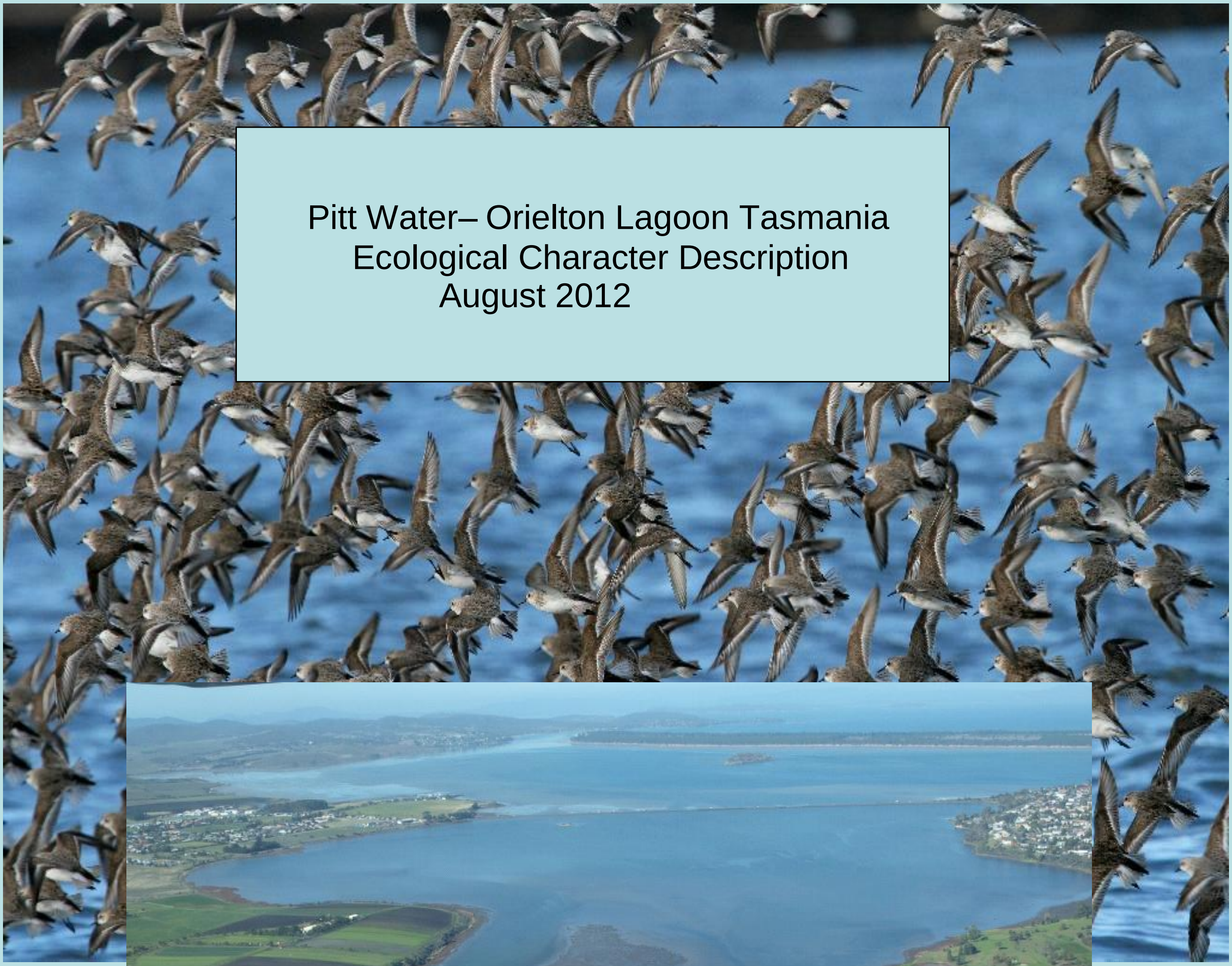

Pitt Water– Orielton Lagoon Tasmania
Ecological Character Description
August 2012

Pitt Water – Orielton Lagoon Tasmania

Ecological Character Description

August 2012

Introductory Notes

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 *Environment Protection and Biodiversity Conservation Act 1999* (Cth), nor replace the role of the Minister or his delegate in making an informed decision to approve an action.

The *Water Act 2007* requires that in preparing the [Murray-Darling] Basin Plan, the Murray Darling Basin Authority (MDBA) must take into account Ecological Character Descriptions of declared Ramsar wetlands prepared in accordance with the National Framework.

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.

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

Executive Summary

This Ecological Character Description (ECD) has been prepared in accordance with the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar wetlands* (DEWHA 2008). The purpose of the ECD is to provide an integrated description of the critical components, processes and ecosystem services for this Ramsar site. It also outlines threats to the ecological character of the site, information gaps and limits of acceptable change. A recommended monitoring program identifies key measurable indicators of change. The ECD draws on available information and knowledge of estuarine ecosystem function, including evidence of some trends at the site since the time of listing in 1982 to 2009.

The Pitt Water - Orielton Lagoon Ramsar site (PWOL) is located in the south east of Tasmania, close to Tasmania's state capital, Hobart, and surrounded by agricultural land and small towns, now within the commuter belt of the capital. The surrounding lands were cleared for agriculture from the time of early settlement in the 1800s and PWOL lies in the path of major transportation routes used since colonial times. These factors have had an effect on PWOL, thereby altering the natural processes of the system for decades. In addition to changes to river flows and sediment transport, two causeways were constructed in 1874 across the upper parts of the estuary. Thus at the time of listing, the site was already a modified system. PWOL lies in the driest area of Tasmania and has variable annual rainfall: therefore it is especially prone to the effects of loss of river flows.

The site boundary crosses the main central basin of the estuary, thereby excluding some estuary features and habitats. The upper areas of the estuary are defined by the presence of the two causeways. The large area, known as Upper Pitt Water, reaches upstream as far as the town of Richmond at the mouth of the Coal River. It marks the upper tidal limit, now barred with a weir. Tides move freely through an extensive bridge in the western causeway. The second distinctive area of PWOL is Orielton Lagoon, formed by the second (eastern) causeway. Once a wide, open bay of a secondary estuary feature, at the time of listing Orielton Lagoon (as it became known) was virtually cut off with only two narrow culverts with sills set at high tide level linking it to the main body of water. As a consequence, the lagoon was almost certainly eutrophic and the extensive saltmarsh at the head of the lagoon was in very poor condition. Nevertheless, Orielton Lagoon was important for bird life. Some other locations within the PWOL boundary but below the causeways also provided small alternative feeding and roosting for birds. These are at Iron Creek and the mouth of the Sorell Rivulet.

When PWOL was Ramsar listed in 1982, it was considered to meet four criteria: 2 a, 2b, 2d, and 3. Since 1982 the Ramsar criteria have been modified and extended, and the standards applied by DSEWPaC (or its former equivalent agencies) have been clarified.

Biodiversity criteria for which the site was originally listed are still supported at the site, albeit with some loss in species diversity and abundance. The condition of the site may be considered to be generally poorer, with the exception of the waters of Orielton Lagoon which has benefited from improved tidal exchange and removal of sewage outfalls. The status of key environmental components and processes within PWOL and the wider estuarine functions that support the system is now considered modified, so the site no longer justifies inclusion under Criterion 1 as a rare or representative wetland in '*natural or near-natural condition*'. PWOL meets five criteria for Ramsar listing as follows:

Group B of the Criteria. Sites of international importance for conserving biological diversity

Criteria based on species and ecological communities

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

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.

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.

Specific criteria based on fish

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.

Specific criteria based on other taxa

Criterion 9: 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.

The PWOL system supports important biodiversity values, including saltmarshes hosting different facies of vegetation communities and species with several saltmarsh, wetland and coastal plant and invertebrate species considered rare in Tasmania. The birdlife of PWOL includes migratory and resident waterbirds, including shorebirds, and seabirds. Orielton Lagoon is the most important site for migratory shorebirds in the Bruny Marine Bioregion. It is the most southerly area used by waders of the East Asian - Australasian Flyway. PWOL supports the biodiversity of the South-East Bioregion and Bruny Marine Bioregion. It is also important as the most significant shark breeding area in southern Tasmania and the habitat it provides for a rare endemic seastar and rare bird species. Details of how PWOL meets the five criteria are provided in Section 2. Figure ES1. summarises the components, processes and services of the site.

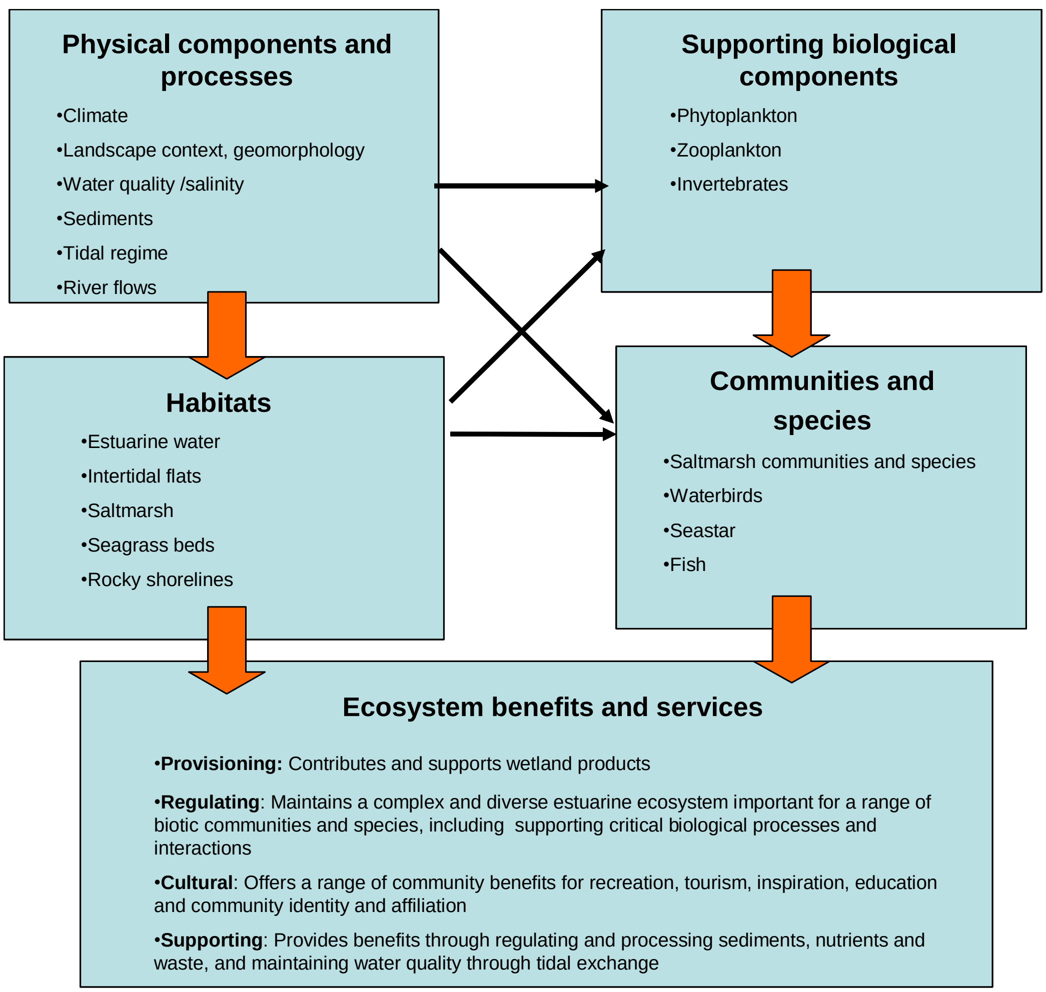

Figure ES1: Summary framework of components, processes and ecosystem services at PWOL.

Section 3 provides details of critical components and processes for the site, summarised in Table ES1. The critical components and processes were selected using the criteria set out in the guidelines.

Table ES1: Critical components and processes in PWOL showing commonalities and differences between the two main areas within the site.

Component	Sub-component	Features and processes	Features and processes
		Upper Pitt Water	**Orielton Lagoon**
Climate	Rainfall	Low and variable	
		Cool temperate climate	
		Exposed to NW and SW winds	
Hydrology	Estuary type	Wave-dominated estuary	
		Shallow estuary with marked tidal channels	Shallow water body ,1.5m
	Tidal exchange	Large tidal exchange	Limited tidal exchange
	Freshwater inflow	Low	
	Stream flow	Often ceases in summer months	
	Groundwater inputs	Low	
Water quality	Salinity	Dominantly marine	Variable - near fresh to hypersaline
	Nutrient levels	Low	High
	Coliforms	Low	High
	Chlorophyll levels	Low	High
	Water temperature	Stable marine	Varies diurnally and seasonally
Geomorphology	Geomorphic type	Drowned valley	Artificially enclosed lagoon
	Intertidal flats	Extensive	
		Complex sandbanks, ridges and bars	
		Sediment movement controlled by tidal movement	Limited sediment movement
	Sediment source	Largely from shoreline erosion	
Littoral vegetation		Saltmarshes	
Submerged vegetation		Seagrass beds	
Invertebrates		Interstitial fauna of intertidal flats	
		Saltmarshes	
		Benthic fauna	
		Fauna of rocky shorelines	
Fish		Estuarine fish community	
		Breeding area for shark	
Birds		Migratory shorebirds	
		Resident shorebirds	
		Waterbirds, seabirds	
		Feeding areas, nest sites, roosting sites	
		Refuges in timess of drought	

The setting for the ecological character of the site is determined by climate, hydrology and geomorphology. These critical components and processes are described for the estuary as a whole and then summarized for the two principal areas within the site boundaries, Upper Pitt Water and Orielton Lagoon (Table ES1). Critical ecosystem services for the ecological character description were identified using the same four criteria. 'Regulating services' and 'Supporting services' (Table ES2) are the two services critical to the ecological character of the site. These services are discussed within the context of relevant components and processes.

