicator to the ecological character of the site; LAC is objectively measurable. **Medium** – Some site specific data or strong evidence for similar systems elsewhere derived from the scientific literature or informed expert opinion; LAC is objectively measurable. **Low** – No site specific data or reliable evidence from the scientific literature or expert opinion; LAC may not be objectively measurable and/or the importance of the indicator to the ecological character of the site is unknown.

Table 19: Limits of acceptable change for the Piccaninnie Ponds Karst Wetlands.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
Hydrology – groundwater discharge	Discharge rates from Outlet Creek have decreased in recent times from average daily discharge of between 60 and 80 megalitres per day in the 1970s and 1980s to average daily discharge 47 megalitres per day over winter months, and 38 megalitres per day in summer for the period 2005 to 2011(DfW unpublished data). The LAC has been set based on a sustained 20 percent decline from current rates of discharge (March 2005 to June 2011) and is based on expert opinion. Continued monitoring of the discharge rates is required as the period 2005-2007 on which the LAC is based is a drought period.	Average winter daily discharge rate is no less than 38 megalitres per day and average summer daily discharge is no less than 30 megalitres per day for three out of any five year period.	High.
Hydrology – wetland extent	Discharge from karst springs supply surface water and produce different wetland types in association with local topographical relief and soil properties. The extent of the karst springs is very limited and not expected to change. Any change is considered significant and as such no decline in extent is considered acceptable to set the LAC. For the other wetland types for which there is baseline extent data (Ramsar types Ts, Tp, U and W, Table 2 and Appendix F) a change in extent (area) is considered more likely and 20 percent has been used for setting the LAC. Limits of Acceptable Change have been set based on expert opinion.	No less than one hectare of karst (Ramsar type Zk(b)) springs (measured as surface area). No less than 69 hectares of peatlands (Ramsar type U). No less than 31 hectares of permanent freshwater marshes or pools on inorganic soils (Ramsar type Tp).	Medium.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
		No less than seven hectares of intermittent marshes or pools on inorganic soils (Ramsar type Ts). No less than 134 hectares of shrub dominated wetlands (Ramsar type W).	
Water quality – salinity	Salinity is consistently higher in Main Ponds than in Outlet Creek at the Piccaninnie weir (Wood 2011; DEWNR unpublished monthly data) and has been attributed to freshening inflows between Piccaninnie Ponds and the Outlet Creek, possibly from springs in the Western wetland. Salinity in the Main Ponds exhibits a seasonal pattern that has salinities higher in the colder, winter months. The maximum surface salinity recorded between July 2008 and March 2011 was 3880 micro Siemens per centimetre in winter 2009. The minimum reading was 1986 micro Siemens per centimetre in March 2010 (DEWNR unpublished data). The seasonal patterns of salinity increases in winter in Main Ponds have not yet been adequately explained (Wood 2011). Current understanding of the toxic effects of salinity on Australian biota is limited, especially when considering the	Salinity in Main Ponds is always less than 4000 milligrams per litre.	Low.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
	potential effects on the different life stages of biota (Neilsen *et al*. 2003; Jolly *et al*. 2008). The majority of work in the field of salinity impacts on wetlands is for inland riverine or arid zone wetlands, not on coastal rising spring karst systems with constant groundwater discharge. As such, extrapolation from other studies is difficult. The LAC has been set on the basis of the sensitivity of non-halophytes such as water milfoil (*Myriophyllum propinquum)* and other freshwater plants which have an upper tolerance of 4000 milligrams per litre (Brock 1981; Neilsen *et al*. 2003). It is believed that sustained salinities above this point would represent a potential change in the salinity regime and have ecological impacts such as a change in plant species. The LAC is based on expert opinion.		
Water quality – nutrients	Nitrogen levels have varied across a number of studies (Scholz 1990; Hammer *et al*. 2000; Fass and Cook 2005; Fairweather *et al*. 2011; DEWNR unpublished data) with most readings falling between 2 to 4.5 milligrams per litre nitrate. Recent monthly monitoring from March 2008 to June 2011 have indicated an increase in nitrate compared to data collected by Fairweather *et al*. (2011) in 2007 to 2008. The most recent dataset is used as the basis for setting the LAC, with the assumption that there is a rising trend in groundwater nitrate levels.	Nitrate not to exceed 10 milligrams per litre for six consecutive months.	Low.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
	The ANZECC guidelines for nitrate to maintain 90 percent of expected species is already exceeded at this site (3.4 milligrams per litre). The trigger for maintaining 80 percent of species is 17 milligrams per litre (ANZECC 2000). This may well represent a state change in the ponds and as such a lower level has been set. LAC is based on expert opinion.		
Water quality – turbidity	Turbidity levels in the Main Ponds are consistently below 10 nephelometric turbidity units and are considered remarkably stable. Small peaks can occur following runoff from storm events but these are quickly cleared by the continual discharge of groundwater. Levels in Pick Swamp are more variable and there are insufficient data to set a LAC for this part of the site. Water clarity is a distinctive feature of the site and as such the LAC has been set at no change.	Less than 10 nephelometric turbidity units in Main Ponds at any time.	Medium.
Water quality – pH	The Main Ponds are slightly alkaline with pH between 7.1 and 7.5 and are reportedly stable both spatially and temporally (Scholz 1990; Fass and Cook 2005). Surface water monitoring by DEWNR (unpublished data) at different locations across the site indicate pH is slightly more alkaline in Pick Swamp than in the ponds, mostly ranging between 7 to 9 between 2008 and 2010, with slightly more acidic conditions recorded in 2010 across the site. Reliable data are not available for 2011 and as	Data insufficient to set LAC.	Not applicable.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
	such it is not clear if the lower readings across the site in 2010 represent a trend to more acidic conditions.		
Vegetation – Silky tea tree shrubland	This vegetation association supports a number of threatened species and is a regionally significant vegetation association in its own right. Ecological Associates (2008) areal extent and floristic description for vegetation associations N, P and AB are the basis of the LAC. The baseline extent is approximately 164 hectares. Although there is information on extent for part of the Ramsar site, there is no indication of variability in this measure. In addition, information on variability in this vegetation association from comparable sites could not be sourced. As such, an objective, statistically based LAC cannot be determined and a figure of five percent change has been selected, informed by local knowledge and the expert opinion of the steering committee. Short to medium decline may be associated with restoration activities and this must be taken into consideration when assessing the LAC.	Extent of silky tea tree shrubland as delineated by Ecological Associates (2008) vegetation associations N, P, and AB to be no less than 156 hectares.	High.
Vegetation – Sedgeland, rushland and grassland	Includes vegetation associations F, O, Q, W, Z, and POW (Ecological Associates 2008). These habitats support a range of plant, waterbird, fish and other fauna. The baseline extent is approximately 38 hectares but is expected to fluctuate naturally. Several of the vegetation	Extent of sedgeland, rushland and grassland wetland habitat as delineated by Ecological Associates (2008) vegetation associations F, O, Q, W, Z and POW to be no less than 30	Medium.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
	associations identified by Ecological Associates (2008) are in a transition phase (due to restoration activities at Pick Swamp) and as such there is expected to be changes in composition as well as areal extent. To date there are no data available to indicate the range of variability in this vegetation type, however as it is expected to change, a figure of 20 percent change in extent has been selected as the basis of the LAC informed by local knowledge and expert opinion of the steering committee.	hectares.	
Vegetation - Aquatic vegetation community – karst	This vegetation type is considered highly characteristic of the site and very stable unless disturbed. The best description for the karst associations are that of Scholz (1987) and Hallam and Thurgate (1995). The LAC is based on the vertical distribution of ribbon weed (*Triglochin procerum*) and presence of the freshwater species of water milfoil (*Myriophyllum propinquum*). LAC is based on expert opinion.	*Triglochin procerum* present within Main Ponds to at least two metres. *Myriophyllum propinquum* present within Main Ponds.	High.
Vegetation - Aquatic vegetation community – fen and marsh	Ecological Associates (2008) areal extent and floristic description for vegetation associations A, B, D, G, H, I, and J are the basis of the LAC. The baseline extent is approximately 75 hectares but expected to fluctuate. Several of the vegetation associations identified by Ecological Associates (2008) are in a transition phase (due to restoration activities at Pick Swamp) and as such there is expected to be changes in composition as well as areal	Extent of fen and marsh as delineated by Ecological Associates (2008) vegetation associations A, B, D, G, H, I, and J to be no less than 60 hectares.	Medium.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
	extent. To date there are no data available to indicate the range of variability in this vegetation type, however as it is expected to change, a figure of 20 percent change in extent has been selected as the basis of the LAC informed by local knowledge and expert opinion of the steering committee.		
Fish	The fish fauna is characterised by a complete lack of introduced species as well as representing strongholds for endangered species. Ten species have been recorded from the site (Hammer 2002; Hammer *et al*. 2000; Hammer 2008a). LAC is based on no loss of common species and at least 80 percent of total number of fish. It should be noted that some species are only encountered rarely. LAC is based on expert opinion.	Presence of at least eight native fish species over any three sampling events over a five year period in which all habitat including karst, Pick Swamp, and Outlet Creek are sampled. Small-mouthed hardyhead (*Atherinosoma microstoma*) and common galaxias (*Galaxias maculates)* present in each survey**.**	High.
Waterbirds – number of species	The site supports a diversity of waterbirds with a total of 79 species including 25 migratory species listed under international agreements have been recorded from the site. There is insufficient information to set baseline regarding abundance, breeding and composition data is insufficient as yet to determine natural variation. Monthly data from May 2007 to June 2011 (Birds South East	Presence of at least 37 species in at least 5 years of any 10 year period in which surveys are undertaken.	Medium.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
	2011) is available for Pick Swamp with and average annual number of species of 46 species. LAC is based on a 20 percent decline in annual number of species. This percentage was chosen as numbers of waterbirds are highly variable and are affected by factors external to the site. LAC is based on expert opinion.		
Maintenance of hydrological regimes	Discharge from karst springs supply surface water and produce different wetland types in association with local topographical relief and soil properties. Restoration activities within Pick Swamp will affect the surface water inundation patterns with the intent to reinstate as much of pre European conditions as practicable.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology, see LAC above.	Not applicable.
Special ecological, physical or geomorphic features – karst wetlands	This critical service is linked principally to changes in the hydrology. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the groundwater discharge.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology, see LAC above.	Not applicable.
Physical habitat which supports waterbird breeding	This critical service is linked to changes in the frequency and duration of wetland wetting and drying as well as changes in the extent and condition of wetland and floodplain vegetation. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the hydrological regime and vegetation.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and vegetation. See LAC above.	Not applicable.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
Physical habitat which supports waterbird feeding.	This critical service is linked to changes in the frequency and duration of wetland wetting and drying as well as changes in extent and condition of wetland. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the hydrological regime and vegetation.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology and vegetation. See LAC above.	Not applicable.
Threatened species – Australasian bittern	Australasian bittern has been reliably recorded annually from Piccaninnie Ponds Karst Wetlands since 2005. The species is known to be cryptic and not easily detected, but is considered resident within the site. LAC is set based on expert opinion.	Presence within Ramsar site on an annual basis.	Medium.
Threatened species – orange-bellied parrot	Baseline population of the site is not known. Further work is needed to establish the proportion of the population that uses the site. Extent and type of habitat used at the site is poorly documented, but it is unlikely that the species is using the site opportunistically. Continued presence is considered an appropriate LAC for this species. Based on expert opinion.	Presence within Ramsar site during winter migration periods every one in three years.	Low.
Threatened species – Yarra pygmy perch	No population data is available and as such quantitative LAC cannot be set. Continued presence is considered an appropriate LAC for this species. LAC is based on expert opinion.	Presence within Crescent Pond on an annual basis.	High.
Threatened species – dwarf galaxias	No population data are available and as such quantitative LAC cannot be set. Continued presence is considered an appropriate LAC for this species. LAC is based on expert opinion.	Presence within Hammerhead Pond and Pick Swamp on an annual basis.	High.

Critical Components, Processes and Services	Baseline/Justification for LAC	Limit of Acceptable Change	Confidence level
Threatened species – swamp greenhood	No population data are available and as such quantitative LAC cannot be set. Continued presence is considered an appropriate LAC for this species. LAC is based on expert opinion.	Presence within Ramsar site on an annual basis.	Low.
Biodiversity	The site is hydrologically connected between the river and a series of interconnected floodplain lakes in which wetland dependent species are established. The wetting and drying of the lakes promotes diversity and this service is maintained by hydrology. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology. Changes in LAC for fish and waterbirds could also be used as surrogate measures for this service.	No direct LAC has been developed and instead the critical service will be assessed indirectly through changes in hydrology; see LAC above.	Not applicable.
Ecological connectivity	Piccaninnie Ponds are only 700 metres from the Southern Ocean and are permanently connected via Outlet Creek. This service is maintained by hydrology and can also be indicated by the species richness of native fish. The key elements of connectivity are unimpeded flow and connection to the Southern Ocean. LAC is set on the basis of maintaining all diadromous fish species within the site. Based on expert opinion.	Maintain fish passage between Main Ponds and Southern Ocean. To be measured on basis of continued presence of all diadromous fish species in any three of five years sampled.	High.