Table ES2: Critical Ecosystem Services at PWOL Ramsar site.

Regulating services - benefits obtained from regulation within the ecosystem or as a result of ecosystem processes	
Pollution control and detoxification	Treated effluent and stormwater enter the estuary and are diluted to acceptable levels
Potential to moderate the effects of sea level rise in limited areas	Narrow channel and causeways may dampen effects of SLR
Supporting services - services that are necessary for production of all other ecosystem services , including sustaining biodiversity and habitats	
Nutrient cycling	PWOL plays a role in cycling and discharge of nutrients from the surrounding catchments
Sediment cycling	Tidal movement and freshwater flows resuspend and recycle sediments and maintain sedimentary environments
Maintainence of biodiversity	Diversity of intertidal and subtidal habitats for marine life and shorebirds Supports a range of ecological communities including fish, saltmarsh vegetation, invertebrates of saltmarsh, intertidal flats and benthic environments Supports a number of nationally and locally threatened species Supports extensive and diverse area of a threatened non-forest vegetation community - saltmarsh

Only limited data were available from the time of listing. For some components and processes these data could be extrapolated from more recent data. For some components there was considerable anecdotal information. Saltmarsh communities were the only significant component with comparable systematic data for the time of listing and the time of writing the ECD. Climate data were available for a time-scale of several decades but critical flow data did not exist prior to listing.

The ECD includes conceptual models of both the system as a whole and separately for Upper Pitt Water and Orielton Lagoon. Conceptual diagrams of the two areas of the site show the differences in functioning at the time of listing and at the time of writing the ECD (Sections 4 and 6).

Critical components and processes for which LACs may be proposed were selected using a set of criteria. The criteria identified those components and indicators which were primary determinants of ecological character, where a baseline could be established and for which natural variability could be estimated. A further consideration was whether it was feasible to monitor the indicators and potential for management intervention. Seven components and processes met this selection process: water quality including salinity, tidal regime, river flows, intertidal flats, seagrass beds, saltmarsh communities and species, and the seastar *Parvulastra vivipara*.

In accordance with the guidelines for preparing an ECD, the Limits of Acceptable Change refer to the ecological character of the site at the time of listing. For each component, specific indicators are identified, baseline condition and natural variation are documented and limits of acceptable change proposed (Section 5).

Changes since listing are detailed in Section 6. Since the listing of the site over two decades ago, significant deliberate changes have been made to hydrology of the Coal River and Orielton Lagoon. For Orielton Lagoon, the baseline at time of listing was not a healthy or sustainable condition, amelioration of which has been undertaken since listing. Insufficient time has elapsed since changes in tidal exchange for natural variability to become evident. The Upper Coal Estuary has suffered loss of freshwater inputs with the construction of a large in-stream dam.

The ECD documents a range of changes in the PWOL Ramsar site since the time of listing including:

- Alteration of flow regimes in the Coal River
- Increasing tidal exchange and improvement of water quality in Orielton Lagoon
- Changes in sediment deposition
- Decline in abundance and diversity of birds, fish and invertebrates

- Decline in the extent of seagrass beds
- Change in saltmarsh flora and condition.

Two negative changes and one positive change in ecological character of the site are noted: changing flow regimes in the Coal River and loss of biodiversity are negative changes while improvements to Orielton Lagoon may be considered positive.

The change in the hydrology and associated processes in Upper Pitt Water exceeds the limit of acceptable change for freshwater flows entering the upper estuary. The changes in freshwater flows affect the salinity profile and sediment processes with consequences for the associated communities and species of Upper Pitt Water.

The decline in biodiversity and abundance of communities throughout the site can be measured for saltmarshes and seagrass. These show decline in area and changes in community composition in the period since listing considered to exceed limits of acceptable change, although in the case of seagrass, losses appear to be an ongoing trend that commenced prior to listing. The threatened seastar *Parvulastra vivipara* has retreated from some areas it formerly occupied within the site. Anecdotal evidence indicates loss of diversity and abundance across fish and invertebrate communities. These declines may be attributed to the (increasingly) modified condition of the site.

The change in the water quality in Orielton Lagoon is a positive change in ecological character. At the time of listing, the lagoon was almost closed off from the sea and water quality was poor. In addition, discharge from a sewage treatment plant and stormwater brought nutrients and pollutants into the confined waterbody. Now culverts have been installed to allow some tidal flow, drainage channels encourage circulation within the lagoon and now grey water is not directly discharged. The system may not yet have achieved equilibrium.

Ongoing threats to the ecological character of PWOL are identified in Section 7. These are:

- Loss of freshwater inputs to system
- Changes in sediment transport

- Agricultural activities adjacent to PWOL
- Waste products
- Urban and rural development
- Invasive species
- Climate change.

Gaps in information are recorded and the proposals for monitoring include strategies to address these gaps in order to set baselines. Other monitoring requirements are prioritised with reference to the Ramsar values of the site, critical components and processes, and limits of acceptable change.

Key communication messages bring together the ecological values of the site with the social and economic benefits of the area to the community. The location of the site so close to urban areas makes it important for communicating message about Ramsar values but also makes it vulnerable to the consequences of human activity. As parts of the area within PWOL are under management of the Parks and Wildlife Service, a management plan is crucial, but other agencies, community groups and individuals will need to play a role in the protection of the site, its values and ecosystem services.

Acknowledgements

The author of this document thanks the project Steering Committee for their assistance to the project. The Steering Committee members were:

- Ken Morgan, Wetlands Section, Department of Sustainability, Environment, Water, Population and Communities, Canberra
- Stewart Blackhall, Wildlife Biologist, Wildlife and Marine Conservation Section, Biodiversity Conservation Branch DPIPWE
- Ian Houshold, Senior Geomorphologist, Land Conservation Branch, DPIPWE
- Stephen Harris, Section Head & Principal Scientist (Vegetation Conservation), Biodiversity Conservation Branch DPIPWE.
- Annie McCuaig, Senior Planning Officer, DPIPWE (deputy for one meeting Lynne Sparrow, Southern Regional Planner DPIPWE)
- Kaylene Allen, Technical and Facilitation Support – Water, NRM South
- Emma Williams Program Coordinator **-** Healthy Coasts and Seas, NRM North
- Nicole Walsh, Project Support Officer NRM North
- Sally Fenner, Regional NRM Facilitator, Cradle Coast NRM

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Jackie Bice, Volunteer Facilitator, Parks and Wildlife Service
Alastair Morton, Senior Marine Environmental Officer (Pests & Assessments)
Water & Marine Resources DPIPWE

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Abbreviations

ASS	Acid Sulphate Soils
BOM	Bureau of Meteorology
BP	Before Present
CAMBA	China-Australia Migratory Bird agreement
CCIMPE	Consultative Committee for Introduced Marine Pest Emergencies
DEWHA	Department of Environment, Water, Heritage and the Arts
DIN	Dissolved inorganic nitrogen
DPIPWE	Department of Primary Industry, Parks, Water and Environment
DPIW	Department of Primary Industry and Water
DPIWE	Department of Primary Industry, Water and Environment
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (formely DEWHA)
EAAF	East-Asian Australasian Flyway
ECD	Ecological Character Description
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FTU	Formazin Turbidity Unit (See NTU)
IBRA	Interim Biogeographic Regionalisation of Australia
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
JAMBA	Japan-Australia Migratory Bird agreement
LIST	Land Information System of Tasmania
MEA	Millenium Ecosystem Assessment
NTU	Nephelometric turbidity units (turbidity measure)
OL	Orielton Lagoon
PN	Particulate nitrogen
PWOL	Pitt Water – Orielton Lagoon Ramsar site
PWS	Parks and Wildlife Service
RIS	Ramsar Information Sheet
ROKAMBA	Republic of Korea - Australia Migratory Bird agreement
STP	Sewage Treatment Plant
TN	Total nitrogen

TSPA	Threatened Species Protection Act 1995
WIST	Water Information System Tasmania

Section 1 Background and context

1.1 PWOL listing and landscape context

Pitt Water and Orielton Lagoon Ramsar site (PWOL) lies in southern Tasmania and forms a component of the larger Derwent Estuary system. The site is located approximately 20kms east of Hobart in an area important for a range of primary industries and as a hub for tourism. The land surrounding the estuary was some of the earliest developed by settlers for agriculture and was an important route to the Tasman peninsula and the East Coast.

Pitt Water is the name given to the estuary of the Coal River. The wide estuary was formed by near closure of the mouth of the river by a geologically recent spit at Seven Mile Beach. Several smaller rivers and creeks feed into the estuary, the largest being Orielton Rivulet. The bay into which this rivulet discharged was modified by the construction of a causeway and it became known as Orielton Lagoon.

The site was listed under the Ramsar Convention in 1982, largely on account of its importance for bird life, especially as a feeding ground for migratory waders. It was also recognised as a good example of a large-scale wave-dominated barred estuary and an important location for the conservation of saltmarsh vegetation communities. Several plants and invertebrates considered rare or threatened in Tasmania have also been recorded at the site.

Surrounding land use and construction of causeways have impacted on the site for over 150 years. Land clearance for cropping began in the 1820s and various forms of intensive farming activities extended throughout the catchment. In the 1980s marine farming of oysters was introduced to several bays within the estuary, bringing some intensive new land-based activities to the shorelines. The areas around the site have seen considerable population growth, bringing both opportunities for education and interpretation to a wide community and the potential for further threats and pressures to the integrity of the PWOL ecosystem.

The boundary and immediate land use context is shown in Figure 1.1. Figure 1.2 shows the landscape setting and location within the Derwent Estuary

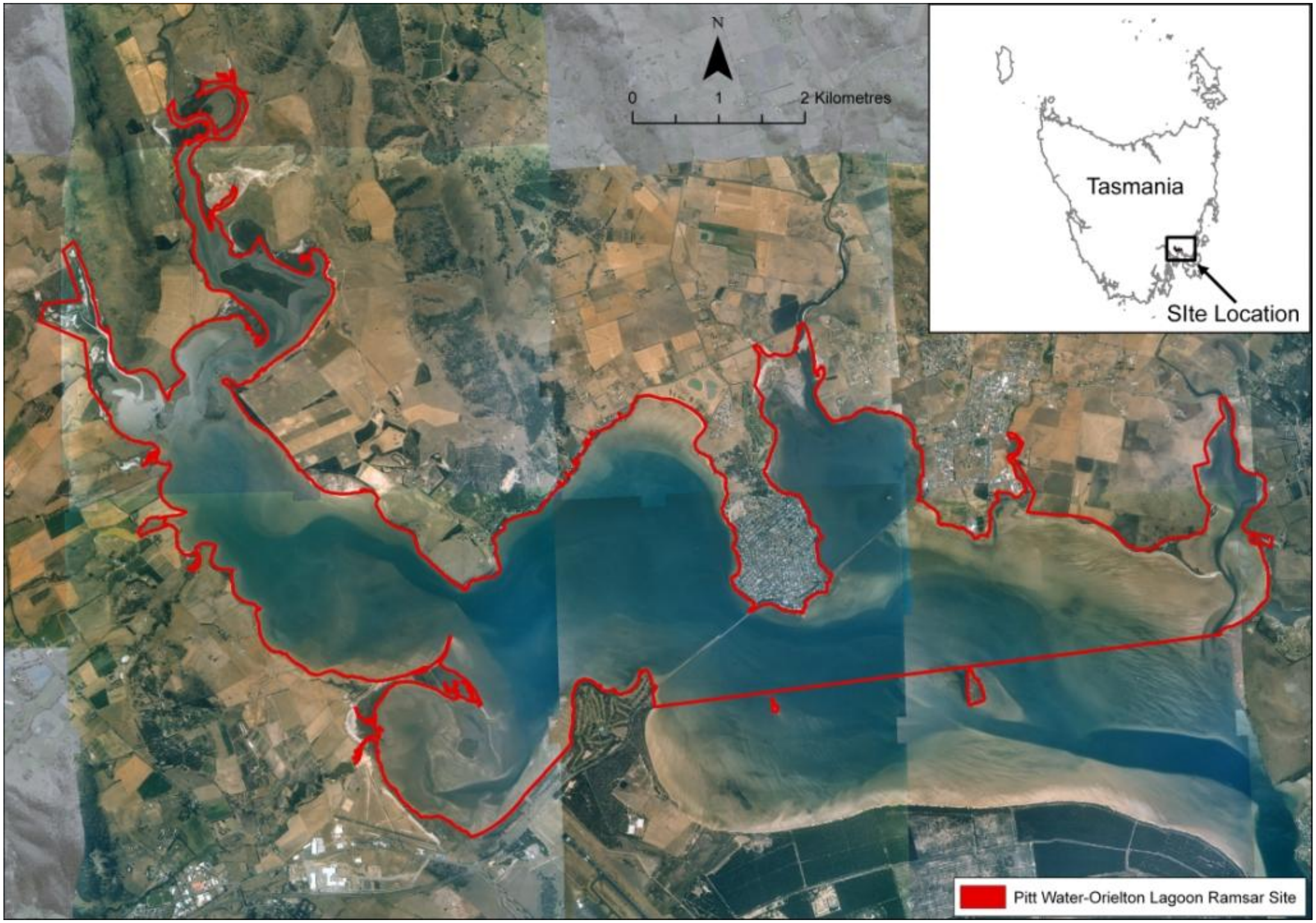


Figure 1.1: Pitt Water – Orielton Lagoon Ramsar site: Boundary and landuse context. (Source: Datum GDA94 UTM Zone 55, created by Prahalad 2009, University of Tasmania, based on LIST).

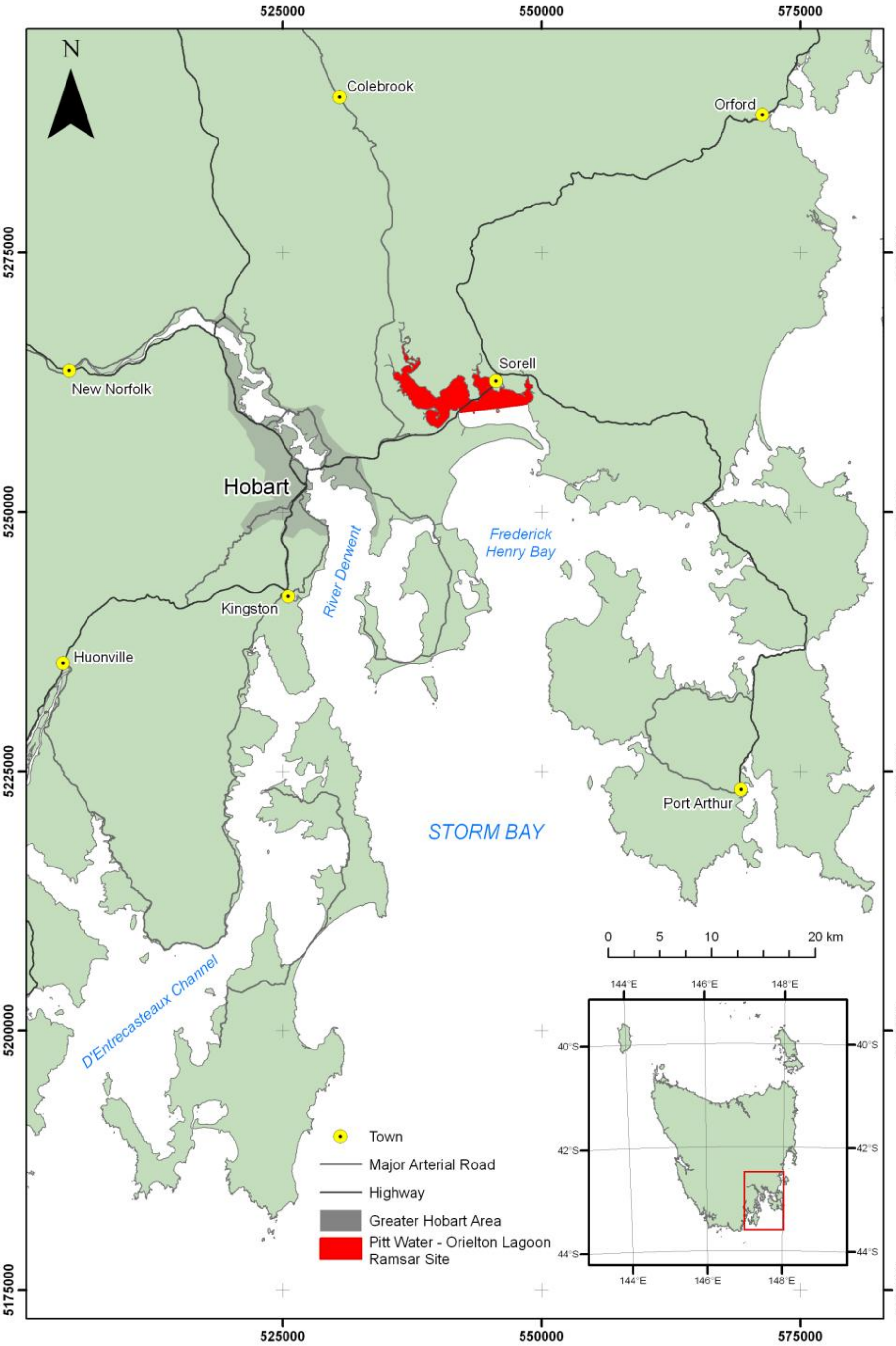


Figure 1.2: Pitt Water – Orielton Lagoon Ramsar site: Local setting (Datum GDA94 UTM Zone 55) (Source: M.Morffew, Centre for Spatial Information Sciences, School of Geography and Environmental Studies, University of Tasmania 2009)

A small proportion of the Ramsar site is classified as Nature Reserve and subject to a Parks and Wildlife Service Management Plan (currently in preparation). This ECD will provide support for management of the Nature Reserve and will contribute to a Management Plan for the Ramsar site as a whole.

The ECD is written to describe the site at the time of listing in 1982. Some significant changes have occurred since then, notably changes to the tidal exchange at Orielton Lagoon and construction of a dam on the Coal River affecting river flows. These changes are documented and conceptual models are used to summarise the key processes at the time of listing and the current situation.

1.2 Approach to preparing the ECD

Owing to its location so close to Tasmania's centre of population, some aspects of the PWOL Ramsar site and its ecology have been documented in some detail going back up to 150 years. Other features and processes are poorly described or understood. New pressures and demands on the area in recent decades have generated targetted studies for particular purposes.

Information in this ECD has been drawn from many sources that were readily available to piece together the nature of the ecosystem, the key processes that maintain its integrity and the factors that might determine its future. Every effort has been made to use all available data while avoiding interpretations of that data that may tend towards particular interests or outcomes. The reference date for this ECD is the time of listing in 1982. However documentation used is not limited to information available at that date. Other data are used where these clearly contribute to understanding the site and are most likely to have been continuous, i.e. pre-dating 1982 through to recent years. As much as possible of the data is presented visually as maps, tables and conceptual models. Nomenclature of flora follows Buchanan (2009).

The ECD covers the scope required under the *National Framework and guidance for describing the Ecological character of Australia's Ramsar wetlands* (DEWHA 2008). Some sections are re-ordered in the interests of developing unambiguous descriptions of the main elements of the site. Specifically, the processes and models for Orielton Lagoon are dealt with separately from the main body of Pitt Water for the following reasons. The nature of Orielton Lagoon has been dramatically altered over a period of some 150 years from the time the earliest causeway was constructed, thereby changing what was once an open, shallow bay. Orielton Lagoon had, at the time of listing, very limited exchange with the main body of renewing sea water. The processes that underpin the character of what is now Orielton Lagoon are quite different from processes that are important to Pitt Water estuary. Although improvements have been made to allow greater exchange of sea water, it remains a constrained estuarine system.

Emphasis has been placed on the components and processes that sustain the key Ramsar values of the site, i.e. saltmarsh communities, shorebirds (especially migratory waders), rare and threatened species associated with coastal areas and fish nursery for commercial shark species.

It is clear that increased human activity has resulted in changes since the time of listing as a Ramsar site. The wider impacts of climate change and sea level rise also appear to be in evidence. These changes and their implications are discussed in later sections of the report.

The project has been undertaken under the guidance of a Steering Committee established by NRM North. The committee represented expertise in flora, wetlands and geomorphology, a representative from the Wetlands Unit of DSEWPaC, project administrators from NRM and a Parks and Wildlife Service planner. In addition, an informal advisory group was assembled later in the project to assist in the generation of appropriate conceptual models for the site. This group included individuals who knew the site well and could evaluate the legitimacy of the models as representations of how the system 'behaves'. This also helped to ensure that the models were comprehensible to a wider audience and potential users.

The questions of how to engage the local community in the process of developing the ECD and how to enter dialogue with Aboriginal interests in the site were taken to the regional planner. Contact with the wider community was also undertaken in liaison with the volunteer facilitator for the south east field centre of Parks and Wildlife Service. Further information about landowner and community information sharing is provided in Section 10.

1.3 Site summary

Site Name	**Pitt Water - Orielton Lagoon**
Location in coordinates	42 degrees 48' 00", 147 degrees 30' 00"
General location of site	The site is located in the south east of Tasmania, Australia, in the north east sector of the major Derwent River estuary. PWOL is some 20 kilometres east of the state capital Hobart
Area of site	3334 ha
Date of Ramsar designation	1982
Ramsar criteria met by the wetland	2a, 2b,2d, 3 (Criteria 1982) 1, 3, 4, 8, 9 (Criteria 2005)
Management Authority	Parks and Wildlife Service, Department of Primary Industries, Parks, Water and Environment, Tasmania
Date the ecological character description applies	1982 with updates to 2009
Date of compilation	March 2010
Names of Compilers	Dr Helen Dunn, University of Tasmania
Reference for Ramsar Information Sheet	Pitt Water - Orielton Lagoon, Tasmania- 6. Compiled by Blackhall, McEntee and Rollins DPIW, Tasmania 2003 Revised Dunn 2009
Reference to the Management Plan	No current plan. Parks and Wildlife Service (1999) *Draft Pitt Water/Orielton Lagoon Ramsar site (including the Pitt Water Nature Reserve) Management Plan*. Parks and Wildlife Service Department of Primary Industries, Water and Environment, Hobart. A draft plan for the Pitt Water Nature Reserve which covers some key areas within the site was in preparation (2009). Once completed a revised Management Plan for the Ramsar site can be compiled.

1.4 Statement of purpose

The statement of purpose is based on the Statement provided in the National Framework and guidance for describing the ecological character of Australian Ramsar wetlands (DEWHA 2008).

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* (Cth):
   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 Ramsar Information Sheet 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.
7. To develop a dynamic models of the Pitt Water Orielton Lagoon system integrating descriptive data from the time of listing with more recent and extensive data, including impacts of human and natural change.
8. To provide an ecological basis for management to support the full range of ecosystem services of the wetland and protection of its Ramsar values.

1.5 Legislation, treaties and other instruments

Much of the legislation listed below was enacted since the listing of the site under the Ramsar convention in1982 and is listed in this ECD as it best outlines the legislation available for protection and management of the site and its values. Key legislation at Commonwealth level is the *Environment Protection and Biodiversity Conservation Act 1999*, which also encompasses the provisions of international treaties. Key state legislation includes acts applying to land and to marine waters. In addition, state policies and local government (Sorell and Clarence municipalities) planning schemes can be relevant to PWOL.

Key legislation and agreements for PWOL are:

Environment Protection and Biodiversity Conservation Act 1999, Australia.

Convention on Wetlands (Ramsar, Iran, 1971)

Japan-Australia Migratory Bird Agreement (JAMBA)

China-Australia Migratory Bird Agreement (CAMBA)

*Republic of Korea-Australia migratory Bird Agreement (*ROKAMBA)

National Parks and Reserves Management Act 2002, Tasmania

Crown Lands Act 1976, Tasmania

National Parks and Reserved Lands Regulations 1999, Tasmania and subsequent Amendments 2000 and 2006

Nature Conservation Act 2002, Tasmania

Threatened Species Protection Act 1995, Tasmania

Wildlife Regulations 1999 of the Nature Conservation Act 2002, Tasmania

Living Marine Resources Management Act 1995, Tasmania

Weed Management Act 1999, Tasmania

Forest Practices Amendment (Threatened Native Vegetation Communities Act) 2006, Tasmania

Marine Farming Planning Act 1995, Tasmania

Environmental Management and Pollution Control Act 1994 Tasmania

Water Management Act 1999 Tasmania

State Policy on Water Quality Management 1997

Aboriginal Lands Amendment Act 2004 Tasmania

Aboriginal Relics Act 1975 Tasmania

Aboriginal Lands Act 1995, Tasmania

1.5.1 Commonwealth legislation

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Australian Government's central piece of environmental legislation.

It provides a legal framework to protect and manage nationally and internationally important ecological communities and heritage places, defined as 'matters of national environmental significance'. Seven matters of national significance are listed.

Matters of environmental significance to which the EPBC Act applies in PWOL are:

- Wetlands of international importance (Ramsar sites)
- Migratory species.

The EPBC Act comes into effect when a proposal is made which may have a significant impact upon any matter of environmental significance. Such a proposal may originate beyond the boundaries identified for a site.

'A significant impact is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts' (http://www.environment.gov.au/epbc/about/glossary.html#significant).

The EPBC Act has guidelines to define 'significant impact' for each of the matters of international significance (http://www.environment.gov.au/epbc/publications/pubs/nes-guidelines.pdf).

For Ramsar sites the significant impact criteria are:

> areas of wetland being destroyed or substantially modified;
>
> a substantial and measurable change in the hydrological regime of the wetland, for example a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland;
>
> the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetland being seriously affected;
>
> a substantial and measurable change in the water quality of the wetland– for example, substantial change in the level of salinity, pollutants or nutrients in the wetland, or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health; or

an invasive species that is harmful to the ecological character of the wetland being established (or an existing invasive species being spread) in the wetland.

For migratory species the significant impact criteria are:

substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species;

result in an invasive species that is harmful to the migratory species becoming established in an areas of important habitat for the migratory species; or

seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

The Act aims to balance protection of environmental and cultural values with society's social and economic needs through a legal and decision-making process.

Australia's commitments and obligations under international environmental convention and agreements are administered through the EPBC Act.

1.5.2 International treaties

The Convention on Wetlands (Ramsar, Iran, 1971) usually referred to as the Ramsar Convention is an international treaty dedicated to the conservation and sustainable use of wetlands**.** The Ramsar Convention has identified a suite of wetland types and a set of criteria which define wetlands of international significance. Details of wetland types and criteria met at PWOL are provided in Section 2.

Australia is signatory to three bilateral agreements for migratory birds. These are the China–Australia Migratory Bird Agreement (CAMBA), the Japan-Australia Migratory Bird Agreement (JAMBA) and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA). These agreements aim to protect migratory birds by protecting and conserving their habitats, as well as other measures to foster intergovernmental cooperation for migratory bird conservation. In addition, Australia has endorsed the East Asian - Australasian Flyway Partnership.

Details of the bilateral migratory bird agreements can be found at:

http://www.environment.gov.au/biodiversity/migratory/waterbirds/bilateral.html

Details of the international flyway partnership can be found at:

http://www.environment.gov.au/biodiversity/migratory/waterbirds/flyway-partnership/index.html

1.5.3 State legislation

The *National Parks and Reserves Management Act* 2002 provides the framework for management of Crown Lands, including reserved Crown Lands.

The *Crown Lands Act 1976* provides for the management of non-reserved Crown Lands, including submerged Crown Land.

Nature Conservation Act 2002, is the legislation under which national parks and other reserves (except 'public reserves') are declared. It sets out the values and purposes of listing for each types of reserve. This Act also makes provision for the conservation of biodiversity and geodiversity of Tasmania.