6 Threats to the ecological character of Piccaninnie Ponds Karst Wetlands

The condition and biodiversity associated with the Piccaninnie Ponds Karst Wetlands is potentially at risk from a number of threats, which are often interrelated, and operating at multiple temporal and spatial scales. For example, vegetation patterns can be modified as a result of changed hydrology, land clearing and grazing pressure (individually or in combination), the effects of which may be a legacy of past practices (decades) or current activities. In addition, changes in land use and associated activities increases the risk of invasion by weeds, introduced predators such as foxes pose risks to threatened fauna, while uncontrolled access for recreation increases the risks to wetland vegetation (for example via introduction of weeds or pathogens, or by physical damage).

While there are many potential threats that may impact on the habitat condition and biodiversity values of the wetland system, most are controlled under current management arrangements for the site. For example, water levels in the wetland complex are now controlled by infrastructure (i.e. outlet structure and fishway). The perimeter of the Piccaninnie Ponds Conservation Park is fenced to exclude livestock, and road access is controlled and camping is limited to designated areas. The number of visitors that can dive or snorkel in Piccaninnie Ponds is also limited by a booking system administered by DEWNR and requirements for appropriate scuba diving qualifications. Overall, reinstatement of water levels in the Piccaninnie Ponds Karst Wetlands and other rehabilitation measures in place (or proposed) have the potential to improve the condition and protect the values of the wetland system. Ongoing monitoring and evaluation of these measures is recommended in order to assess recovery and adjustments to flora and fauna communities, as well as provide an early warning for any re-emergence of threats.

The following sections provide an overview of the major threats to the Piccaninnie Ponds Karst Wetlands. The ability to manage most of these threats at the local scale is a key factor in maintaining the ecological character of the system in the future.

6.1 Altered hydrology

The hydrology of south-east South Australia has been altered by a combination of drainage schemes, land clearance and water extraction. European settlement of the region expanded after the establishment of pastoral runs in the 1840s and the commencement of drainage schemes in the 1860s (DEP 1984, Turner and Carter 1989). Original surveys of the Piccaninnie Ponds area in 1896 indicate a larger, wetter wetland system than at present, which extended from Green Point (approximately five kilometres to the west) to the Glenelg River near the Victorian border. The wetland included drainage via Stony Creek to the seas at the western end of the system and via Freshwater Creek to the Glenelg River estuary to the east (SENRCC 2004, DEP 1992). Between 1906 and 1917, water levels were affected by various actions, such as the damming and diversion of Freshwater Creek.

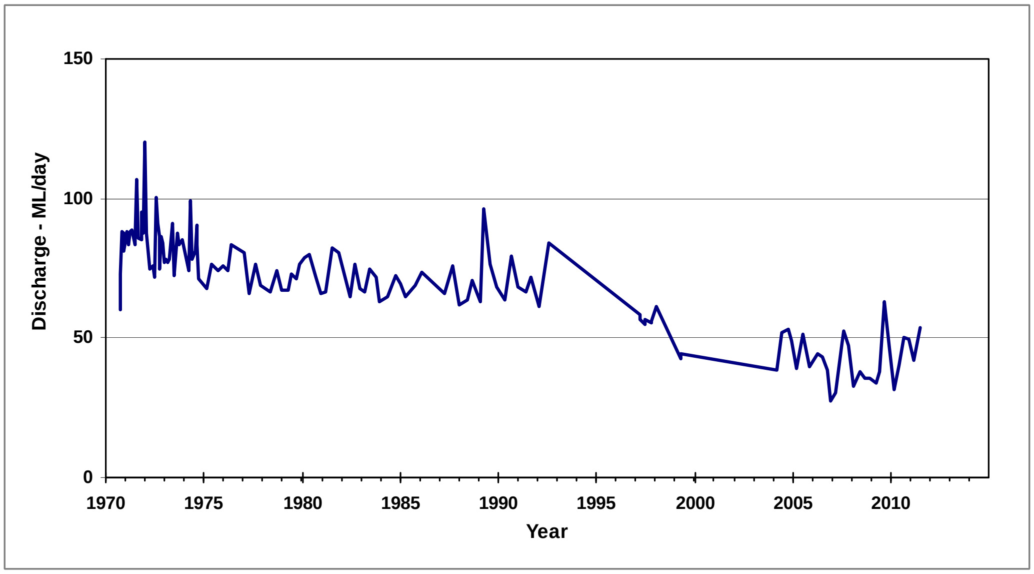
By 1944, changes in hydrology due to changes to the original Freshwater Creek, excavation of Stony Creek to accommodate drains in that area, and excavation of an outlet from the Main Ponds to the sea had altered the inundated area of the wetland system. While the northern extent of the wetland system remained similar to that surveyed in 1896, changes to hydrology and mobilization of sand dunes resulted in large areas along the southern boundary of the wetland system being in-filled (SENRCC 2004). In the 1960s, excavation of the main outlet drain to the sea resulted in further lowering of water levels and subsequent drying across the wetland system. Since then, local vegetation patterns have responded to an increased area of dry land and reduced area of permanent inundation (e.g. increased area of terrestrial species such as coastal wattle, *Acacia longifolia ssp. sophorae*). Bachmann and van Weenen (2001) note that the reduced water level has the potential to have a significant negative impact on the Silky Tea Tree Tall Closed Shrubland, a vegetation community of considerable conservation value.

However works are in the process of restoring water levels to that of the late 19th and early 20th centuries. The outlet from the wetland has been raised with the installation of new infrastructure, which includes a fish ladder to allow passage of diadromous fish between the main wetland and the sea. Vegetation communities are again responding to changed water levels, with evidence of die-back of terrestrial vegetation such as coastal wattle in now permanently inundated margins of the wetland (Figure 62). Also, the purchase of Pick Swamp in 2005 and subsequent closure of drains on the acquired property has seen an increase in water levels over time in this section of the wetland complex. Aquatic vegetation has shown a very positive response to the restored hydrological regime. (Clarke 2008).

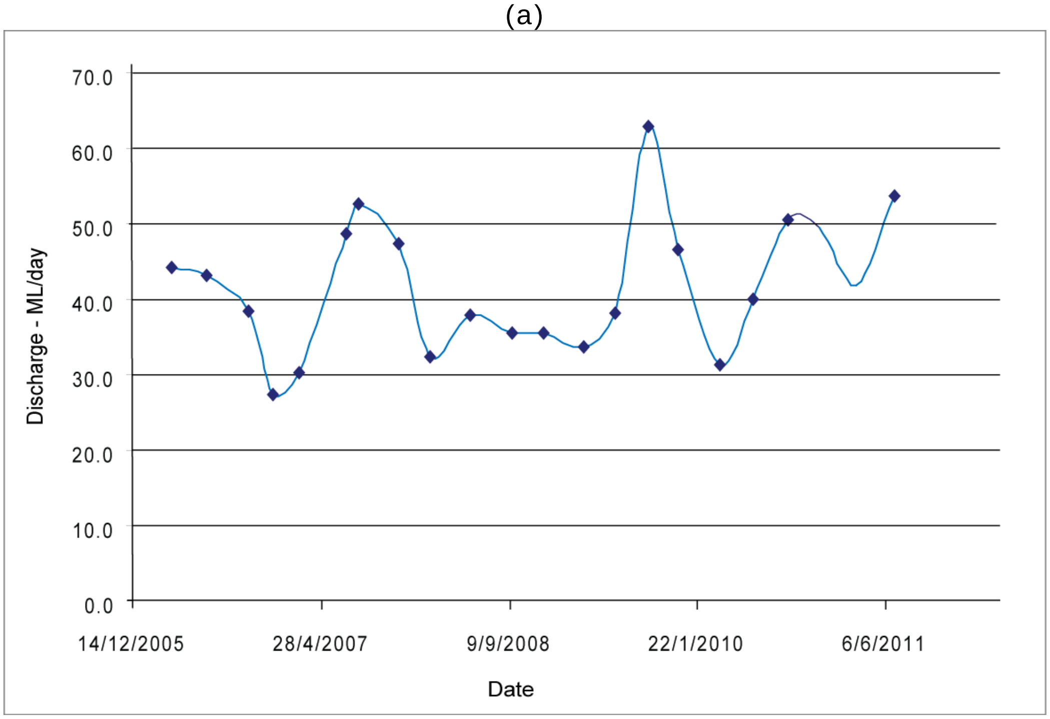
Figure 62: Die-back of coastal wattle at Piccaninnie Ponds, May 2008 (Photo: Peter Cottingham)

While the regional hydrology and that of the Piccaninnie Ponds Karst Wetlands is complex and a topic of ongoing research, extraction of groundwater across the region for industry and agriculture and an extended period of low rainfall is thought to have resulted in a decline in groundwater discharge rates through the wetland complex. For example, Scholz (1987) noted a decline in spring discharge in the period 1961/62-1970/71, and suggested that increased exploitation of ground water reserves over this period was the most likely explanation for the decline. Ongoing monitoring of flow from the springs confirms the observation of declining discharge over the past four decades (Figure 63). As Figure 64 (b) indicates groundwater discharge has increased on average over the past 5 years.

The discharge of water from both Piccaninnie Ponds and Pick Swamp is now controlled through the installation of weirs in the artificial drains, to allow a return nearer to 1896 levels. While discharge has shown a measureable reduction it should be noted that significant volumes of water, in excess of that needed to meet the ecological requirements of the site, are still discharged to the sea each day through the existing regulated outlets.



(a)



(b)

Figure 63: Discharge patterns for Piccaninnie Ponds, including (a) series for 1971-2011 and (b) seasonal pattern between December 2006 and June 2011 (data supplied by DfW).

6.2 Land clearance and grazing by livestock

While the region has a long history of drainage, land clearance and grazing by livestock, fencing of the Piccaninnie Ponds Conservation Park since its inception in 1972 has seen the exclusion of livestock and maintenance of largely native vegetation. Pick Swamp's history as pastoral land means that land clearance and grazing by livestock have impacted on the condition and values of the wetland for many decades. The physical disturbance, introduced plant species, grazing pressure, weeds and potential pathogens expected on grazing land have affected (plant and animal) habitat availability and condition, native vegetation patterns and species richness. Water quality at Pick Swamp is also likely to have been affected by increased nutrient loading, turbidity, suspended solids, and biochemical oxygen demand.

Following the acquisition of Pick Swamp by the South Australian Government in 2005, extensive fencing and alteration to drainage patterns means that risks associated with livestock will diminish over time. As mentioned previously, there are indications that native vegetation is already responding to the removal of livestock and the reinstatement of a more natural wetting and drying regime (Clarke 2008).

6.3 Introduced species (weeds and animal pests) and pathogens

As noted previously, native and introduced weeds are present across the wetland complex. These include a number of species that were introduced to the region to 'improve' pasture for livestock (for example Yorkshire fog grass *Holcus lanatus*, Kentucky blue grass (*Poa pratensis*), strawberry clover (*Trifolium fragiferum* var. *fragiferum*), subterranean clover *Trifolium subterraneum,* tall meadow fescue (*Festuca arundinacea*), and rye grass (*Lolium rigidium*). Others such as sea spurge (*Euphorbia paralias*), mirror bush (*Coprosma repens*) and various species of thistles have been introduced incidentally under various transport mechanisms (e.g. attached to livestock and in faeces, in fodder, attached to equipment used for management and rehabilitation, wind-borne or by birds). The control of most of weeds is already recognised in existing management plans for the wetland complex (DEP 1992). Native species such as coastal wattle have also expanded over the southern boundary of the wetland complex. However, it is likely that its coverage will decrease as water levels return to pre-drainage (1896) levels.

Pest animas such as foxes (*Vulpes vulpes*), cats (*Felis catus*), rabbits (*Oryctolagus cuniculus*), house mouse (*Mus domesticus*), black rat (*Rattus rattus*) also occur across the wetland complex. Programs to control foxes, rabbits and cats are in place and carried out by regional Natural Resource Management staff.

There is potential for the introduction of weed species and pathogens to Pick Swamp as it is rehabilitated. If not controlled, such weed invasion may affect habitat availability for fauna and reduce indigenous flora biodiversity, as well as increase the cost of management at the site. Care must be taken to minimise the risk of new weed introductions when undertaking rehabilitation works.

As of 2011, no introduced diseases and pathogens are known to exist within the Piccaninnie Ponds Karst Wetlands, although further study is required to confirm this, particularly given that the cause of aquatic vegetation die-back in the site in the period 1984-86 was never established.