The *Threatened Species Protection Act* 1995 specifically addresses the protection and management of Tasmania's threatened flora and fauna.

Wildlife Regulations 1999 of the Nature Conservation Act 2002 set out regulations governing duck-shooting and other related wildlife matters.

Living Marine Resources Management Act 1995 provides for the sustainable management of the State's marine resources, including setting catch and size limits for commercial and recreational fisheries, provision of nursery areas.

Marine Farming Planning Act 1995, sets the framework for marine farming activities, including shellfish farming.

Environmental Management and Pollution Control Act 1994 sets guidelines and standards for environmental parameters arising from human activity. For PWOL, standards for discharge of effluent and waste products into marine waters are the most significant component.

Water Management Act 1999 applies to freshwater in Tasmania. Its purposes include the sustainable development use of water resources and maintaining the ecological processes and genetic diversity for aquatic and riparian ecosystems.

Weed Management Act 1999 provides the framework for dealing with the State's proclaimed weeds.

Section 2. Overview of the site

2.1 Site location and bioregional context

PWOL is located in the south east of Tasmania some 20 kilometres east of Hobart. PWOL Ramsar site lies generally between the settlements of Cambridge and Sorell to the south and to Richmond in the north. Pitt Water is the estuary formed by the mouth of the Coal River, opening into the eastern arm of the larger Derwent estuary complex (Figure 1.2).

The entire state of Tasmania lies in a single Drainage Division, the Tasmanian Drainage Division http://www.bom.gov.au/hydro/wr/basins/basin-hi_grid.jpg. Two examples of the estuary type occur within this Drainage Division, of these, Pitt Water is the largest and most clearly expressed.

Since site values relate to flora and to a marine system, the site may also be considered within terrestrial and marine bioregional contexts. PWOL lies within the Tasmanian South-east bioregion (IBRA) http://www.environment.gov.au/parks/nrs/science/pubs/map9.pdf and the Bruny marine bioregion (IMCRA http://soer.justice.tas.gov.au/2003/image/423/index.php).

The boundary of the Ramsar site largely follows mean high water mark from a point just south of the first causeway at Pitt Water Bluff around upper Pitt Water estuary and Orielton Lagoon, Sorell Rivulet estuary and Iron Creek estuary to Shellfish Point and then directly across lower Pitt Water back to the origin.

Figure 2.1 shows the Ramsar site boundary. Figure 2.2 shows locations in and around the site that are mentioned in the text.

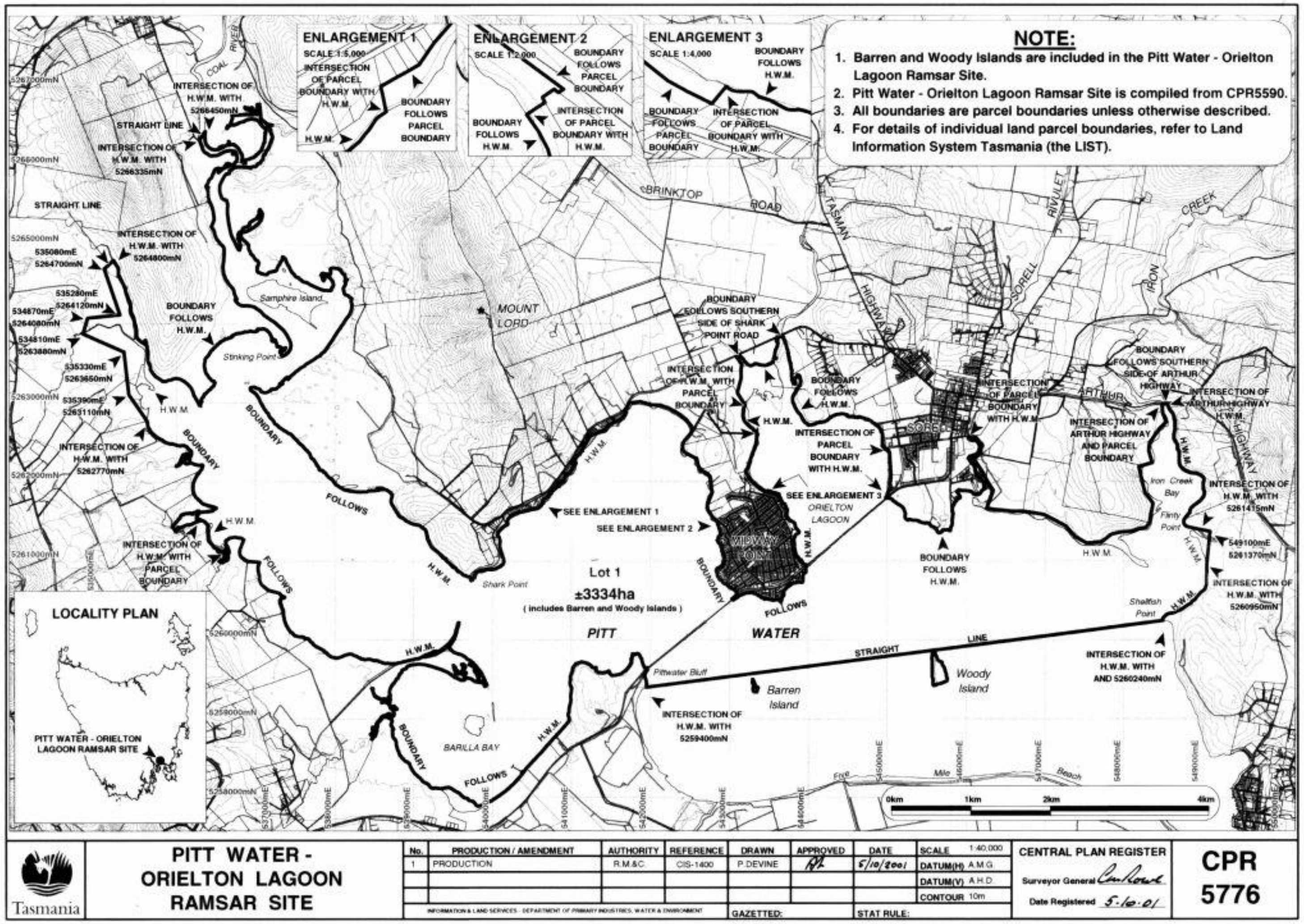


Figure 2.1: Pitt Water – Orielton Lagoon Ramsar site showing area, location and boundary.
(Source: Central Plan Registry, Land Titles Office Department of Primary Industry and Water, Tasmania)

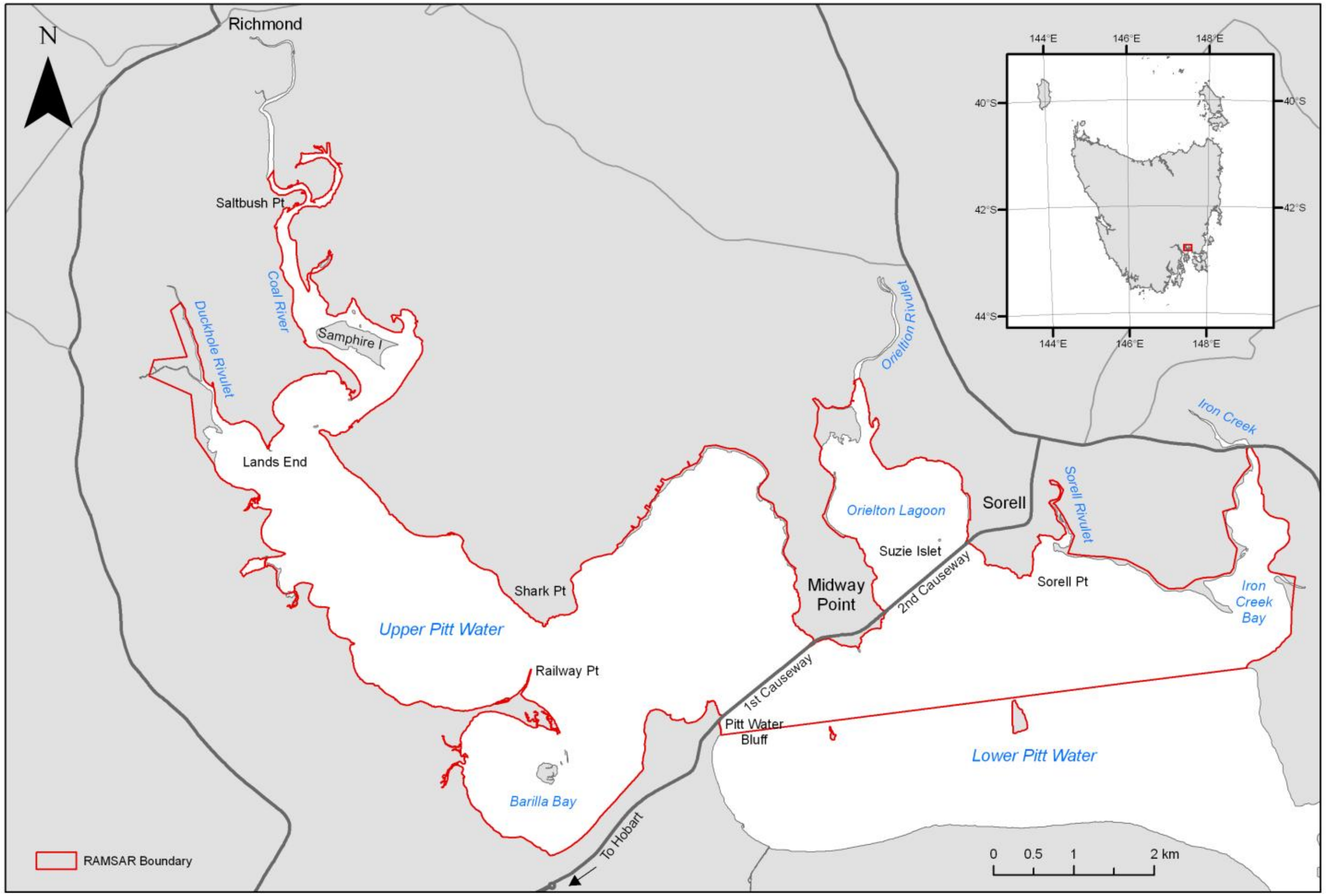


Figure 2.2: Pitt Water-Orielton Lagoon Ramsar site showing locations of features used in the text. (Source: M.Morffew, Centre for Spatial Information Sciences, School of Geography and Environmental Studies, University of Tasmania 2009)

2.2 Catchment features

The total catchment of PWOL comprises approximately 890 sq kilometres, of which approximately 620 sq km is the catchment of the Coal River. Smaller catchments supply Orielton Rivulet, Sorell Rivulet and Iron Creek while minor streams flow into Upper Pitt Water (Figure 2.3).

The Coal River rises in the hills of around 550m elevation to the east of Tunnack and flows north-westerly towards Lake Tiberias and turns due south for nearly 70km to Richmond (Daley 1999).The valley is approximately 20km wide and is bounded by roughly parallel north-south ridges up to 850m in height. North of Colebrook it passes through a gorge before meandering through the broader plains of the lower valley.

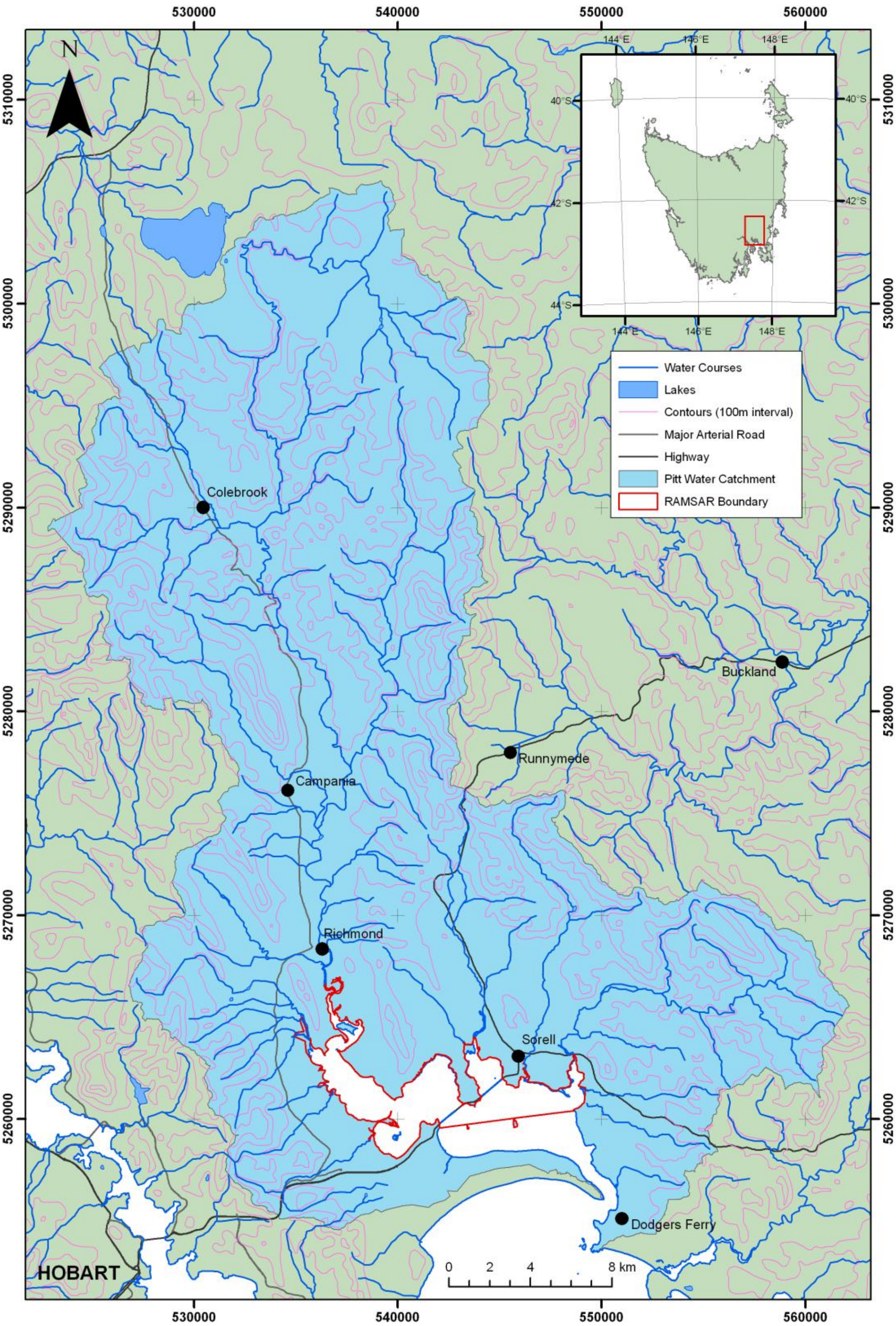


Figure 2.3: Catchment of Pitt Water-Orielton Lagoon Ramsar site. (Source: M.Morffew, Centre for Spatial Information Sciences, School of Geography and Environmental Studies, University of Tasmania 2009)

2.3 Summary description

Pitt Water is a mainly shallow estuary formed by the near closure of the mouth of the Coal River by a mid-bay spit at Seven Mile Beach. Orielton Lagoon was once an open shallow bay of the Pitt Water estuary. The PWOL system is now bisected by two causeways, first from Pitt Water Bluff to Midway Point, the second causeway from Midway Point to Sorell. The history and impacts of these causeways on the PWOL system are discussed in later sections.