As of 2011, there are currently no introduced fish species within the Piccaninnie Ponds Karst Wetlands. The invasive fish species gambusia (*Gambusia holbrooki*) and redfin (*Perca fluviatilus*) pose a potential risk to the site, having been recorded in nearby systems. (M. Hammer, Aquasve Consultants, pers. comm. 2007).

6.4 Water quality

Contamination of the unconfined groundwater aquifer by point and diffuse pollution sources in the region has long been recognized (e.g. Emmett and Telfer 1993) and the disposal of wastewater point-sources to the aquifer is now prohibited (EPA 2003, EPA http://www.epa.sa.gov.au/water_se.html accessed in June 2008). However, nutrients and other contaminants remain in regional groundwater as a legacy of past practices and due to recharge from urban, industrial and agricultural land.

Of particular concern for the Piccaninnie Ponds Karst Wetlands are nutrients and contaminants (for example pesticides, pathogens) in both the groundwater discharge (generally) and in surface runoff from Pick Swamp (given the latter's land use history of livestock grazing and surrounding agricultural practices). For example, higher nutrient (nitrate and phosphate) concentration may alter the balance between cyanobacterial, algal and macrophyte production and coverage. Given that the main springs are phosphorus limited (Scholz 1987), additional inputs of phosphate is to be avoided.

Regional extraction of groundwater will also pose a risk to water quality and ecosystem condition should this result in less dilution of salt water intrusion to the Chasm, thereby resulting in increased salinity across the wetland system. Hydrological investigations at the site and in the region could be used to identify the extent of this issue. .

6.5 Tourism and recreation

Uncontrolled access for tourism and recreation purposes would pose an increased risk to the condition of the wetland complex from threats such as physical disturbance, erosion and litter. However, current management arrangements include control of access via a single, well maintained road, along with designated camping, parking areas and walking tracks. Diving and snorkelling, both very popular recreation activities, are also regulated (cave divers must be suitably qualified and members of the Cave Divers Association of Australia, CDAA) and controlled (diving and snorkelling permits must be obtained and bookings made for a time slot with DEH). The CDAA is also involved in ongoing investigations of the hydrology of the cave system at Piccaninnie Ponds in cooperation with DFW.

6.6 Aquatic vegetation die-back

A die-back of aquatic vegetation occurred in Turtle Pond at Piccaninnie Ponds in 1985 and 1986, when vegetation such as *Lepilaena cylindrocarpa, Myriophyllum porpinquum* and *Ruppia polycarpa* 'lifted' and exposed the underlying sediments (Scholz 1987). While numerous hypotheses were proposed (for example changed water quality, physical disturbance, pathogens), no conclusion could be drawn as to the factor(s) that caused of the die-back. The die-back event was, however, the catalyst for the cessation of diving and snorkelling activities for some time, and the introduction of regulation and control measures to reduce the risk of damage by overcrowding and prolonged diving/snorkelling activity.

6.7 Climate change

The latest climate projection models for the South East South Australia suggest that by 2030 it is likely that average temperatures will increase 0.2 to 1.4 degrees Celsius by 2030 and 0.6 to 4.4 degrees Celsius by 2070 (McInnes *et al* . 2003), and there will be a tendency towards lower rainfall across the year. There are also suggestions that climate change is already in evidence (Dairy SA 2008) given the following:

- Since 1950, temperatures have increased by up to one degree Celsius across most areas of Australia;
- Southern and eastern Australia have had more heat waves, fewer frosts and less rain; and
- The past 11 years have been amongst the warmest 12 years since 1850.

Anecdotal evidence suggests that South Australian dairy farmers have noticed that pasture growth patterns have changed and that spring growth now starts about four weeks earlier than it used to (Dairy SA 2008).

Any reduction in rainfall, runoff and groundwater recharge associated with climate change and its effect on regional temperature and rainfall patterns increases the potential to exacerbate effects such as the decline in groundwater discharge from Piccaninnie Ponds. The risk of water quality impacts may also increase as existing contaminant loads (for example nutrients, salt) become less ‘diluted’ with any decrease in recharge. Increased temperatures will result in increased evaporation and evapotranspiration potentially leading to reduced recharge in the catchment and increased losses from wetlands.

Climate change is also predicted to have an effect on sea level with predicted increases of three to 17 centimetres in sea level in southern Australia by 2030 (compared to 1990; Hennessy 2006). This combined with predicted increases in storm surges could significantly impact on the beach areas and increase rates of erosion. The potential impact of sea level rise on the hydrology of the Ramsar site including the freshwater / saltwater groundwater interface remains unknown.

6.8 Wildfire and anthropogenic fire regimes

Wildfires have been rare within the Piccaninnie Ponds Conservation Park, with only anecdotal records of burns used to control shrub development on nearby land (DEP 1992). The current management arrangements for the Conservation Park include maintaining boundary access tracks, the prohibition of wood fires, and measures to suppress fires should they occur. Such arrangements will also be conferred to Pick Swamp. The exclusion of fire can favour woody vegetation over grassland species, which may partly account for the transition of savannah grasslands to shrubland over the past three decades (R. Anderson, DEWNR, pers. comm. 2007).

Wetlands can experience extended dry periods, such as during drought, or artificially via drainage. In such circumstances fire can have a significant impact on the wetlands affecting nutrient cycling, vegetation development and habitat structure and availability. Fire can cause degradation and catastrophic loss of peat soils, affecting carbon storage (loss of carbon to atmosphere on combustion). Fires can also limit peat accumulation by removal of organic material.

6.9 Summary of threats

The threats considered in the previous sections have been summarised in Table 20.

Table 20: Summary of the main threats to the Piccaninnie Ponds Karst Wetlands.

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or service	Likelihood	Timing of threat
Altered hydrology.	• Changed water depth. • Altered area of wetland inundated. • Changed area of wetland experiencing periodic flooding and drying. • Changed vegetation distribution (e.g. die-back of flood-intolerant species) and loss/reduction of species using the habitat.	Certain	Immediate – medium term (5-10 years)
Land clearance – historic on site.	• Altered vegetation pattern at Pick Swamp (now being reversed as part of rehabilitation measures).	Certain	Medium term (5-10 years) as site is rehabilitated.
Livestock grazing – historic on site.	• Previous grazing at Pick Swamp resulted in removal or damage to native vegetation. • Increased nutrient	Certain	Medium term as site is rehabilitated.

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or service	Likelihood	Timing of threat
	and sediment inputs and turbidity. • Increased risk of pathogens and weeds.		
Native and introduced weeds and pathogens.	• Changed vegetation distribution and reduced flora diversity. • Die-back of vegetation (aquatic, emergent, terrestrial).	Medium-low	Medium-long term
Water quality impact of historic discharge of wastewater to regional groundwater	• Increased nutrient concentration in groundwater recharge.	To be confirmed	Medium-long term, depending on regional groundwater hydrology.
Tourism and recreation	• Damage to wetland vegetation and site infrastructure. • Increased risk of introduced weeds and pathogens.	Low with current management arrangements in place	Long term (ongoing)
Aquatic vegetation die-back	• Altered aquatic vegetation patterns.	Unknown as cause of previous events has not been established	
Climate change resulting in: • Increased temperature • Increased frequency of extreme events • Decreased rainfall runoff • Increased risk of wildfire • Sea-level rise	• Altered hydrological regime (e.g. recharge rates, rainfall-runoff, rate of drying). • Altered flora and fauna distribution. • Reduced habitat condition. • Potential risks from sea-level rise are unknown.	Medium Sea-level rise is highly likely to occur but unlikely to impact the site	Medium-long term.
Wildfire	• Loss of vegetation cover. • Changed vegetation patterns.	Low	Long term (ongoing).

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or service	Likelihood	Timing of threat
	• Loss of peat and stored carbon. • Loss of fossil pollen record. • Increased contaminant load in runoff. • Reduced habitat condition.		

7 Changes in ecological character

Change in ecological character is defined as the human-induced adverse alteration of any ecosystem component, process and/or ecosystem benefit or service (Ramsar Convention 2005, Resolution IX.1 Annex A). Change should be established against the ecological character at the time a site was listed as a Ramsar site. As this is the first description of the ecological character of the Piccaninnie Ponds Karst Wetlands prepared at the time of nomination, it is not possible to document change to the ecological character *per se*. What is provided here, and in Section 2.2, is the historical setting and notable changes in the site as recorded in the literature and oral histories from the Boandik people (see Appendix B).

Changes to the ecological character of the wetland outside natural variations may signal that uses of the site or externally derived impacts on the site are unsustainable and may lead to the degradation of natural processes and thus the ultimate breakdown of the ecological, biological and hydrological functioning of the wetland (Ramsar Convention 1996, Resolution VI.1).

There are significant knowledge gaps concerning the current status of ecological components and processes which have been discussed in the preceding sections and summarised in section 8. A summary of changes in key ecological components, the time frame in which change occurred and the source of information is provided in Table 21. The most notable change in the site has been modification of the surface water regime through drainage and also the reduced discharge rates.

As hydrology is a primary determinant of the ecological signature of wetlands, these changes will have influenced the current ecological character of the site. There are a number of possible consequences that may have arisen from the altered hydrology (not necessarily an exhaustive list):

- Reduced frequency, duration and area of inundation of wetlands
    - Loss of specific habitat types – e.g. potential reduction in fen wetland areas, and associated loss of species
    - Reduced spawning areas and or recruitment success
    - Decline in waterbird species richness and abundance
    - Decline in wetland vegetation
    - Loss of connectivity – e.g. loss of connection to Glenelg River estuary

Table 21: Historical changes in character of key ecological components and processes of the Piccaninnie Ponds Karst Wetlands.

Component/process	Change in character	Time frame	Source
Reduced groundwater discharge	Regional drawdown of unconfined aquifer. *'Look after the groundwater and everything else will be ok'*	Since 1960s	Scholz (1987) DEWNR unpublished data.
Surface hydrology	*'The drains are cleared out every year which digs them down deeper into the peat and the groundwater which increases the rates of drainage. The surface flooding has gone'* *'Important that sheet flows from upwellings are allowed to flow across the country without being blocked up or drained to sea – we will kill this country if don't get the water balance right – they are draining off the water and leaving behind the salt'* Drainage of Pick Swamp for agriculture. Altered flow pathway for discharge from karst wetlands.	< 70 since early 1900s	Baondik Clarke 2007
Invasive species – Coastal Wattle	*'Coorong wattle has been moving in since the 1930s after the really bad rabbit plagues'* Accelerated invasion of wetland area as surface waters have been drained.	50 years	Baondik; Bachman 2002, S. Clarke, DEH, pers. comm. 2007.
Loss of fen habitat	Loss of fen habitat due to drainage activities	< 70 since early 1900s	Clarke 2007

Note that the changes observed in the flora of the Piccaninnie Ponds documented by Thurgate (1995) are not included here as they are believed to be a result of natural variation brought about by competition between species.

8 Knowledge gaps

Throughout the preceding sections of this Ecological Character Description mention has been made of knowledge gaps and data deficiencies for the system. Scientists and natural resource managers have requirements for knowledge and a desire to fully understand complex wetland systems. There is much still to be learned about the interactions between components and processes in this and other wetlands (Hale and Butcher 2008).

A number of key attributes have yet to be fully described with only limited data from sporadic and older investigations having addressed a few key components and processes within the site. Most of the site specific investigations were carried out in the late 1980s and early 1990s (for example Scholz 1987; 1990; Hallam and Thurgate 1992; Thurgate 1995).. The work in the 1980s and 1990s tended to focus predominantly on the Piccaninnie Main Ponds, with very little attention to interactions of processes between the different wetland types across the entire site. As Pick Swamp has only been a relatively recent addition to the reserve network (in 2010), investigations into the recovery of this part of the site have only been conducted since restoration works commenced in 2009.

The key knowledge gaps that are required to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met are outlined in Table 22, together with a brief description of the action required to address these gaps.

Table 22: Summary of knowledge gaps for key components relevant to the maintenance of the ecological character of the Piccaninnie Ponds Karst Wetlands.

Component/ Process	Knowledge Gap	Recommended Action
Hydrology	Groundwater discharge into the Main Ponds is relatively well documented; however understanding of the water regime of the whole site is limited.	Monitor groundwater discharge at multiple sites. Create a water budget for the wetland system.
Soil types – peat	Very limited data are available on the type and extent of peat throughout the wetland system. Peat wetlands are highly susceptible to desiccation and constitute one of the most threatened wetland types globally. Hydrology is a primary process for peat formation, so understanding the water balance of the system and surface hydrological patterns is important. Depending on how the peat is formed, peat formation can also affect surface hydrology patterns. The type of peat development is not known, nor is there an understanding of the biogeochemistry of the peat and how that affects primary productivity and diversity in the fen wetlands.	Baseline investigations into peat type, distribution, formation processes, hydrology and biochemistry are required.
Algae	The relative importance of algae and periphyton in food webs and primary production in the karst wetlands is poorly understood.	Investigate food webs and levels of primary productivity within karst wetlands. Baseline surveys of algal composition.
Water Quality	Water quality information for the site is limited to only a few years of data with little is known about inter-annual variability over long time scales. Water clarity is considered a key feature of the karst wetlands, but there is no data on this aspect of water quality. Turbidity is linked with water movement and it is possible that the flushing rates of the ponds restrict turbidity and also phytoplankton growth.	Regular water quality monitoring (salinity, nutrients, pH, irradiance) at karst and other wetland types. Establishment of data loggers in key wetlands to collect baseline data.
Vegetation communities	There is virtually no quantitative information on the condition of vegetation communities within the nominated Ramsar site. Ecological Associates (2008) provide the first floristic mapping of the wetlands, but this is not linked to wetland type.	Assessment of condition to be linked to recent floristic mapping (Ecological Associates 2008) and ongoing restoration activities at Pick Swamp.

Component/ Process	Knowledge Gap	Recommended Action
	The karst vegetation associations are poorly understood, particularly in Crescent and Hammerhead Ponds. Available data is 20 years old and needs to be updated. Understanding of primary productivity is also limited.	Baseline of extent, composition and condition for karst submergent macrophyte and algal associations to be determined. Identify plant species irradiance requirements and link to monitoring of water quality.
Threatened species	Several species of conservation significance are recorded from the site. Some of the data is sporadic and requires additional survey work to establish frequency of use.	Investigation into the status of these threatened species within the site.
Waterbirds	Understanding of the abundance and species of waterbirds that use the wetland is based on limited survey work. Current survey efforts by Birds South East should be continued to help establish patterns of use. Key species, notably the Australian bittern, sanderling and hooded plover should be targeted as records for these species are based on isolated or sporadic records.	Annual waterbird surveys to continue in addition to specific investigations into the status of the Australasian bittern, sanderling, and hooded plover.
Fish	Reasonably well understood, but likely additional information will arise with further investigations.	Continue investigations of population extent and habitat preferences. Link to restoration activities in Pick Swamp. Studies of species dynamics in response to varied environmental conditions, especially for the dwarf galaxias are required.
Invertebrates and food web	Understanding of the invertebrate communities is highly limited, with virtually no data available. The karst fauna in particular is not known, and as cave fauna often have a high number of rare and endemic species this would add to the unique biodiversity values of the site. The relative importance of invertebrates in food webs is also poorly understood.	Baseline surveys are required to establish community types and species richness data.

9 Monitoring

As a signatory to the Ramsar Convention, Australia is obliged to maintain the ecological character of its Wetlands of International Importance. While there is no explicit requirement for monitoring the site, in order to ascertain if the ecological character of the wetland site is being protected a monitoring program is required.

While there may be existing monitoring and assessment programs in place for components within Piccaninnie Ponds Karst Wetlands, there is no over-arching monitoring program designed to detect and manage changes to the ecological character of the wetlands *per se*. A management plan has been prepared for the system, which will act as an overarching guide for decision makers and stakeholders in the region.

A comprehensive monitoring program is not required as part of the ecological character description, only a guide to the broad areas which require monitoring relevant to the maintenance of ecological character and their relative priority. More detail on monitoring requirements will be set forth in the management plan.

The purpose of the monitoring recommended in this ECD is to:

- Identify objectives for monitoring essential and critical components, processes, services or threats;
- Recommend indicators or measures to be used and the frequency of monitoring;
- Provide priorities for monitoring; and
- Address key knowledge gaps identified for the site.

The recommended monitoring for the Piccaninnie Ponds Karst Wetlands are provided in Table 23.

Table 23: Monitoring needs for the Piccaninnie Ponds Karst Wetlands.

Component/ process	Purpose	Indicator/s	Location/s	Frequency	Priority
Geomorphology.	Establishment of baseline and detection of change.	Composition and stability of geomorphic units. Use LiDar and ground surveys.	Entire site.	Every 10 years.	Moderate.
Soils – peat.	Establish benchmark of fine scale baseline map of soil profile.	Soil type.	Entire site.	Once off.	Low.
Hydrology – groundwater discharge.	Establishment of baseline and detection of change.	Fluctuation in discharge rates, water quality, isotopes and major ions and cations	Entire site – include Crescent and Hammerhead Ponds.	Continual to establish baseline for first year then seasonal. Separate loggers to be used for water quality parameters.	High.
Hydrology – surface water.	Establishment of baseline and then detection of change for extent of wetland type and surface water flow paths.	Digital Elevation Model (DEM) and wetland mapping of frequency and duration of inundation and hydrological connectivity. Gauging station and gauge boards to be used to establish groundwater and surface water interactions.	Entire site.	Surface water logged at gauging boards – continuous.	High.
Water quality – clarity.	Establishment of baseline and detection of change.	Turbidity and irradiance (light penetration).	Karst wetlands.	Monthly to establish baseline.	Moderate.
Water quality -	Establishment of	EC and nutrients (total	Karst wetlands.	Monthly to establish	Moderate.

Component/ process	Purpose	Indicator/s	Location/s	Frequency	Priority
salinity and nutrients.	baseline and detection of change.	nitrogen, nitrate, total phosphorous). Salinity depth profiles.	Groundwater bore CAR011.	baseline.	
Vegetation – extent of broad types.	Establishment of baseline and detection of change	Extent of broad community types – remote sensing.	Entire site	Every 10 years.	High.
Vegetation – community composition.	Establishment of baseline and detection of change.	Community composition of vegetation types (field surveys) and extent of changes.	Entire site.	Every 5 years.	High.
Karst vegetation associations.	Establishment of baseline and detection of change.	Composition and percent cover of species. Need to establish temporal and seasonal variability.	Karst wetlands. Include baseline for Crescent and Hammerhead Ponds.	Monthly to establish baseline and then annually. Requires cave diving licence.	High.
Fish – general.	Detection of change	Community composition, particularly continued exclusion of introduced species. Maintenance of hydrological connectivity to the sea for diadromous species.	Entire site.	Annual.	Moderate.
Fish – abundance.	Detection of change.	Abundance of key species Yarra pygmy perch, dwarf galaxias.	Crescent Pond and Pick Swamp.	Annual.	Moderate.
Aquatic invertebrates.	Establishment of baseline and detection	Community composition	Entire site	Seasonal, relate to inundation patterns of	Low to moderate.

Component/ process	Purpose	Indicator/s	Location/s	Frequency	Priority
	of change			intermittent wetlands	
Waterbirds – general.	Establishment of baseline and detection of change.	Counts and species identifications, breeding observations. Habitat preferences.	Entire site.	Monthly to seasonal.	Low to moderate.
Threatened species.	Establishment of baseline and detection of change.	Location, abundance.	Entire sits.	Opportunistic, linked to other survey work.	Moderate.

10 Communication and education

Under the Ramsar Convention a Program of Communication, Education, Participation and Awareness (CEPA) was established to help raise awareness of wetland values and functions. At the Conference of Contracting Parties in Korea in 2008, a resolution was made to continue the CEPA program in its third iteration for the next two triennia (2009 – 2015).

The vision of the Ramsar Convention's CEPA Program is: "People taking action for the wise use of wetlands." To achieve this vision, three guiding principles have been developed:

a) The CEPA Program offers tools to help people understand the values of wetlands so that they are motivated to become advocates for wetland conservation and wise use and may act to become involved in relevant policy formulation, planning and management.
b) The CEPA Program fosters the production of effective CEPA tools and expertise to engage major stakeholders' participation in the wise use of wetlands and to convey appropriate messages in order to promote the wise use principle throughout society.
c) The Ramsar Convention believes that CEPA should form a central part of implementing the Convention by each Contracting Party. Investment in CEPA will increase the number of informed advocates, actors and networks involved in wetland issues and build an informed decision-making and public constituency.

The Ramsar Convention encourages that communication, education, participation and awareness are used effectively at all levels, from local to international, to promote the value of wetlands.

A comprehensive CEPA program for an individual site is beyond the scope of an ECD, but key communication messages and CEPA actions, such as a community education program, can be used as a component of a management plan.

The key public awareness messages identified in the preparation of this ecological character description for Piccaninnie Ponds Karst Wetlands are:

- The unique and iconic status of the Piccaninnie Ponds Karst Wetlands. Noting that not only is the site an excellent site for cave diving, but that this unique karst wetland formation supports a internationally important wetland complex with exceptional biodiversity values.
- The site meets five of the nine criteria for listing as a Wetland of International Importance and includes highly significant areas of coastal fen wetlands and unique karst rising spring wetlands.
- The site falls within a national biodiversity hotspot and supports a significant amount of regional diversity.
- That restoration of altered sections of the site to a more natural state is progressing effectively, with a focus on the restoration of wetland habitat at Pick Swamp.

- The importance of understanding groundwater supply and interactions at the regional scale – that what happens in the north of the catchment affects what happens at the site.
- The importance of privacy for nesting waterbirds and minimisation of disturbance to nesting sites from agricultural and recreational activities (particularly on the beach).
- The ecological importance of the remnant vegetation associations and how these support a high proportion of regionally and nationally endangered species.
- The deleterious effects of altering the hydrology of wetlands by draining land, thus reducing the condition of wetland as a whole.
- The cultural value of the site.

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Glossary

Definitions of words associated with ecological character descriptions (DEWHA 2008) (see DEWHA 2008 for references cited below).

Administrative Authority	the agency within each Contracting Party charged by the national government with oversight of implementation of the Ramsar Convention within its territory [http://www.ramsar.org/about/about_glossary.htm].
Adverse conditions	ecological conditions unusually hostile to the survival of plant or animal species, such as occur during severe weather like prolonged drought, flooding, cold, etc (Ramsar Convention 2005).
Alkalinity	The property of water to neutralize acids. Usually expressed in terms of calcium carbonate equivalents (USA EPA 1999)
Aquifer	a water-bearing horizon, sufficiently permeable to transmit groundwater and yield such water to wells and springs (Ramsar 2006).
Assessment	the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (as defined by Ramsar Convention 2002, Resolution VIII.6).
Baseline	condition at a starting point. For Ramsar wetlands it will usually be the time of listing of a Ramsar site.
Benchmark	a standard or point of reference (ANZECC and ARMCANZ 2000). a pre-determined state (based on the values which are sought to be protected) to be achieved or maintained.
Benefits	Benefits or services are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems (Ramsar Convention 2005, Resolution IX.1 Annex A). See also "Ecosystem Services".
Biogeographic region	a scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc (Ramsar Convention 2005).
Biological diversity	the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity), and of ecological processes. This definition is largely based on the one contained in Article 2 of the Convention on Biological

	Diversity (Ramsar Convention 2005).
Calcium carbonate	naturally occurring compound with the chemical formula $CaCO_3$, the major component of carbonate rocks including limestone and marble (Ramsar 2006).
Catchment	the total area draining into a river, reservoir, or other body of water (ANZECC and ARMCANZ 2000).
Change in ecological character	is defined as the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005, Resolution IX.1 Annex A).
Chamber	an enlargement in a cave passage or system (Ramsar 2006)
Community	an assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000).
Community Composition	all the types of taxa present in a community (ANZECC and ARMCANZ 2000).
Community Structure	all the types of taxa present in a community and their relative abundances (ANZECC and ARMCANZ 2000).
Conceptual model	wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Gross 2003)
Contracting Parties	are countries that are Member States to the Ramsar Convention on Wetlands; 153 as at September 2006. Membership in the Convention is open to all states that are members of the United Nations, one of the UN specialized agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice [http://www.ramsar.org/key_cp_e.htm].
Critical stage	meaning stage of the life cycle of wetland-dependent species. Critical stages being those activities (breeding, migration stopovers, moulting etc.) which if interrupted or prevented from occurring may threaten long-term conservation of the species. (Ramsar Convention 2005).
Ecological character	is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. Within this context, ecosystem benefits are defined in accordance with the variety of benefits to people (Ecosystem Services). (Millennium definition of ecosystem services as "the benefits that people receive from ecosystems" (Ramsar Convention 2005, Resolution IX.1 Annex A). The phrase "at a given point in time" refers to Resolution VI.1 paragraph 2.1, which states that "It is essential that the ecological character of a site be described by the Contracting Party concerned **at the time of designation for the Ramsar List**, by completion of the Information