The waters are predominantly marine in character. PWOL is characterised by extensive areas of intertidal flats, shallow sandy beds and bars, some vegetated with seagrass, and clear deeper channels. The perimeter is marked by variety of shorelines: a number of diverse saltmarshes, sandy, silty and rocky shores, as well as considerable lengths of artificial filled shorelines and bridge supports. Low rocky bluffs pin the shorelines at the Pitt Water Bluff, Shark Point, Midway Point, Sorell Point and Shellfish Point.

Upper Pitt Water is a well flushed estuarine system, while Orielton Lagoon is now much restricted in its tidal movement, essentially functioning as a secondary barred estuary.

The Ramsar site boundary mostly follows High Water Mark (Figure 2.1). Thus not all saltmarshes lie within the site boundary. Those within the boundary include several areas on private land around Duckhole Rivulet, two saltmarsh islands and the Nature Reserve at Orielton Lagoon. The boundary on the southern or seaward perimeter cuts across the main open basin from Pitt Water Bluff to the mouth of Iron Creek, excluding some important underwater geomorphic features of the estuary. At the time of listing this boundary definition accommodated concerns of the marine farming industry regarding potential future expansion into the southern sections of the basin.

2.4 Climate

PWOL lies in an area with a temperate maritime climate. The warmest summer month is January with temperatures ranging from a mean daily minimum of 12.0C to a mean daily maximum of 22.5C (BoM 2009). In the coldest month, July, temperatures range between a mean daily minimum of 4.1C to a mean daily maximum of 12.4C. Temperatures rarely fall below freezing (Fig 2.4).

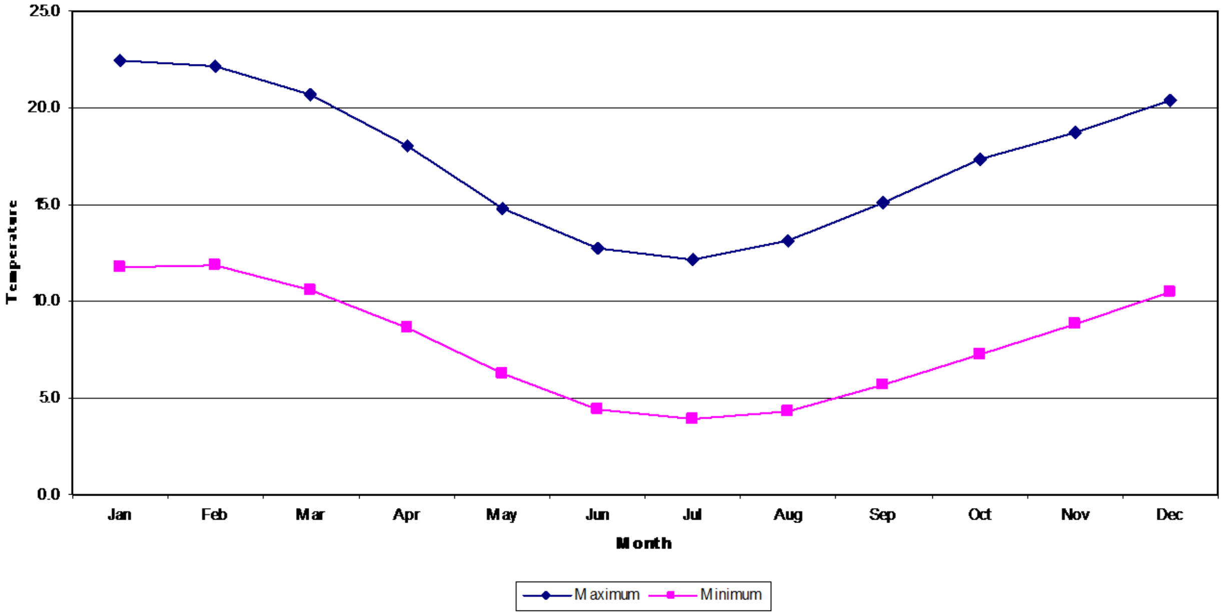


Figure 2.4: Mean monthly temperatures at Hobart Airport, 1958 – 2008. (Source: Bureau of Meteorology BoM http://www.bom.gov.au/climate/averages/)

The Pitt Water estuary area receives an average of six hours of sunlight daily, ranging between four hours in winter to eight hours in summer (Figure 2.5). Clear days are spread throughout the year (Figure 2.6). Winds are generally from the northwest in the mornings veering to south and southwesterly in the afternoons with the sea breeze (Figure 2.7). The afternoon south-westerly sea breeze predominates in the summer months (December – March) while in other months afternoon winds may be southerly, westerly or north-westerly.

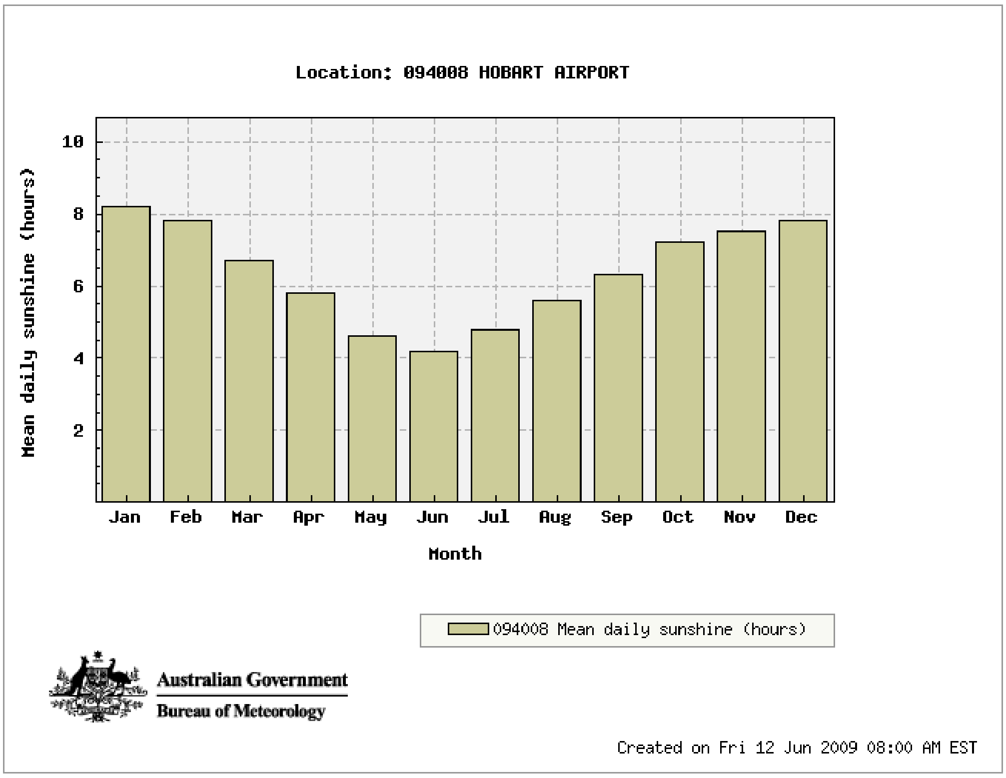


Figure 2.5: Mean hours of sunlight at Hobart Airport, average of 1958 – 2008. (Source: BoM http://www.bom.gov.au/climate/averages/)

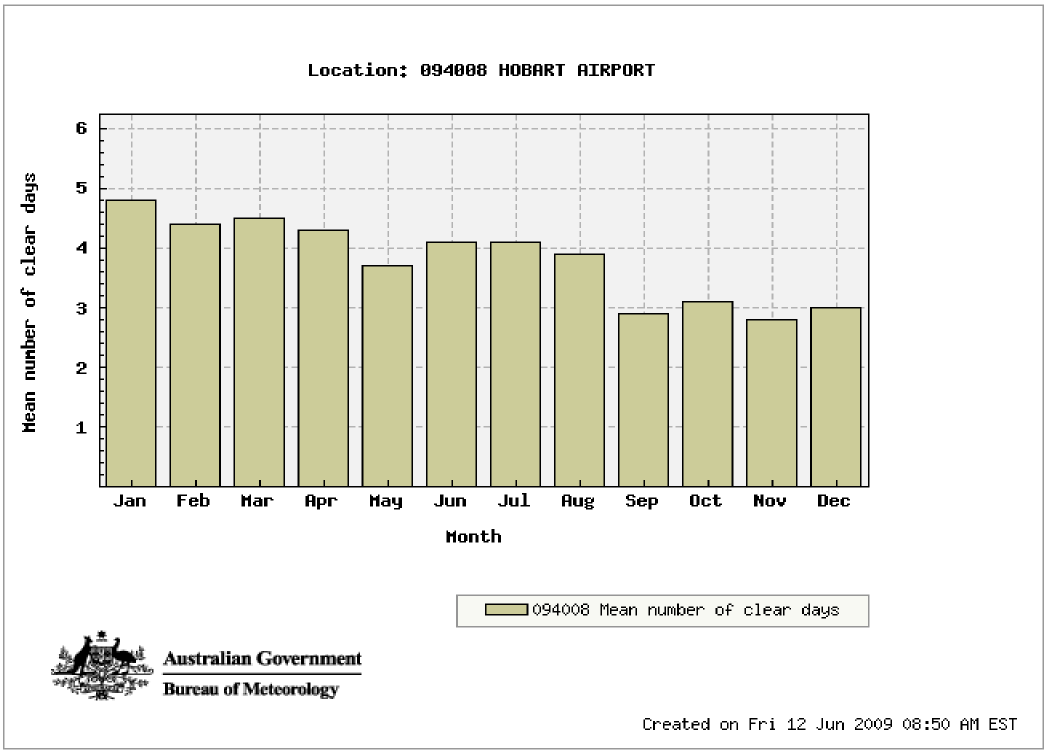


Figure 2.6: Mean number of clear days at Hobart Airport, average of 1958 – 2008. (Source: BoM http://www.bom.gov.au/climate/averages/)

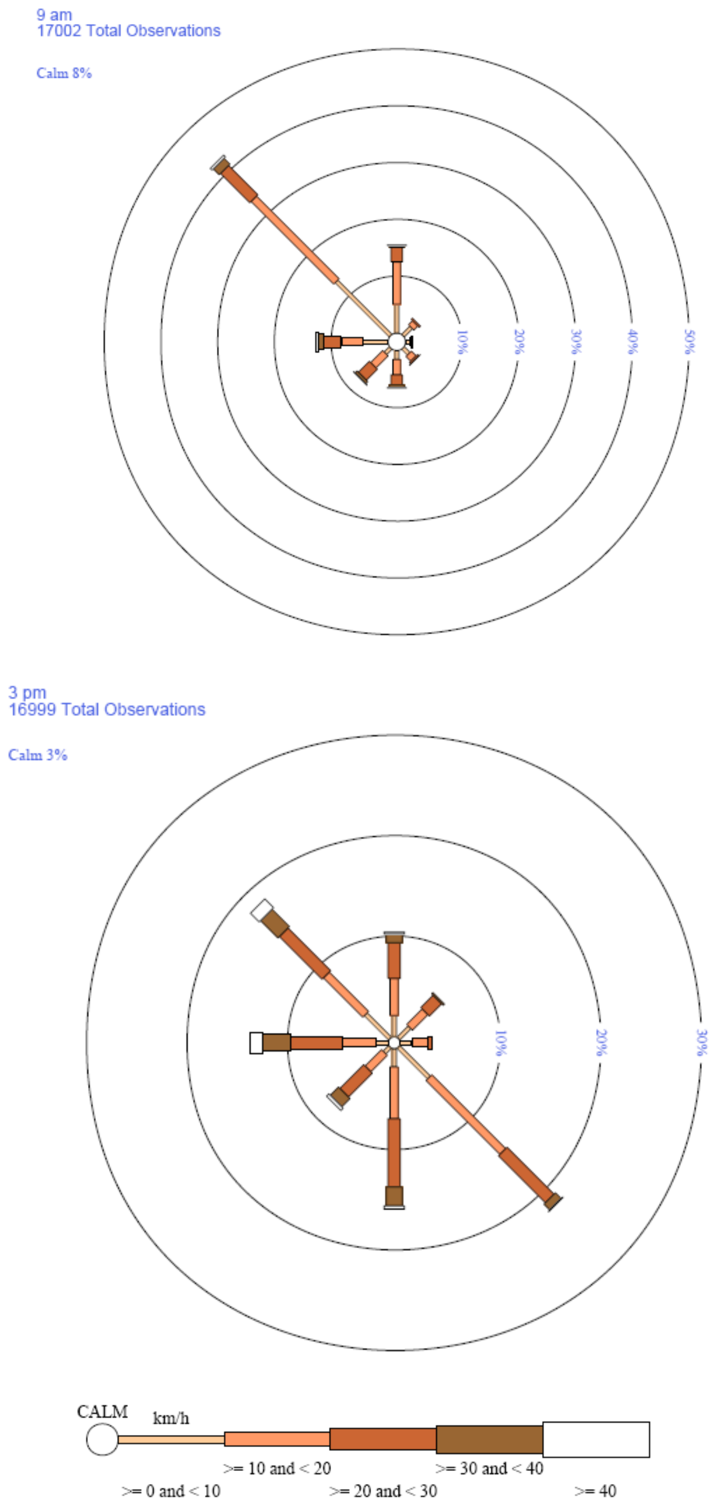


Figure 2.7: Windroses for Hobart Airport, 9 am and 3 pm. (Source: BoM http://www.bom.gov.au/climate/averages/)

The circular lines mark % of records (frequency) while the bars indicate direction and strength.

PWOL lies within the driest region of Tasmania. The prevailing winds are westerly and the area lies in a rainshadow. Rainfall is lower than Hobart and is spread throughout the year (Figure 2.8). Short periods of heavy rain may fall in spring and autumn when weather patterns bring easterly winds. The mean annual rainfall is 497 mm (mean of records from 1958 – 2009 at Hobart Airport, BoM) but variable between years (Figure 2.9). Lowest rainfall recorded at Hobart Airport between 1959 and 2008 was 297mm in 2006, the highest 735mm in 1975. After a period of some twenty years when annual rainfall tended to be below average, 2009 yielded annual total of 693mm with heavy falls from July to September.

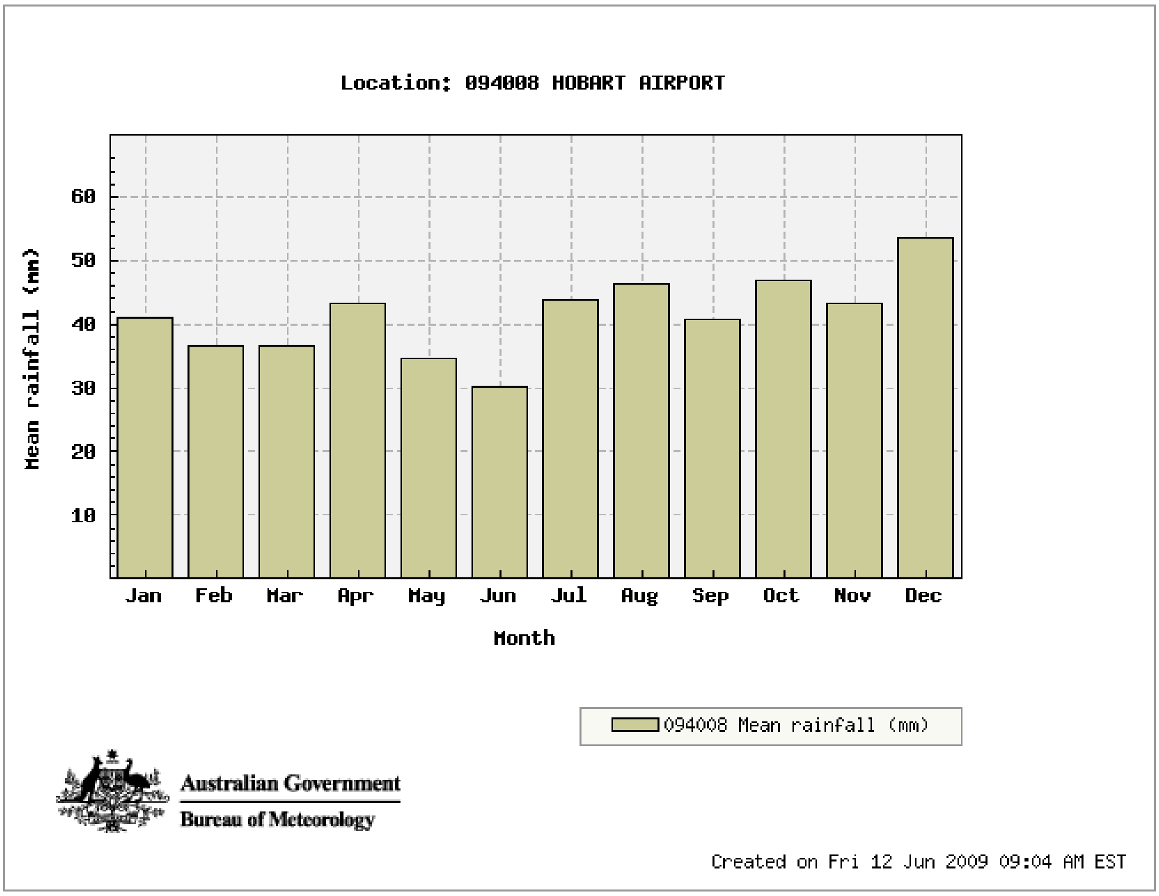


Figure 2.8: Mean monthly rainfall at Hobart Airport, average of 51 years. (Source: BoM http://www.bom.gov.au/climate/averages/)

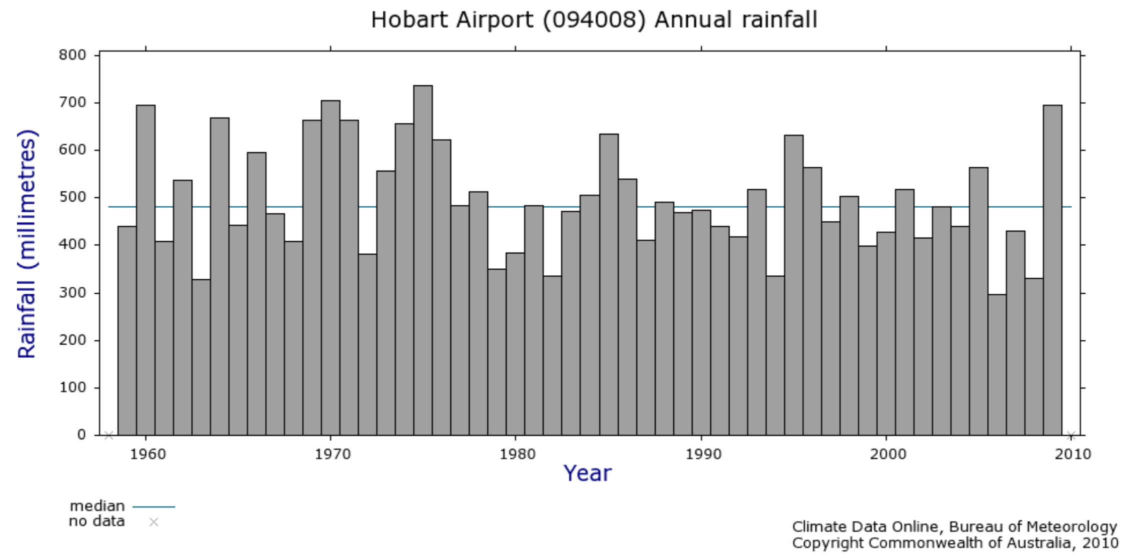


Figure 2.9: Annual rainfall at Hobart Airport 1959 -2009. (Source: BoM http://www.bom.gov.au/climate/averages/)

All stations in the Pitt Water area demonstrate similar variable annual rainfall. Stations in the Pitt Water catchment have different lengths of record: the overall patterns of similar years of high or lower rainfall are evident in the combined graph (Figure 2.10).

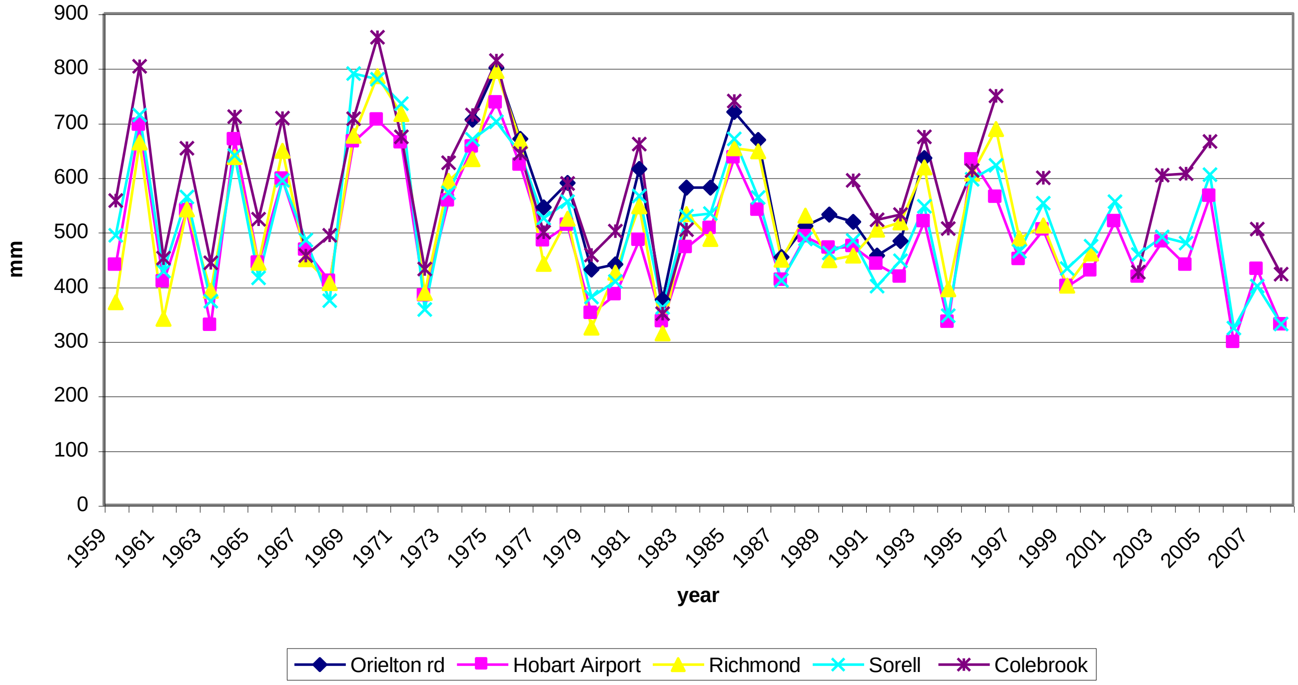


Figure 2.10: Annual rainfall at five stations in the PWOL catchment. (Source: BoM http://www.bom.gov.au/climate/averages/)

2.5 Land Tenure

The majority of the area of the site lies in public ownership (Table 2.1). Two parcels, one in Duckhole Rivulet area and one at the mouth of Iron Creek, are on private land.

Table 2.1: Area of each type of land tenure found within PWOL Ramsar site. (Source: P Wyatt, PWS)

Tenure type	Total (ha)
Crown Land	102.39
Freehold title	46.517
Marine Crown Land	1450.586
Tidal Crown Land	768.896
Unclassified Crown Land	952.787
Unknown	4.551
Total*	**3325.727**

*Note: discrepancy with recorded area in RIS likely to be due to boundary mapping issues.

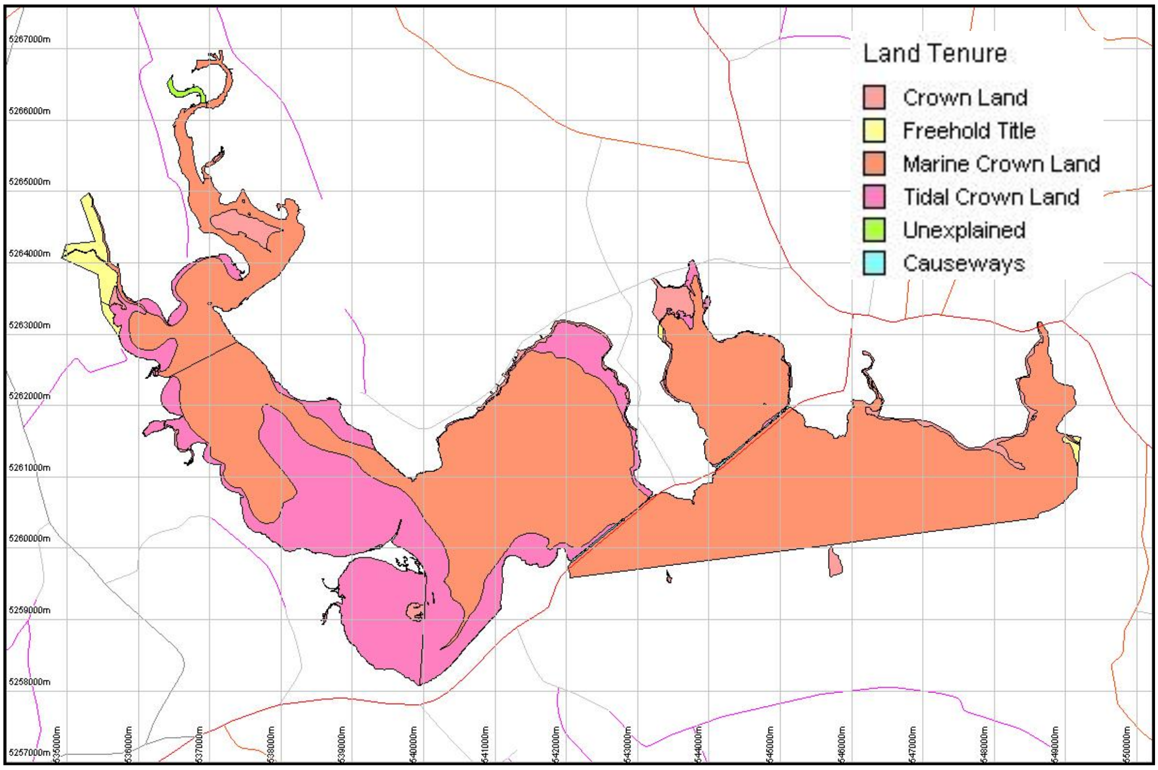


Figure 2.11: Distribution of land tenure types in PWOL. (Source: P Wyatt, Parks and Wildlife Service Tasmania based on LIST Tasmania 2009)

Note: Marine Crown Land is land owned by the Crown that lies below high water mark.