	Sheet on Ramsar Wetlands (as adopted by Recommendation IV. 7).
Ecological communities	any naturally occurring group of species inhabiting a common environment, interacting with each other especially through food relationships and relatively independent of other groups. Ecological communities may be of varying sizes, and larger ones may contain smaller ones (Ramsar Convention 2005).
Ecosystems	the complex of living communities (including human communities) and non-living environment (Ecosystem Components) interacting (through Ecological Processes) as a functional unit which provides inter alia a variety of benefits to people (Ecosystem Services). (Millennium Ecosystem Assessment 2005).
Ecosystem components	include the physical, chemical and biological parts of a wetland (from large scale to very small scale, e.g. habitat, species and genes) (Millennium Ecosystem Assessment 2005).
Ecosystem processes	are the changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological. (Ramsar Convention 1996, Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment, that result in existing ecosystems and bring about changes in ecosystems over time (Australian Heritage Commission 2002)
Ecosystem services	are the benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (e.g. food & water), regulating (e.g. flood control), cultural (e.g. spiritual, recreational), and supporting (e.g nutrient cycling, ecological value). (Millennium Ecosystem Assessment 2005). See also "Benefits".
Ecologically Sustainable Development	development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ANZECC and ARMCANZ 2000).
Geomorphology	the study of water-shaped landforms (Gordon *et al* . 1999)
Groundwater	a subsurface water that lies below the water table in the saturated or phreatic zone (Ramsar 2006)
Indicator species	species whose status provides information on the overall condition of the ecosystem and of other species in that ecosystem; taxa that are sensitive to environmental conditions and which can therefore be used to assess environmental quality (Ramsar Convention 2005).
Indigenous	a species that originates and occurs naturally in a

species	particular country (Ramsar Convention 2005).
Introduced (non-native) species	a species that does not originate or occur naturally in a particular country (Ramsar Convention 2005).
Limestone	sedimentary rock containing at least 50% calcium carbonate by weight (Ramsar 2006)
Limits of Acceptable Change	the variation that is considered acceptable in a particular component or process of the ecological character of the wetland without indicating change in ecological character which may lead to a reduction or loss of the criteria for which the site was Ramsar listed' (modified from definition adopted by Phillips 2006).
List of Wetlands of International Importance ("the Ramsar List")	the list of wetlands which have been designated by the Ramsar Contracting Party in which they reside as internationally important, according to one or more of the criteria that have been adopted by the Conference of the Parties [http://www.ramsar.org/about/about_glossary.htm].
Monitoring	the collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management (Ramsar Convention 2002, Resolution VIII.6).
Ramsar	city in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands was signed on 2 February 1971; thus the Convention's short title, "Ramsar Convention on Wetlands" [http://www.ramsar.org/about/about_glossary.htm].
Ramsar Criteria	Criteria for Identifying Wetlands of International Importance, used by Contracting Parties and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values. http://www.ramsar.org/about/about_glossary.htm
Ramsar Convention	*Convention on Wetlands of International Importance especially as Waterfowl Habitat*. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987. The abbreviated names "Convention on Wetlands (Ramsar, Iran, 1971)" or "Ramsar Convention" are more commonly used [http://www.ramsar.org/index_very_key_docs.htm].
Ramsar Information Sheet (RIS)	the form upon which Contracting Parties record relevant data on proposed Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological, and socioeconomic issues among others, ownership and jurisdictions, and

	conservation measures taken and needed (http://www.ramsar.org/about/about_glossary.htm).
Ramsar List	the List of Wetlands of International Importance [http://www.ramsar.org/about/about_glossary.htm].
Ramsar Sites	wetlands designated by the Contracting Parties for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar Criteria [http://www.ramsar.org/about/about_glossary.htm].
Ramsar Sites Database	repository of ecological, biological, socio-economic, and political data and maps with boundaries on all Ramsar sites, maintained by Wetlands International in Wageningen, the Netherlands, under contract to the Convention [http://www.ramsar.org/about/about_glossary.htm].
Spring	point where underground water emerges on to the surface, not exclusive to limestone, but generally larger in cavernous rocks (Ramsar 2006)
Threatened ecological community	an ecological community which is likely to become extinct in nature if the circumstances and factors threatening its extent, survival or evolutionary development continue to operate (Ramsar 2006)
Waterbirds	(Criteria 5 & 6) - The Convention functionally defines waterfowl (a term which, for the purposes of these Criteria and Guidelines, is considered to be synonymous with "waterbirds") as "birds ecologically dependent on wetlands" (Article 1.2). This definition thus includes any wetland bird species. However, at the broad level of taxonomic order, it includes especially: • penguins: *Sphenisciformes*. • divers: *Gaviiformes*; • grebes: *Podicipediformes*; • wetland related pelicans, cormorants, darters and allies: *Pelecaniformes*; • herons, bitterns, storks, ibises and spoonbills: *Ciconiiformes*; • flamingos: *Phoenicopteriformes*: • screamers, swans, geese and ducks (wildfowl): *Anseriformes*; • wetland related raptors: *Accipitriformes* and *Falconiformes*; • wetland related cranes, rails and allies: *Gruiformes*; • Hoatzin: *Opisthocomiformes*; • wetland related jacanas, waders (or shorebirds), gulls, skimmers and terns: *Charadriiformes;* • coucals*: Cuculiformes;* and • wetland related owls: *Strigiformes*; Ramsar (2006b).

Water table	the top surface of a body of groundwater that fills the pore spaces within a rock mass. Above it lies the freely draining vadose zone, and below it lies the permanently saturated phreas. Individual cave conduits may be above or below the water table, and therefore either vadose or phreatic, and the water table cannot normally be related to them. The water table slope (hydraulic gradient) is low in limestone due to the high permeability, and the level is controlled by outlet springs or local geological features. High flows create steeper hydraulic gradients and hence rises in the water level away from the spring (Ramsar 2006).
Wetlands	are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention 1987).
Wetland Assessment	the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Finlayson *et al* . 2001; Ramsar Convention 2002).
Wetland Ecological Risk Assessment	a quantitative or qualitative evaluation of the actual or potential adverse effects of stressors on a wetland ecosystem
Wetland types	as defined by the Ramsar Convention's wetland classification system [http://www.ramsar.org/ris/key_ris.htm#type].
Wise use of wetlands	is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches[1], within the context of sustainable development[2]" (Ramsar Convention 2005 Resolution IX.1 Annex A). 1. Including *inter alia* the Convention on Biological Diversity's "Ecosystem Approach" (CBD COP5 Decision V/6) and that applied by HELCOM and OSPAR (Declaration of the First Joint Ministerial Meeting of the Helsinki and OSPAR Commissions, Bremen, 25-26 June 2003). 2. The phrase "in the context of sustainable development" is intended to recognize that whilst some wetland development is inevitable and that many developments have important benefits to society, developments can be facilitated in sustainable ways by approaches elaborated under the Convention, and it is not appropriate to imply that 'development' is an objective for every wetland.

Appendix A: Method

The method for compiling this ECD comprised of the following tasks:

Project Inception:

Consultant team leader Rhonda Butcher met with the South Australian Department of Environment and heritage (DEH) project manager to confirm the scope of works and timelines as well as identifying relevant stakeholders that would be consulted. This included a half day site visit.

Task 1: Review and compilation of available data

The consultant team reviewed preliminary drafts of an ECD and RIS for the site that DEH had prepared. These documents were not based on the national framework for preparing ECDs and lacked detail on limits of acceptable change, conceptual models, monitoring and communication messages in particular.

The consultant team then undertook a thorough desktop review of information on the ecology of the Piccaninnie Ponds/Pick Swamp wetland complex to complement the data already collated in the DEH draft RIS and ECD. Relevant experts and team members were consulted to ensure a focus on key documents and relevant data. Knowledge gaps that are considered essential to the success of the nomination were determined, along with the need for additional data collection identified early in the project.

Task 2: Stakeholder engagement and consultation

DEH provided a number of key contacts for stakeholders with an interest in the ECD and management planning process including individuals recognised as Boandik, local naturalist groups, cave diving groups, SA Tourism Commission, Birds Southeast among others.

Peter Cottingham and Kerri Muller met with key stakeholder representatives early in the project to explain the project and its purpose and gather information about stakeholder views on the ecological values of the Piccaninnie Ponds Karst Wetlands and the threats to those values. Information session(s) were held in Mt Gambier on 22nd and 23rd May 2008.

Kerri Muller introduced the project to the SE Indigenous Focus Group in May and individuals recognised as Boandik were engaged through specific meetings and site visits with community members who could speak for country and with other community members as advised by the Nation's recognised representatives.

Task 3: Development of a draft ECD

Consistent with the national guidance and framework (DEWHA 2008) the following steps were undertaken to describe the ecological character of the Piccaninnie Ponds Karst Wetlands.

Steps from the national draft (2008) framework	Activities
1. Document introductory details	Prepare basic details: site details, purpose, legislation
2. Describe the site	Based on the above literature review describe the site in terms of: location, land tenure, Ramsar criteria, wetland types (using Ramsar classification).
3. Identify and describe the critical components, processes and services	Identify all possible components, processes, services and benefits. Identify and describe the critical components, processes, services and benefits responsible for determining ecological character
4. Develop a conceptual model of the system.	Models were developed for the system that highlighted important aspects of the ecology of the site. The first details the hydrological processes of the site based on current understanding. The second details the formation of fen wetlands. Quantitative models are not possible at this site due to limited data.
5. Set Limits of Acceptable Change	For each critical component process and service, establish the limits of acceptable change.
6. Identify threats to the site	This process identified both actual and potential future threats to the ecological character of the wetland system.
7. Describe changes to ecological character since the time of listing	As this ECD forms part of the nomination documents for the site, this section is not relevant. A brief summary of known historic impacts on the site is documented.
8. Summarise knowledge gaps	This identifies the knowledge gaps for not only the ecological character description, but also for its management.
9. Identify site monitoring needs	Based on the identification of knowledge gaps above, recommendations for future monitoring are described.
10. Identify communication, education and public awareness messages	Following the identification of threats, management actions and incorporating stakeholder comments, a general description of the broad communication / education messages are described.

Task 4: Revision of the Ramsar Information Sheet (RIS)
The information collated during Task 2, together with the draft Ecological Character Description was used to produce a RIS in the standard format provided by Ramsar.

Task 5 Finalising the ECD and RIS

The draft ECD and RIS were submitted to DEH and interested stakeholders including the Wetlands and Waterbirds Taskforce member for South Australia. Dr Bill Phillips, Mainstream Environmental Consulting and Dr Roger Jaensch also reviewed the draft ECD. Dr Michael Hammer provided expert review on the fish sections of the ECD.

A meeting with then DEH and DWLBC staff from Mt Gambier was held in August 2008 at which time the draft ECD was presented and discussed. Comments from agencies and stakeholders were incorporated to produce revised ECD and RIS documents.

A.2 Consultant team for ECD development

The consultant team was led by Dr Rhonda Butcher of Water's Edge Consulting in association with Jennifer Hale, Peter Cottingham, and Dr Kerri Muller (Kerri Muller NRM).

Dr Bill Phillips (Mainstream Environmental Consulting) and Dr Roger Jaensch (Wetlands International – Oceania) provided expert peer review of the first draft of the ECD. In addition Dr Roger Jaensch and Dr Michael Hammer provide expert technical input for waterbirds and fish respectively.

Rhonda Butcher (team leader)

Rhonda is considered an expert in wetland ecology and assessment. She has a BSc (Hons) and a PhD in wetland ecology and biodiversity assessment together with over twenty years of experience in the field of aquatic science. She has worked for CSIRO/Murray Darling Freshwater Research Centre, Monash University/CRC for Freshwater Ecology, Museum of Victoria, Victorian EPA and the State Water Laboratories of Victoria. She has been operating Water's Edge Consulting since 2004.

Rhonda has specialist expertise in the areas of aquatic biological monitoring, biodiversity assessment, invertebrate ecology as well as wetland and river ecology. Having worked on a diverse range of ecosystems, Rhonda has garnered a broad understanding of the ecology of aquatic biota including macrophytes, fish, waterbirds, and amphibians, and their responses to varying hydrological regimes. Rhonda has worked on numerous Ramsar related projects over the past eight years, including the first pilot studies into describing ecological character. She has subsequently co-authored, provided technical input, and peer reviewed a number of Ecological Character Descriptions. ECD projects Rhonda has had technical input to include the Coorong and Lakes Alexandrina and Albert, Lake MacLeod, and Peel-Yalgorup Ramsar sites.

Jennifer Hale

Jennifer has over eighteen years experience in the water industry having started her career with the State Water Laboratory in Victoria. Jennifer is an aquatic ecologist with expertise in wetland, riverine and estuarine systems. She is qualified with a Bachelor of Science (Natural Resource Management) and a Masters of Business Administration. Jennifer is an aquatic ecologist with specialist fields of expertise including phytoplankton dynamics, aquatic macrophytes, sediment water interactions and nutrient dynamics. She has a broad understanding of the ecology of aquatic macrophytes, fish, waterbirds, macroinvertebrates and floodplain vegetation as well as geomorphic processes. She has a solid knowledge of the development of ecological character descriptions and has been involved in the development of ECDs for the Peel-Yalgorup, the Coorong, Lake MacLeod, Elizabeth and Middleton Reefs, Ashmore Reef and the Coral Seas Ramsar sites. Jennifer also has a solid knowledge and understanding of estuarine systems.

Peter Cottingham

Peter Cottingham is a versatile and experienced facilitator and project manager, experience garnered from a diversity of technical and non-technical environments over the past 16 years. Peter was a senior Knowledge Broker with the Cooperative Research Centre for Freshwater Ecology for eight years. In this capacity, Peter contributed to the synthesis, packaging and delivery of specialised knowledge for clients as part of 'joint problem solving' efforts in water resource management and river rehabilitation. He also directly managed or coordinated much of the consulting work undertaken by the CRC. This included a number of Scientific Panels that were convened to develop environmental flow recommendations for regulated rivers in Victoria, and also to the development of a consistent monitoring and assessment framework from which to measure the performance of environmental flow releases. He has a proven track record in communication at all levels of NRM organisations and across a broad range of stakeholder groups, planning and completion of projects on time and within budget, establishing and managing high-performing teams, including scientific panels and consulting teams. Peter has exceptional skills as a knowledge broker with vast experience in the preparation of technical and scientific reports, presentations at conferences, seminars and workshops, both nationally and internationally.

Kerri Muller

Kerri has more than 16 years experience in Natural Resource Management (NRM) establishing *Kerri Muller NRM* in 2004 with Brett Love to respond to a growing demand for provision of quality consulting services to the NRM sector. Kerri is recognised as a leader in the field of NRM. She has a unique blend of skills with 11 years of academic training and more than 15 years of on-ground experience working with rural landholders and indigenous communities. Kerri holds a Ph.D. in wetland ecology from The University of Adelaide and has worked as a University researcher and teacher, designer of constructed wetlands, catchment manager, NRM Project Officer, adult educator, meeting facilitator and consulting ecologist. She is a graduate of the Murray Darling Basin Leadership Program, is an EMS Associate Auditor (ISO14001) and has been a member of the Australian Society for Limnology since 1991. She is also a member of the Murray Darling Basin Ministerial Council Community Reference Group, providing advice on all aspects of the implementation of The Living Murray Business Plan to the Community Advisory Committee.

Appendix B: Boandik consultation on the Ramsar listing of Piccaninnie Ponds and Pick Swamp

Dr Kerri Muller
July 2008

Introduction

The Boandik (also know as Bunganditj) people of south-east Australia are the Traditional Owners of Piccaninnie Ponds and Pick Swamp. Consultation has been hindered by accessing the small number of Boandik people who are still actively using country and the fact that the Boandik people are not as well resourced in terms of NRM engagement as other groups such as the Ngarrindjeri people. Dr Muller met with the SE Indigenous Focus Group and with people recognised as Boandik: Aunty Valda Brennan, Uncle Malcolm Anderson and Ken Jones. Auntie Valda and Uncle Malcolm met with Kerri in Mt Gambier and Ken Jones took Kerri on a tour of the region showing the issues in the catchment as well as on-site works and impacts. The following comments were made during that consultation period.

Boandik comments

- The area from Browns Bay to the Glenelg River should be managed as one hydrological unit without worrying about State borders
- Sheet flow is very important to the wetland system. Any disruption to that disrupts the whole wetland system.
- Fences need to be removed where ever possible to open up the country again
- In areas that are grazed by sheep and cattle there are 4 native plant species compared with 60 in areas that are only grazed by native fauna
- Important corridor for Orange-bellied Parrot and blue wings (parrots?) along the coast that is being converted to houses – also important from them to have open grasslands near by – bird counts are conducted in the open grassy areas
- The drains are cleared out every year which digs them down deeper into the peat and the groundwater which increases the rates of drainage. The surface flooding has gone.
- We are in trouble if they are having to irrigate peat soils – the groundwater is dropping away rather than filling the wetlands
- The pivots are the biggest problem – taking away the water from the wetlands – so are the trees, the gums and the pines, taking away the water from the wetlands
- Important to let the drains back up and flood out over country and wet the wetlands
- Important Emu Wren habitat in the scrub near Browns Bay
- Need to purchase land between AS DEH owned parcel and the Glenelg River so that the sheet flow can be re-established and the OBP corridor can be preserved
- Mark Bachmann and Steve Clarke have maps of what the country looked like when white man came

- Black people have been silenced by losing the land and their lives – we had the best country so we were almost wiped out very quickly
- We use the wetlands for eels, fish, bush tucker – there are middens and stone huts here that show permanent settlement – this place was very important tucker and very good place to live, so abundant for the old people
- Coorong wattle has been moving in since the 1930s after the really bad rabbit plagues
- Areas that are watered with centre pivots take a long time to recover
- Crescent sinkhole in Pick Swamp is really important – just like Piccanninie Ponds but much harder to get to and so is in better condition – we don't go there much just occasionally – brolgas are breeding in there – one pair that comes back each year – getting smarter about where to build nests each year
- Important that sheet flows from upwellings are allowed to flow across the country without being blocked up or drained to sea – we will kill this country if don't get the water balance right – they are draining off the water and leaving behind the salt
- The sea is coming back up the drain in to Piccaninnie Ponds – the salt will kill it
- The upper freshwater lens has been pumped dry and now people are getting into saltier water underneath – like the Woolwash Caravan Park -= they ran out of fresh water
- Purchase more land to include the puddings – water should sit on country from the coastal dunes back to the puddings – they are important sites for men's initiations – buy back Greenpoint wetland or co-manage for wetland ecoservices – don't build an embankment to save a few lambs when the wetlands are worth so much more
- Reconnect the waterways from Browns Bay to the Glenelg River
- We need a regional plan for our assets all the way across from Victoria to the Coorong
- There are important eel smoking trees here that were used to smoke eels for trading with other indigenous people who had things Boandik wanted
- Connection between the wetlands and the stringy bark woodlands is really important
- Cultural economy is linked to wetland health
- All species of ducks are here
- 3 pairs of bitterns
- Unimin might be interested in co-management or a land trade for the puddings
- Corporate responsibility is also an important thing to foster – so much of our important country is privately owned
- Along the coastline Boandik people lived anywhere there was freshwater
- Look after the groundwater and everything else will be ok
- The Blue Lakes are dropping that is a sign that too much water is being taken out or drained to sea
- The whole area being drained from Penola to the coast is the biggest threat to the wetlands in the whole region – other Ramsar sites too like Bool Lagoon are at threat from that
- We have to save water, bring it back inland and not drain it to sea
- 8 Mile, Blackfords Drain all of them, turn them inland

- Put stones in the drains to block them up and change the gradient back to the wetlands not to sea
- Dam the drains and make wetlands again
- There were very few places that freshwater ran to sea before white man started draining
- We need to get out onto country with DEH staff, we need to walk around with Peter Alexander and show how it is supposed to work and how we need to change the drains

Appendix C: Listed species and communities of conservation significance

Plant species conservation status based on Barker *et al*. (2005) and regionally threatened communities based on Croft *et al*. (1999). Fish species conservation status at the State level is based on Hammer *et al*. (2007). Invertebrate species conservation status based on Sands and New (2002).

R = rare, V = vulnerable, E = endangered, CE = critically endangered, P = protected, LC = Least concern.

National = *Environment Protection and Biodiversity Conservation Act 1999*, State = *National Parks and Wildlife Act 1972.*

Group	Common Name	Scientific Name	National	State
Waterbirds				
	Magpie Goose	*Anseranas semipalmata*		E
	Musk Duck	*Biziura lobata*		R
	Australasian Bittern	*Botaurus poiciloptilus*	E	V
	Latham's Snipe	*Gallinago hardwickii*		V
	Brolga	*Grus rubicunda*		V
	Lewin's Rail	*Lewinia pectoralis*		V
	Eastern Curlew	*Numenius madagascariensis*		V
	Little Tern	*Strenula albifrons*		R
	Hooded Plover	*Thinornis rubricollis*		V
Wetland associated non waterbirds				
	Azure Kingfisher	*Ceyx azureus*		E
	Sea Eagle	*Haliaeetus leucogaster*		E
	Orange-bellied Parrot	*Neophema chrysogaster*	CE	E
Fish				
	Short Finned Eel	*Anguilla australis australis*		R
	Climbing Galaxias	*Galaxias brevipinnis*		R
	Dwarf Galaxias	*Galaxiella pusilla*	V	V
	Spotted Galaxias	*Galaxias truttaceous*		E
	Pouched Lamprey	*Geotria australis*		V
	Southern Pygmy Perch	*Nannoperca australis*		E, P
	Yarra Pygmy Perch	*Nannoperca obscura*	V	E, P
	Variegated Pygmy Perch*	*Nannoperca variegata*	V	E, P
	Congolli	*Pseudaphritis urvillii*		R
Mammals				
	Swamp Antechinus	*Antechinus minimus*		E
Reptiles				
	Swamp skink	*Egernia coventryi*		E

Group	Common Name	Scientific Name	National	State
Invertebrates – Lepidoptera with wetland plant species as host plants				
	Sedge-skipper	*Hesperilla chrysotricha*		LC
	Flame Sedge-skippers	*Hesperilla idothea*		V
	Bright-eyed Brown butterfly	*Heteronympha cordace wilsoni*		CE
Parastacidae				
	Glenelg Spiny Crayfish	*Eustacus bispisnosu*	E	
Plants				
		Baumea laxa		R
	Grass Daisy	*Brachyscome graminea*		R
	Leafy Twig Rush	*Cladium procerum*		R
		Carex gunniana		R
	Heath Bent Grass	*Deyeuxia densa*		R
	Sun Dew	*Drosera whittakeri* ssp. *aberrans*		R
	Tall Sawsedge	*Gahnia clarkei*		R
	Mountain Gentain	*Gentianella gunniana*		V
		Glycine latrobeana		V
		Haloragis brownii		R
	Branching Rush	*Juncus prismatocarpus*		V
	Creeping Cotula	*Leptinella reptans* (syn. Cotula reptans)		R
		Luzula flaccida		V
	Bottlebrush Tea-tree	*Melaleuca squarrosa*		R
	Slender Mint	*Mentha diemenica*		R
	Scented Onion Orchid	*Microtis rara*		R
	Varied Milfoil	*Myriophyllum variifolium*		R
	Entire Marshwort	*Nymphoides gemmata*		V
	Scaly Poa	*Poa fax*		R
	Maroon Leek-orchid	*Prasophyllum frenchii*	E	E
	Swamp Greenhood	*Pterostylis tenuissima*	V	V
	River Buttercup	*Ranunculus inundatus*		R
	Scented Fan Flower	*Scaevola calendulacea*		V
Regionally Threatened Communities with South Australia				
	Swamp Gum	*Eucalyptus ovata* Woodland		E
	Silky Teatree	*Leptospermum lanigerum* Tall Closed Shrubland (Wet Shrubland)		E

* The variegated pygmy perch (*Nannoperca variegata*) does not appear to regularly occur at Piccaninnie Ponds Karst Wetlands; there is only one historic and unverified record of this species at the site.

Appendix D: Fish species and ecology

Fish species recorded from Piccaninnie Ponds Karst Wetlands, including current and historic records (source Hammer 2002; Hammer *et al* . 2000; Hammer 2008a)

Migration type: A - Anadromous, Am – Amphidromous, C - Catadromous, F – Obligate freshwater.

Ecology and biological information sourced from FishBase (Froese, R. and D. Pauly. Editors. 2008. FishBase. World Wide Web electronic publication. www.fishbase.org , version (04/2008) (original references not cited) and Hammer (2001; 2002).