All types of Crown Land within the site are under the management of the Parks and Wildlife Service under the *Crown Lands Act 1976.*

The site incorporates an area gazetted under the *Nature Conservation Act 2002*, as the Pitt Water Nature Reserve. This comprises five separate areas within the Ramsar site: the head of the estuary near Richmond; an area of Crown Land and the waterbody of Orielton Lagoon; intertidal flats at Barilla Bay and two islands in Lower Pitt water, Barren Island and Woody Island.

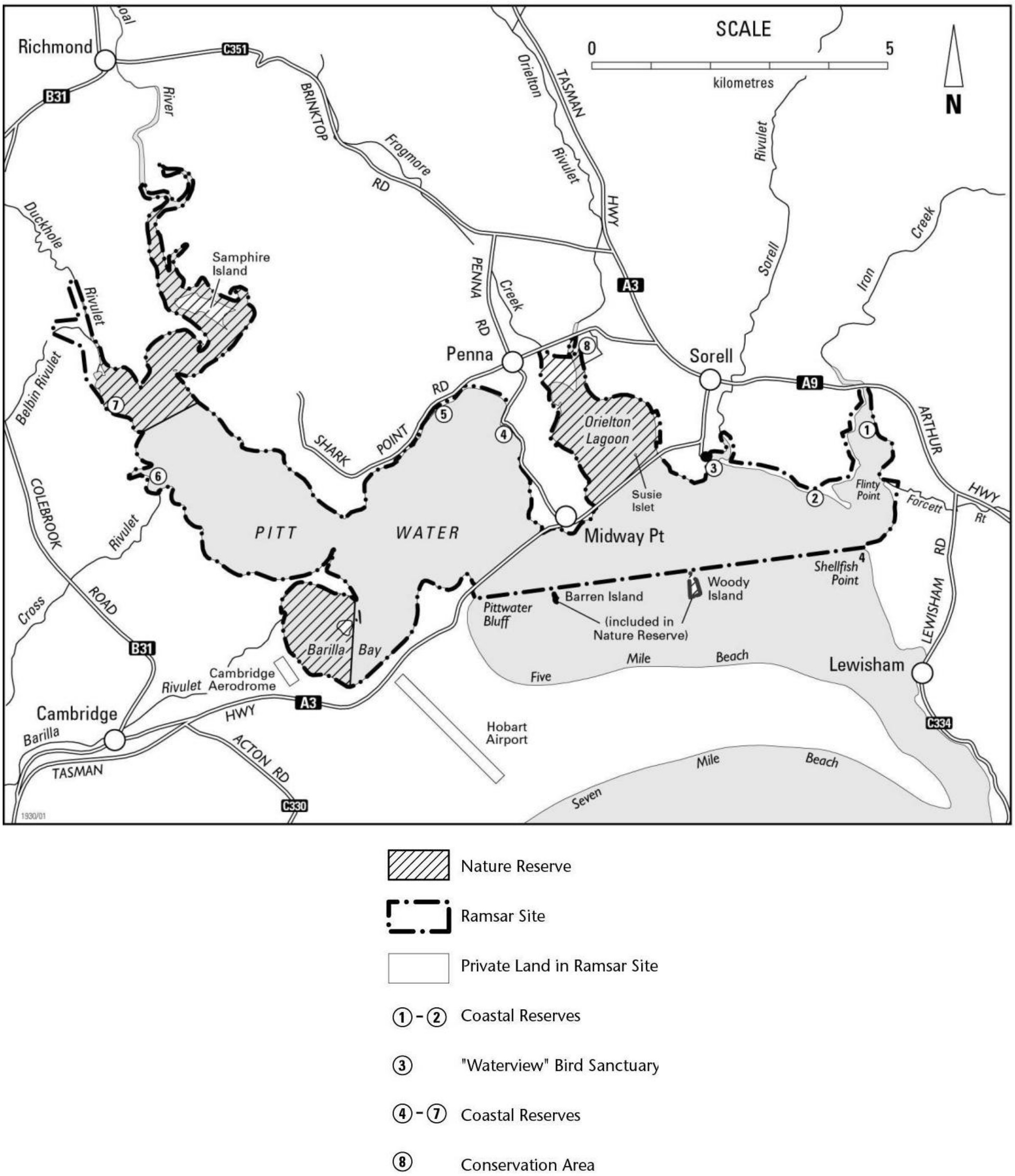


Figure 2.12: Pitt Water Nature Reserve. (Source: Parks and Wildlife Service 2009)

2.6 Criteria for listing

The PWOL site was nominated for Ramsar listing under four criteria (PWS n.d.) (Table 2.2). The criteria used refer to those adopted by the First Conference of the Contracting Parties, Cagliari (24-29 November, 1980) (see Appendix 1).

Table 2.2: Criteria for which PWOL was listed in1982 (1980 criteria).

Criterion 2: a wetland should be considered internationally important if it:

(a) supports an appreciable number of a rare, vulnerable or endangered species or subspecies of plant or animal,
or (b) is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna,
or (d) is of special value for its endemic animal or plant species or communities.

Criterion 3 a wetland should be considered internationally important if it is a particularly good example of a specific type of wetland characteristic of its region.

Subsequently specific criteria were added that recognised the importance of wetlands for fish and other fauna. The current criteria are shown in Appendix 2. The significance of PWOL based on current criteria is shown in Table 2.3. Section 2.7 demonstrates the values present in PWOL that meet current criteria. These values were present at the time of listing.

Table 2.3: Ramsar criteria met at PWOL in 2009 (2005 criteria).

Group B of the Criteria. Sites of international importance for conserving biological diversity

Criteria based on species and ecological communities

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

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.

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.

Specific criteria based on fish

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.

Specific criteria based on other taxa

Criterion 9: 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.

Criterion 1, identifying representative or rare wetland types in natural or near-natural condition, is not included in the list for 2009. The estuary has been assessed as being significantly modified (Edgar *et al* 1999, Mount *et al* 2005) by alterations to freshwater inputs, catchment modification, causeway construction and some degradation in biotic components (Rees 1994, Mount *et al* 2005, Prahalad 2009). Thus it cannot be considered to be in 'natural or near-natural condition'.

2.7 How PWOL meets the current Ramsar criteria

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

The Tasmanian endemic viviparous seastar *Parvulastra vivipara* (formerly*Patiriella vivipara)* is listed as 'vulnerable' on the Commonwealth *EPBC Act* and State *Threatened Species Protection Act 1995* (TSPA). http://www.environment.gov.au/cgi bin/sprat/public/publicspecies.pl?taxon_id=66767. *Parvulastra vivipara* is endemic to south east Tasmania and its distribution is restricted to 13 isolated subpopulations in sheltered waters of the Bruny Marine Bioregion. The seastar occurs commonly in PWOL and has its greatest productivity in this habitat (Byrne 1996).

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.

PWOL is an important area for maintaining biodiversity of saltmarshes, birds and fish.

The estuary is fringed with saltmarshes hosting different facies of vegetation communities and species. Although the area of saltmarsh within the Ramsar boundary encompasses only about 3.5% of the estimated total area of saltmarsh in Tasmania, the floristic communities include 12 of the 15 identified by Kirkpatrick and Glasby (1981). More extensive areas of saltmarsh lie adjacent to PWOL and are integral to the ecological character of the entire estuary.

Saltmarsh, wetland and coastal plant and invertebrate species considered rare in the Tasmanian Drainage Division occur within the site. These species include *Calocephalus citreus* and *Wilsonia humilis, Limonium australe, Lepilaena preissii, Stuckenia pectinata* (syn. *Potamogeton pectinatus*) and the saltbush blue butterfly *Theclinesthes serpentata lavara*, all listed as rare on the TSPA.

The birdlife of PWOL includes migratory and resident shorebirds, waterbirds and seabirds (Appendix 3). Rocky and sandy shorelines and islands provide roosting and nesting sites and the waters of the estuary are a rich food source. The extensive intertidal flats provide feeding areas for migratory and resident shorebirds and seabirds. The saltmarshes provide roosting and foraging areas. Transient visitors to the area include the great crested grebe *Podiceps cristatus* (listed as vulnerable under the TSPA) and the swift parrot *Lathamus discolour* (listed as endangered under the TSPA and EPBC Act).

Estuarine and marine fish species inhabit PWOL some continuously, others on a seasonal basis (Edgar *et al* 1999, Aquenal 2000). Diverse habitats including sandy shoals and bays, seagrass beds and open water are used by different fish species.

These components of PWOL were evident at the time of listing and the species diversity continues, albeit with changes in some communities and species abundance.

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.

PWOL regularly attracts at least seven species of migratory shorebirds as a feeding ground in the (northern) winter (Birds Tasmania unpublished data 2009). Orielton Lagoon is the most important area for migratory shorebirds in the Bruny Marine Bioregion (Bryant (2002). The shorebirds use the entire area of the wider Pitt Water system (Aquenal 2008d), moving between sites according to tides, food supplies and weather conditions (P.Park pers.comm.). Orielton Lagoon is one of only two sites in Tasmania that are included in the Flyway site network of the Partnership for the East Asian –Australian Flyway http://www.eaaflyway.net/network.php. At the time of listing, PWOL was considered one of the most important wader habitats in Tasmania, particularly for Eastern Curlew (now listed as endangered on the Tasmanian *Threatened Species protection Act 1995)* and the Lesser Golden Plover (Reid and Park 2002). It remains an important area for waders despite lower numbers being recorded and severe decline in some species (Birds Tasmania unpublished data 2009). The reasons for the fall in numbers are complex and common to some other migratory bird sites.

Pitt Water has fish species diversity typical of estuarine systems with both estuarine and marine species (Edgar *et al* 1999, Aquenal 2000). Several species of commercial shark use the area as breeding grounds (CSIRO 1993, Healey 1996, Aquenal 2000). Fish diversity and breeding has been consistent from the time of listing and at present, although abundance appears to have declined (Aquenal 2000).

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.

PWOL has been identified as the most important breeding ground in the Bruny Marine Bioregion for several species of commercially harvested shark species (CSIRO 1993, Healey 1996, Aquenal 2000). The most significant numbers of juvenile school sharks *Galeorhinus galeus* were found in Pitt Water (Aquenal 2000). Pitt Water is a declared Shark Refuge Area under the *Living Marine Resources Management Act 1995* Tasmania.

Criterion 9: 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.

PWOL is the stronghold for the endemic seastar *Parvulastra vivipara*. The total population of this species is estimated at about 350,000. The species is limited to about 13 sites, of which PWOL hosts the greatest numbers (Prestedge 1998). Estimates of the percentage of the total population suggest some 92% of the population occurs in the Pitt Water area, of which around half (or around 45 % of the total population) would fall within the PWOL boundary (http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=66767).

2.8 Wetland types

Ramsar wetland types occurring in PWOL are summarized in Table 2.4. The table is based on classification table at the Ramsar website http://ramsar.org/ris/key_ris_e.htm#type.

Areas of each type are summarized in Table 2.5 and Figure 2.13 shows the location of the different wetland types. The saltmarsh layer was generated using the TASVEG digital mapping of Tasmania's vegetation communities. Submerged habitat and intertidal marshes were mapped using the protocols and products of the SEAMAP digital mapping of underwater habitats (http://www.utas.edu.au/tafi/seamap). Some SEAMAP categories were combined to reflect Ramsar classification of wetland types.

Table 2.4: Wetland types in Pitt Water-Orielton Lagoon Ramsar site.

			Ramsar wetland code
Saline water	Permanent	<6m deep	A
		Underwater vegetation	B
		Coral reefs	C
	Shores	Rocky	D
		Sand, shingle, pebble	E
Saline or brackish water	Intertidal	Flats (mud, sand, or salt)	G
		Marshes	H
		Forested	I
	Lagoons		J
	Estuarine waters		F
Saline, brackish or fresh water	Subterranean		Zk (a)

Shaded wetland types occur in Pitt Water-Orielton Lagoon.

Note: Despite its name, Orielton Lagoon is considered to approximate to a modified barred estuary rather than a coastal lagoon.

Table 2.5: Areas of each wetland type in PWOL.

Ramsar_id	Description	Area ha
B	Underwater vegetation	110.2
D	Rocky shore	32.9
E	Sand, shingle or pebble shore	24.6
F	Estuarine waters	1814.0
G	Flats (mud, sand or salt)	1234.7
H	Marshes	115.7
	Total	3332.0

Note that ‘underwater vegetation’ overlays ‘estuarine waters’. The vegetated area is not included in calculation of the area of estuarine water.