Family	Scientific name	Common name	Life cycle	Ecology/ biology	Wetland type/lactation
Geotriidae	*Geotria australis*	Pouched lamprey	A	Demersal. Typically found in mud burrows in upper reaches of coastal streams for the first four years of life, and then they migrate back to the sea. Adults inhabit the sea for an undetermined period and are parasitic on other fishes. Migrate upstream which may last for 16 months and spawn in freshwater. Adults are often found below weirs and dams during their spawning migration which may take them considerable distances upstream of the coast. Migration mostly takes place in rainy nights when water levels are rising, with temperatures between 12-14.5°C and when there is extensive cloud cover or during the dark phase of the moon. Sometimes they exit the water by wriggling up the bank to bypass obstacles to migration. Adults stop feeding while in freshwater and die shortly after spawning.	**9 – Drains** • Outlet Creek
Galaxiidae	*Galaxias brevipennis*	Climbing galaxias	Am	Benthopelagic, free swimming. Inhabits mainly clear streams, often deeply shaded and relatively fast-flowing. The existence of a marine stage is regarded to be facultative rather than obligatory in Australia. Swims near the bottom, usually around the cover of	**9 – Drains** • Outlet Creek

Family	Scientific name	Common name	Life cycle	Ecology/ biology	Wetland type/lactation
				rocks and logs.	
	Galaxias maculatus	Common galaxias, (also called common jollytail)	C	Benthopelagic, free swimming. Use a variety of habitat, but mostly prefer still or slow-flowing waters, mainly in streams, rivers and lakes within a short distance of the sea. Will also occur in landlocked wetlands. Feed on aquatic and terrestrial invertebrates. Adults typically migrate downstream into estuaries during high spring tides in autumn to spawn on fringing vegetation and also algal mats. Spawning does not occur beyond the river estuaries, making this species 'only marginally catadromous'. Many perish after spawning but some survive another year. Coastal populations have a marine juvenile stage.	**Zk (b) Karst wetlands** • Hammerhead Pond • Piccaninnie Ponds • Crescent Pond **U – Non forested peatlands** • Pick Swamp • Piccaninnie Ponds surrounding wetland **9 – Drains** • Outlet Creek • Pick Swamp
Galaxiidae	*Galaxiella pusilla*	Dwarf galaxias	F	Demersal. Frequently found among vegetation along the edge of still or slow-running waters like swamps, drainage ditches and backwaters of creeks. Adults live in both ephemeral and permanent habitats. A short-lived fish, reaching maturity in the first year of life and perishing shortly after spawning. Fish occupying ephemeral water possibly aestivate or shelter in crayfish burrows when surface water evaporates during summer. Probably an annual species. Peak breeding in late winter, potentially to take advantage of seasonally inundated habitats. Limited information on diet – may take small invertebrates and algae.	**U – Non forested peatlands** • Pick Swamp
Galaxiidae	*Galaxias truttaceus*	Spotted galaxias	Am	Demersal, free swimming. Occurs in still or slow-flowing waters at low elevations close to the sea; most abundant along shore margins in rocky areas. Found around plants, rocks or logs on the margins of still or flowing rivers, streams and lakes. The species has a marine juvenile stage, indicative of a	**Zk (b) Karst wetlands** • Crescent Pond **U – Non forested peatlands** • Pick Swamp

Family	Scientific name	Common name	Life cycle	Ecology/ biology	Wetland type/lactation
				diadromous life cycle. Spawning takes place from autumn to winter, among aquatic vegetation. Newly hatched larvae drift down current and out to sea where they spend their first few months, eventually returning to fresh water during spring among annual whitebait migrations. In lacustrine and other landlocked populations, adults move upstream into feeder streams to spawn. The larvae are then swept downstream into lakes. Feeds mainly on aquatic and terrestrial insects.	**9 – Drains** • Outlet Creek
Nannopercidae	*Nannoperca australis* (SE sub-species)	Southern pygmy perch	F	Benthopelagic. Occurs in lotic and lentic freshwater bodies, preferring vegetated margins in still or gently flowing water. Forms small groups and is a very common prey item for introduced fishes, such as the Redfin perch and trout. Prefers habitats not affected by stock access. Feeds on small invertebrates. Breeds from September to January, when water temperatures rise above 16°C. Reproductive habits and biology are typical of the family. Maximum life expectancy is about 5 years.	**Zk (b) Karst wetlands:** • Hammerhead Pond • Piccaninnie Ponds • Crescent Pond **U – Non forested peatlands** • Piccaninnie Ponds surrounding wetland **9 - Drains** • Outlet Creek • Pick Swamp
Nannopercidae	*Nannoperca obscura*	Yarra pygmy perch	F	Benthopelagic. Inhabits streams and small lakes; preferring more permanent and flowing water with abundant cover in the form of aquatic vegetation. Occurs in creeks and lakes, usually among aquatic weeds. Feeds on aquatic invertebrates. Breeding season is in spring, slightly earlier than the Southern Pygmy Perch.	**Zk (b) Karst wetlands:** • Crescent Pond
Nannopercidae	*Nannoperca variegata*	Variegated pygmy perch	F	Benthopelagic; non-migratory. Prefers fast flowing streams and ponds in clear water, most common in creeks between ponds. Feeds on aquatic invertebrates. Breeds from spring to early summer.	**Zk (b) Karst wetlands:** • Piccaninnie Ponds Historic record – no date;

Family	Scientific name	Common name	Life cycle	Ecology/ biology	Wetland type/lactation
				First discovered in the early 1980s. Co-occurs with *N. australis* at Ewen ponds, but generally prefers faster flowing streams rather than ponds.	record can not be verified (Hammer *et al* . 2007)
Bovichtidae	*Pseudaphritis urvillii*	Congolli	C	Benthopelagic. Found in streams and estuaries. Inhabits slow-flowing water around log snags, under over-hanging banks or among leaf litter. Adult fish migrate downstream to spawn in weedy estuaries from late April to August. Predatory feeding on invertebrates and fishes. Often buries itself in the substrate to ambush passing prey. A highly efficient osmo-regulator, able to withstand direct transfer from salt to fresh water without any indication of stress.	**Zk (b) Karst wetlands:** • Piccaninnie Ponds
Anguillidae	*Anguilla australis australis*	Short finned eel	C	Benthopelagic; occurring in streams lakes and swamps. Feeds on fishes, invertebrates, aquatic plants, and terrestrial and aquatic insects. Long lived species which migrate to near the Coral sea to breed. Larval eels return as elvers (around 10cm).	**Zk (b) Karst wetlands:** • Piccaninnie Ponds • Hammerhead Pond **9 – Drains:** • Outlet Creek
Atherinidae	*Atherinosoma microstoma*	Small mouthed hardyhead	A	Pelagic. Found in shallow coastal bays, estuaries and lakes ranging from pure fresh to salinities in excess of seawater. Occurs abundantly in estuaries around eel-grass thickets, occasionally penetrating the lower freshwater reaches of rivers. Feeds on tiny crustaceans and insects. Breeds in spring (September to October). An annual species (living for only one year), dying shortly after spawning	**Zk (b) Karst wetlands:** • Piccaninnie Ponds **U – Non forested peatlands** • Piccaninnie Ponds surrounding wetland • Pick Swamp
Prototroctidae	*Prototroctes maraena*	Grayling	A	Demersal. Adults inhabit creeks and rivers, usually in cool, clear waters over gravel bottoms in sections alternating between pools and rapids. Usually found in clear, moderate to fast-flowing water in the upper reaches of rivers (sometimes to altitudes above 1000 metres). Often forming aggregations below barriers to upstream movement. Timid species that forms fast-	**Zk (b) Karst wetlands:** • Piccaninnie Ponds Historic record 1980-1989. Vulnerable at the National level. Presumed locally extinct (Hammer 2002)

Family	Scientific name	Common name	Life cycle	Ecology/ biology	Wetland type/lactation
				moving shoals. Often form large schools especially prior to spawning. Feed on small crustaceans, insects and their larvae and algae. The intestinal tract is long, s specialization to assist in the breakdown of ingested plant material. Spawn: Feb.-May; 25,000-68,000 eggs which sink to bottom downstream of spawning site. Hatching: 10-20 days; larvae, 6-7 mm TL, swept downstream to estuaries and the sea, return to freshwater after 6 months. Larvae need estuarine waters to mature and recruit; as such the virtual absence of an estuary may limit the presence at the site. This species may have been present when the discharge from the site connected to the Glenelg River estuary.	

Fresh Water Crayfish

Family	Scientific name	Common name	Ecology/ biology	Wetland type/lactation
Parastacidae	*Euastacus bispisnosu*	Glenelg Spiny Cray	EPBC listed endangered. found in cool, flowing fresh water streams or drains with high water quality. Spiny freshwater crayfish use undercut banks, woody debris, rock boulders and cobbled river beds.	**Drain**
Parastacidae	*Engaeus strictifrons*	Burrowing crayfish	Constructs deep, predominantly vertical burrows on flood-plains, in creeks, swamps or in drainage channels.	**Drain and areas near swamp**
Parastacidae	*Geocharax spp.*	Swamp Yabby		**Drain**

Appendix E: Waterbirds

Species listing: M-EPBC = Listed as migratory or marine under the EPBC Act; V-EPBC = Vulnerable under the EPBC Act; E-EPBC = Endangered under the EPBC Act; CE-EPBC = Critically Endangered under the EPBC Act; C= CAMBA; J = JAMBA; R = ROKAMBA, B = BONN Convention; CE-IUCN = listed as Critically Endangered by the IUCN; EN-IUCN = listed as Endangered by the IUCN; V-IUCN = listed as Vulnerable by the IUCN (2012).

Species records based on data supplied by Birds South East survey data 2007-2011, Biodiversity Database of South Australia up to 2006.

Common name	Scientific name	Listed
Australasian bittern	*Botaurus poiciloptilus*	EN-IUCN, E-EPBC
Australasian grebe	*Tachybaptus novaehollandiae*	
Australasian shoveler	*Anas rhynchotis*	M-EPBC
Australian pelican	*Pelecanus conspicillatus*	M-EPBC
Australian reed warbler	*Acrocephalus australis*	B
Australian shelduck	*Tadorna tadornoides*	M-EPBC
Australian spotted crake	*Porzana fluminea*	
Australian white ibis	*Threskiornis molucca*	M-EPBC, J
Australian wood duck	*Chenonetta jubata*	M-EPBC
Azure kingfisher	*Ceyx azureus*	
Black swan	*Cygnus atratus*	M-EPBC
Black-fronted dotterel	*Elseyornis melanops*	
Black-tailed godwit	*Limosa limosa*	M-EPBC, C, J, R, B
Black-tailed native-hen	*Tribonyx ventralis*	
Black-winged stilt	*Himantopus himantopus*	M-EPBC
Blue-billed duck	*Oxyura australis*	M-EPBC
Brolga	*Grus rubicunda*	
Buff-banded rail	*Gallirallus philippensis*	
Caspian tern	*Hydroprogne caspia*	M-EPBC, C, J
Cattle egret	*Ardea ibis*	M-EPBC, C, J
Chestnut teal	*Anas castanea*	M-EPBC
Common greenshank	*Tringa nebularia*	M-EPBC, C, J, R, B
Crested tern	*Thalasseus bergii*	
Curlew sandpiper	*Calidris ferruginea*	M-EPBC, C, J, R, B
Double-banded plover	*Charadrius bicinctus*	M-EPBC, B
Dusky moorhen	*Gallinula tenebrosa*	
Eastern curlew	*Numenius madagascariensis*	M-EPBC, C, J, R, B
Eurasian coot	*Fulica atra*	
Glossy ibis	*Plegadis falcinellus*	M-EPBC, C, B
Great cormorant	*Phalacrocorax carbo*	
Great crested grebe	*Podiceps cristatus*	
Great egret	*Ardea alba*	M-EPBC, C, J
Grey plover	*Pluvialis squatarola*	M-EPBC, C, J, R, B

Grey teal	*Anas gracilis*	M-EPBC
Gull-billed tern	*Gelochelidon nilotica*	M-EPBC
Hardhead	*Aythya australis*	M-EPBC
Hoary headed grebe	*Poliocephalus poliocephalus*	
Hooded plover	*Thinornis rubricollis*	M-EPBC
Intermediate egret	*Ardea intermedia*	
Kelp gull	*Larus dominicanus*	
Latham's snipe	*Gallinago hardwickii*	M-EPBC, C, J, R, B
Lewin's rail	*Lewinia pectoralis*	
Little black cormorant	*Phalacrocorax sulcirostris*	
Little egret	*Egretta garzetta*	M-EPBC
Little penguin	*Eudyptula minor*	M-EPBC
Little pied cormorant	*Microcarbo melanoleucos*	
Little tern	*Sternula albifrons*	M-EPBC, C, J, R, B
Magpie goose	*Anseranas semipalmata*	M-EPBC
Marsh sandpiper	*Tringa stagnatilis*	M-EPBC, C, J, R, B
Masked lapwing	*Vanellus miles*	M-EPBC
Musk duck	*Biziura lobata*	M-EPBC
Orange-bellied parrot	*Neophema chrysogaster*	CE-IUCN, CE-EPBC, M-EPBC
Pacific Black duck	*Anas superciliosa*	M-EPBC
Pacific gull	*Larus pacificus*	M-EPBC
Pied oystercatcher	*Haematopus longirostris*	
Pink-eared duck	*Malacorhynchus membranaceus*	M-EPBC
Purple swamphen	*Porphyrio porphyrio*	
Red-capped plover	*Charadrius ruficapillus*	M-EPBC
Red-kneed dotterel	*Erythrogonys cinctus*	M-EPBC
Red-necked avocet	*Recurvirostra novaehollandiae*	M-EPBC
Red-necked stint	*Calidris ruficollis*	M-EPBC, C, J, R, B
Royal spoonbill	*Platalea regia*	
Ruddy turnstone	*Arenaria interpres*	M-EPBC, C, J, R, B
Sacred kingfisher	*Todiramphus sanctus*	
Sanderling	*Calidris alba*	M-EPBC, C, J, R, B
Sharp-tailed sandpiper	*Calidris acuminata*	M-EPBC, C, J, R, B
Short-tailed shearwater	*Ardenna tenuriostris*	M-EPBC, J, R
Silver gull	*Chroicocephalus novaehollandiae*	M-EPBC
Sooty oystercatcher	*Haematopus fuliginosus*	
Straw-necked ibis	*Threskiornis spinicollis*	
Swamp harrier	*Circus approximans*	M-EPBC
Whimbrel	*Numernius phaeopus*	M-EPBC, C, J, R, B
Whiskered tern	*Chlidonias hybridus*	M-EPBC
White-bellied sea eagle	*Haliaeetus leucogaster*	M-EPBC, C
White-faced heron	*Egretta novaehollandiae*	
White-necked heron	*Ardea pacifica*	
White-winged black tern	*Chlidonias leucopterus*	M-EPBC, C, J, R

Wood sandpiper	*Tringa glareola*	M-EPBC, C, J, R, B
Yellow-billed spoonbill	*Platalea flavipes*	

Appendix F: Floristic associations

Mapped vegetation communities/land units in the Piccaninnie Ponds Karst Wetlands.
Ramsar types:
Tp: Permanent freshwater marshes/pools; ponds, marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
Ts: Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.
U: Non-forested peatlands; includes shrub or open bogs, swamps, fens.
W: Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.
Zk(b): Karst and other subterranean hydrological systems, inland

EAssoc Code	Floristic Description	Total Mapped Area (ha)	Ramsar Wetland type
A	*Eleocharis acuta*, ± *Triglochin procerum* mid sedgeland over *Crassula helmsii*, *Ranunculus amphitrichus*, ± *Cotula coronopifolia* aquatics.	16.9	U
B	*Eleocharis acuta*, ± *Juncus kraussii*, ± *Typha domingensis*, ± *Epilobium billardieranum* ssp., ± **Festuca arundinacea* mid closed sedgeland.	9	U
C	Exotic pasture grasses and forbs – non-native vegetation.	60.4	n/a
D	*Eleocharis acuta*, *Baumea arthrophylla*, ± *Typha domingensis*, ± *Juncus kraussii* mid sedgeland over *Ranunculus amphitrichus*, *Crassula helmsii* aquatics.	1.6	U
E	*Carex appressa*, ± *Juncus kraussii*, ± *Urtica incisa* tall sedgeland over *Eleocharis acuta*, **Holcus lanatus*, *Lythrum hyssopifolia* sedges.	2.6	U
F	*Gahnia trifida*, ± *Ozothamnus ferrugineus*, ± *Leptospermum lanigerum*, ± *Melaleuca squarrosa* tall sedgeland over *Eleocharis acuta*, **Festuca arundinacea*, *Baumea arthrophylla* sedges over ± *Juncus prismatocarpus*, ± *Lepidosperma* sp., ± *Epilobium billardieranum* ssp., ± *Ranunculus amphitrichus*, ± *Lythrum hyssopifolia* forbs.	7.6	U

EAssoc Code	Floristic Description	Total Mapped Area (ha)	Ramsar Wetland type
G	*Juncus kraussii*, *Eleocharis acuta*, ± *Gahnia trifida* mid open sedgeland over ± *Graminae sp., ± *Crassula helmsii*, ± *Ranunculus amphitrichus*, ± **Rumex* sp. grasses	14.7	U
H	emergent ± *Eleocharis acuta*, ± *Juncus kraussii*, ± **Festuca arundinacea*, ± **Rumex* sp. sedges over *Cotula coronopifolia*, ± *Crassula helmsii* low forbland.	1.5	U
I	emergent ± *Eleocharis acuta*, ± *Juncus kraussii* sedges over ± *Crassula helmsii*, ± *Cotula coronopifolia*, ± *Isolepis fluitans* low aquatic bed.	17.2	U
J	*Triglochin procerum*, ± *Eleocharis acuta*, ± *Leptocarpus brownii* tall open aquatic bed over *Crassula helmsii*, ± *Ranunculus amphitrichus*, ± *Myriophyllum salsugineum* aquatics	14	U in Pick Swamp/Tp on edges of Main Pond
K	*Isolepis nodosa*, ± *Juncus kraussii*, ± *Clematis microphylla* var. *microphylla* tall sedgeland over **Holcus lanatus*, ± **Festuca arundinacea*, ± *Acaena novae-zelandiae*, ± *Schoenus* sp. tussock grasses.	8.4	Ts
L	*Schoenoplectus pungens, Juncus kraussii*, ± **Festuca arundinacea*, ± *Isolepis nodosa* mid sedgeland over *Sporobolus* sp., **Melelotus indica*, *Isolepis fluitans*, **Plantago coronopus* ± **Rumex* sp. ± *Crassula helmsii* ± *Distichlis distichophylla* forbs.	7.4	U
M	*Eucalyptus ovata* var. *ovata* low open woodland.	0.8	n/a
N	*Leptospermum lanigerum*, *Melaleuca squarrosa*, ± *Ozothamnus ferrugineus*, ± *Leucopogon parviflorus*, ± *Acacia longifolia* ssp. *sophorae* tall closed shrubland over *Gahnia trifida*, ± *Gahnia clarkei* sedges over Cyperaceae sp., ± *Baumea juncea*, ± *Samolus repens* sedges.	52.3	W
O	*Baumea arthrophylla*, *Baumea juncea*, ± *Typha domingensis* sedgeland over ± *Triglochin procerum* aquatics	11.2	Tp
P	*Melaleuca squarrosa*, ± *Leptospermum lanigerum* mid closed shrubland over *Gahnia trifida*, *Gahnia clarkei*, ± *Typha domingensis* sedges over ± *Baumea juncea*,	111.4	W

EAssoc Code	Floristic Description	Total Mapped Area (ha)	Ramsar Wetland type
	± *Baumea arthrophylla*, ± Graminae sp. sedges.		
Q	*Juncus kraussii, Baumea arthrophylla, Baumea juncea* mid sedgeland over Cyperaceae sp., *Microseris lanceolata*, *Selliera radicans*, **Plantago coronopus*, *Samolus repens* forbs.	1.7	Tp
R	± *Themeda triandra*, ± *Poa poiformis*, ± *Austrodanthonia* sp., ± **Lagurus ovatus*, ± **Cynosorus echinatus*, ± **Lolium* sp., ± **Holcus lanatus*, ± **Hypochieris radicata* low tussock grassland.	22.5	n/a
S	*Acacia longifolia* ssp. *sophorae*, *Leucopogon parviflorus* low open shrubland over *Pimelia glauca*, shrubs over Cyperaceae sp. sedges over *Acrotriche affinis* shrubs.	1.8	n/a
T	*Allocasuarina verticillata* low open forest over *Acacia longifolia* ssp. *sophorae*, *Leucopogon parviflorus* shrubs over Chenopodiaceae sp. shrubs over Graminae sp., *Dianella revoluta* var., *Pteridium esculentum* tussock grasses over *Hydrocotyl hirta*, *Tetragonia implexicoma*, *Acrotriche affinis* forbs.	1.4	n/a
U	emergent ± *Eucalyptus ovata* var. *ovata*, ± *Acacia melanoxylon*, ± *Melaleuca lanceolata* over *Acacia longifolia* ssp. *sophorae*, *Acacia pycnantha*, ± *Leucopogon parviflorus* tall shrubland over ± Chenopodiaceae sp., ± *Alyxia buxifolia*, ± *Gahnia* trifida shrubs over *Pteridium esculentum*, *Lomandra longifolia*, ± *Lepidosperma gladiatum*, ± *Dianella revoluta* var. rushes.	72.6	n/a
W	*Typha domingensis* tall sedgeland over ± *Baumea arthrophylla*, ± *Lepidosperma* sp., ± *Berula erecta*, ± *Epilobium pallidiflorum*, ± *Triglochin procerum.*	13.3	Tp
X	Open water/karst feature with deeply submerged aquatics.	0.74	Zk(b)
Z	*Cladium procerum*, *Typha domingensis* tall closed sedgeland.	2.7	Tp
AB	*Leptospermum lanigerum*, *Gahnia trifida* mid shrubland over *Baumea juncea*, *Leptocarpus brownii*, *Baumea arthrophylla* sedges over *Nymphoides geminata* forbs.	0.93	W

EAssoc Code	Floristic Description	Total Mapped Area (ha)	Ramsar Wetland type
AC	*Schoenoplectus pungens* low closed sedgeland.	0.23	Ts
AD	*Potamogeton pectinatus* low sparse aquatic bed.	0.16	Ts
POW	*Melaleuca squarrosa* mid open shrubland over *Typha domingensis*, ± *Phragmites australis* sedges over *Baumea juncea* sedges.	1.9	W
SE00261	*Leucopogon parviflorus*, *Acacia longifolia* ssp. *sophorae*, *Olearia axillaris*, ± *Myoporum insulare* tall shrubland over *Lepidosperma gladiatum*, *Pimelea serpyllifolia* ssp. *serpyllifolia*, *Isolepis nodosa* sedges over *Carpobrotus rossii*, *Clematis microphylla* var. *microphylla.*	180.9	n/a
SE00271	*Spinifex sericeus* (NC), *Ozothamnus turbinatus*, *Isolepis nodosa*, ± *Olearia axillaris* mid grassland over *Leucophyta brownii*, *Apium prostratum* var., *Cakile maritima* ssp. *maritime.*	8.8	n/a

1existing SA VEG ID and Regional Floristic Description
*introduced species

Appendix G: Waterbird feeding and dietary guilds.

Feeding Guilds: F1= dense inundated vegetation; F2 = Shallows (<0.5m) &/or mud; F3= Deep water (>1m); F4 = Away from wetland habitats
Dietary Guilds: D1= Plants and animals; D2 = Mostly plants; D3= Mostly animals; D4 = Fish. X = Common or usual, O = Occasional.

Waterbirds	Feeding Guilds				Dietary Guilds			
	F1	F2	F3	F4	D1	D2	D3	D4
Waterfowl								
Australasian shoveler		X	X		X			
Australian shelduck		X		X	X			
Australian wood duck				X	X			
Black swan		X	X	X		X		
Blue-billed duck			X		X			
Chestnut teal		X	X		X			
Grey teal		X	X		X			
Hardhead		X	X		X			O
Magpie goose		X				X		
Musk duck			X		X			O
Pacific black duck		X	X	X	X			
Pink-eared duck		X	X		X			
Grebes								
Australasian grebe		X	X				X	X
Great crested grebe			X			O	X	X
Hoary-headed grebe		X	X				X	X
Pelicans and Cormorants								
Australian pelican			X				X	X
Great cormorant			X				X	X
Little black cormorant			X				X	X
Little pied cormorant		X	X				X	X
Herons, Ibis, Egrets and Spoonbills								
Australian white ibis		X		X			X	X
Australasian bittern	X	X					X	
Glossy ibis		X				X	O	X
Great egret		X		X		X	X	X
Intermediate egret		X		X		X	X	X
Little egret		X				X	X	X
Royal spoonbill		X			O	X	X	X
Straw-necked ibis		X		X		X		X
White-faced heron		X		X		X	X	X
White-necked heron		X				X	X	X
Yellow-billed spoonbill		X				X	X	X
Crakes, Rails Water Hens, Coots and Brolga								
Australian spotted crake	X	X			X			

Waterbirds	Feeding Guilds				Dietary Guilds			
	F1	F2	F3	F4	D1	D2	D3	D4
Black-tailed native-hen	X	X		X	X			
Brolga		X			X			
Buff-banded rail	X	X		X	X			
Dusky moorhen	X	X		X	X			
Eurasian coot		X	X		X			
Lewin's rail		X			X			
Purple swamphen	X	X		X	X			
Shorebirds								
Black-tailed godwit		X				O	X	
Black-winged stilt		X				O	X	O
Common greenshank		X			X			
Curlew sandpiper		X					X	
Double-banded plover		X					X	
Eastern curlew		X					X	
Grey plover		X					X	
Hooded plover		X					X	
Latham's snipe		X					X	
Marsh sandpiper		X					X	
Masked lapwing		X					X	
Pied oystercatcher								
Red-capped plover		X		X	X			
Red-kneed dotterel		X			X			
Red-necked avocet		X				O	X	O
Red-necked stint		X			X			
Ruddy turnstone		X					X	
Sanderling		X					X	
Sharp-tailed sandpiper		X			X			
Sooty oystercatcher		X					X	
Whimbrel		X					X	
Gulls and Terns								
Caspian tern			X				X	X
Crested tern			X				X	X
Kelp gull		X	X	X			X	X
Little tern			X				X	X
Pacific gull		X	X	X			X	
Silver gull		X	X	X	X			X
Whiskered tern		X	X				X	X
White-winged tern	X	X	X				X	
Hawks and Eagles								
Swamp harrier	X	X		X			X	X
White-bellied sea-eagle		X	X	X			X	X