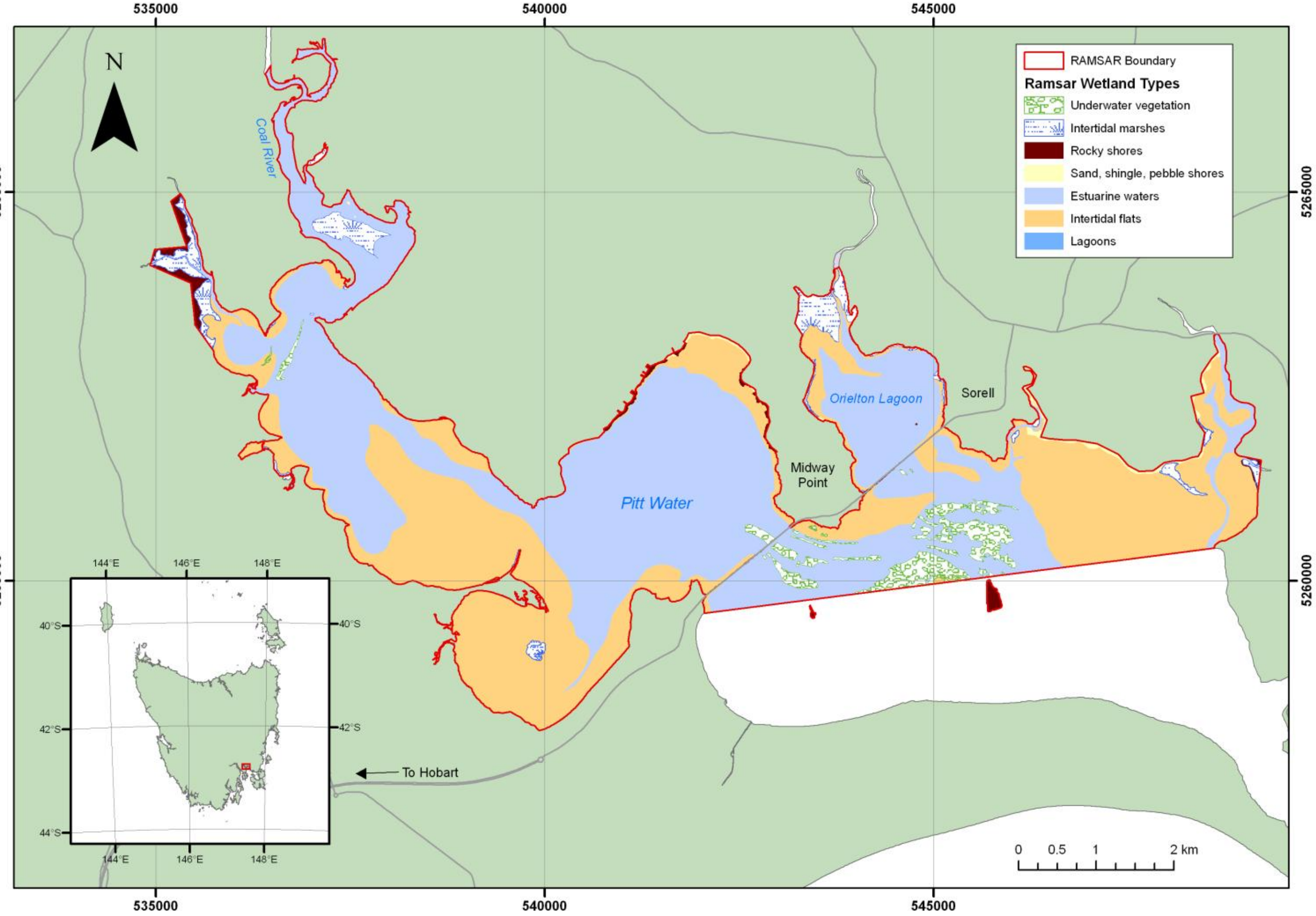


Figure 2.13: Distribution of Ramsar wetland types in PWOL. (Source: M.Morffew, Centre for Spatial Information Sciences, School of Geography and Environmental Studies, University of Tasmania 2009)

Section 3 Components and processes critical to the ecological character of PWOL

3.1 Introduction

PWOL is a complex estuarine ecosystem derived from, and sustained by, a range of physical and biota components and processes and the interactions between them. These components and processes and the broad types of benefits and services that they support are summarized in Figure 3.1.

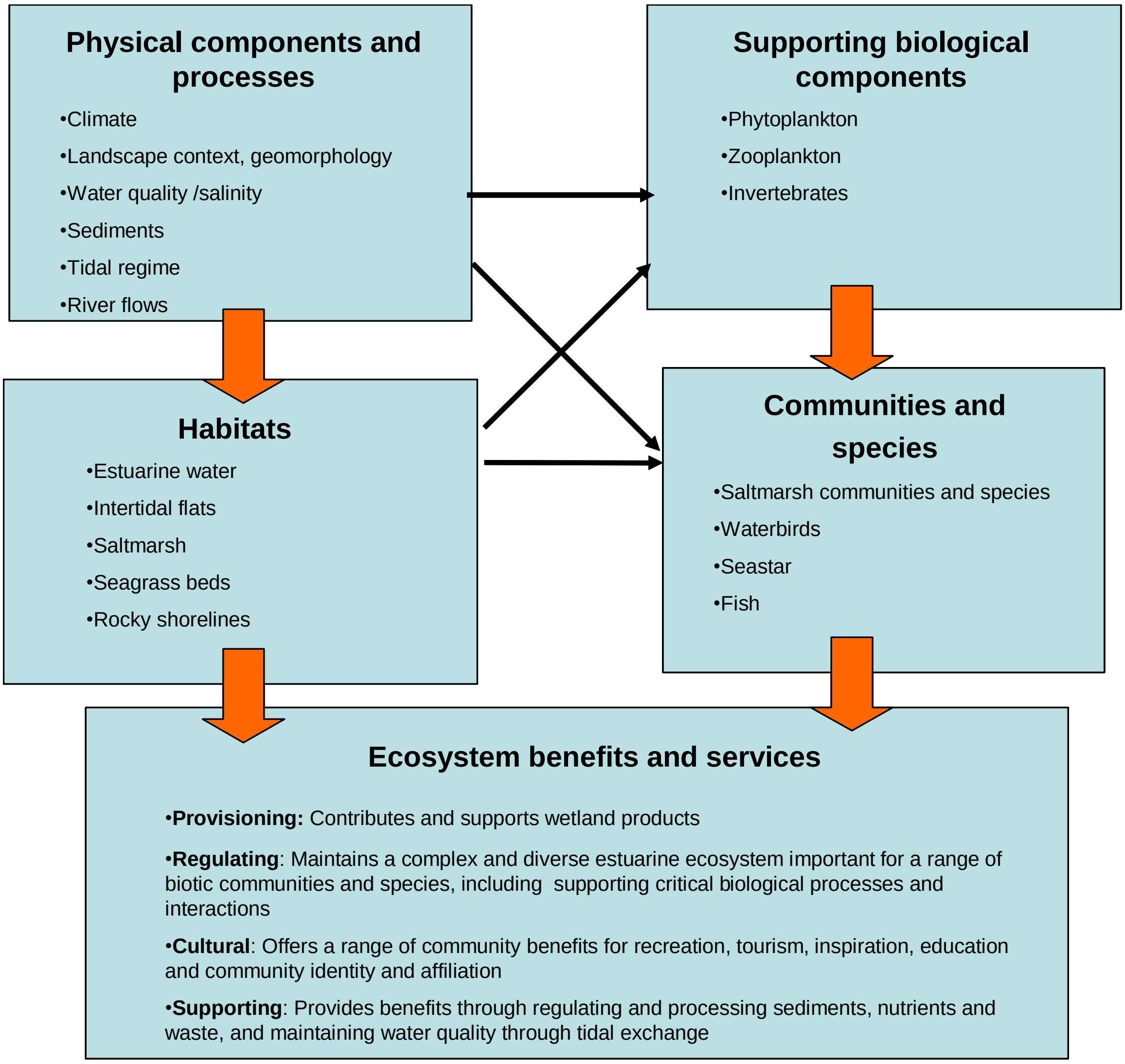


Figure 3.1: Summary framework of components, processes and ecosystem services at PWOL.

3.1.1. Critical components and processes of the PWOL

The National Framework (DEWHA 2008) lays out four criteria for the identification of critical components, processes, benefits and services. Critical components and processes are those:

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

These criteria are used to select the critical components, processes and services at the Site (Table 3.1).

3.1.2 Ecosystem services

For the purposes of the Ramsar convention, ecosystem services are defined in accordance with the Millennium Ecosystem Assessment (MEA) definition of ecosystem services as 'the benefits that people receive from ecosystems' (Millennium Ecosystem Assessment 2005). The National Framework (DEWHA 2008) includes all four of the MEA ecosystem services within the scope of the ecological character description of the site. The ecosystem services identified for PWOL are summarised in Table 3.2 in accordance with the MEA definitions.

If the same criteria for identification of critical benefits and services are applied to the four MEA classes shown in Table 3.2, only 'Regulating' and 'Supporting' services meet the four criteria for inclusion in the ECD. Table 3.3 shows the components and processes that support these ecosystem services and the importance for the ecological character of the site. Discussion of these ecosystem services is incorporated in the following sections describing the components and processes.

As noted in the ECD Framework document (DEWHA 2008), the economic, social and cultural benefits people receive from ecosystems ('Provisioning' and 'Cultural' Services) rely on the underlying ecological components and processes that sustain the ecological character of the wetland.

Table 3.1: Selection of critical components and processes in the PWOL Ramsar site using the four DEWHA (2008) criteria: determinants of the site's character, support Ramsar values, change likely within <100 years and potential for significant negative consequences.

Components and processes	**1**	**2 (Ramsar criteria)**	**3**	**4**
Physical components and processes: Climate Landscape context and geomorphology Water quality/salinity Sediments Tidal regime River flows	✓	✓ 2,3,4 2,3 3,4,8 3,4 2,3,4 2,3,8	✓	✓
Habitats: Estuarine waters Intertidal flats Saltmarsh Seagrass beds Rocky shorelines	✓	✓ 2,3,4,8 4 2,3 3,8 2	✓	✓
Supporting biological components Phytoplankton Zooplankton Invertebrates	✓	✓ 3,8 3,8 4,8	✓	✓
Communities and species Saltmarsh communities & species Waterbirds and shorebirds Fish Seastar	✓	✓ 2,3 4 3,8 2	✓	✓

Table 3.2: Ecosystem services at PWOL based on MEA definitions and classification.

1	**Provisioning services -** products obtained from ecosystems	
	Wetland products	Commercial oyster farming Nursery area for commercial shark fishery
2	**Regulating services -** benefits obtained from regulation within the ecosystem or as a result of ecosystem processes	
	Pollution control and detoxification	Treated effluent and stormwater enter the estuary and are diluted to acceptable levels
	Potential to moderate the effects of sea level rise in limited areas	Narrow channels and causeway may dampen or delay effects of SLR in Orielton Lagoon
3	**Cultural services -** non-material benefits that people obtain from ecosystems through emotive and cognitive experiences and responses	
	Recreation	PWOL is a popular area for fishing both by boat and from the causeway bridge Passive recreational activities such as bird-watching, walking are popular with locals Pittwater is a safe area for sailing, wind-surfing and other water sports
	Tourism	PWOL is in an area with tourism attractions and the route to major tourist destinations of the Tasman Peninsula and East Coast PWOL is beneath the immediate flight-path and first close-up of Tasmania's natural assets for arriving visitors
	Spiritual and inspirational	PWOL plays an important role in defining the character of the Sorell municipality
	Scientific and educational	PWOL has been the site of considerable research over several decades, notably on saltmarsh ecology and impacts of human intervention in the management of a coastal wetland (Orielton Lagoon) PWOL has been included in regular counts of waders for several decades
4	**Supporting services -** services that are necessary for production of all other ecosystem services , including sustaining biodiversity and habitats	
	Nutrient cycling	PWOL plays a role in cycling and discharge of nutrients from the surrounding catchments
	Sediment cycling	Tidal movement, wave action in Orielton Lagoon and freshwater flows resuspend and recycle sediments and maintain sedimentary environments
	Maintainence of biodiversity	Diversity of intertidal and subtidal habitats for marine life and shorebirds Supports a range of ecological communities including fish, saltmarsh vegetation, invertebrates of saltmarsh, intertidal flats and benthic environments Supports a number of nationally and locally threatened species Supports extensive and diverse area of a threatened non-forest vegetation community - saltmarsh

Table 3.3: Critical Ecosystem Services at PWOL, supporting components and processes and the importance for the ECD.

Regulating services - benefits obtained from regulation within the ecosystem or as a result of ecosystem processes

Ecosystem service type	Ecosystem service at PWOL	Components and processes to support service	Importance for ECD
Pollution control and detoxification	Treated effluent and stormwater enter the estuary and are diluted to acceptable levels	Tidal exchange and volume Marine water quality	Important as maintaining water quality for ecosystem health
Potential to moderate the effects of sea level rise in limited areas	Narrow channel and causeways may dampen effects of SLR	Barred estuary in Lower Pittwater Dampening effect of artificial barriers (causeways)	Moderates effects of tides Potential means of monitoring SLR in region
	Baffles in culverts may be manipulated to protect wader habitat from impacts of SLR	Orielton Lagoon form and sediments Shallow bay Artificial culverts and baffles potential for manipulation of extremes of tidal input	Potential to monitor and is desirable, modify effects of SLR on intertidal flats at OL

Table 3.3: Critical Ecosystem Services at PWOL, supporting components and processes and the importance for the ECD (cont.).

Supporting services - services that are necessary for production of all other ecosystem services, including sustaining biodiversity and habitats

Ecosystem service type	**Ecosystem service at PWOL**	**Components and processes to support service**	**Importance for ECD s**
Nutrient cycling	PWOL plays a role in cycling and discharge of nutrients from the surrounding catchments	Estuarine environment Climate River flows Primary production Nutrient cycling	Maintenance of nutrient balance to sustain biological communities
Sediment cycling	Tidal movement, wave action in Orielton Lagoon and freshwater flows resuspend and recycle sediments and maintain sedimentary environments	Estuarine environment Tidal flow and volume of exchange Sediment supply, distribution, resuspension & deposition	Provide and maintain habitats for important ecosystem values, including saltmarshes and intertidal flats
Maintenance of biodiversity	Diversity of supratidal, intertidal and subtidal habitats for marine life and shorebirds	Estuarine environment Climate River flows Tidal flow and volume of exchange Sediment supply, distribution, resuspension & deposition Invertebrate communities Vegetation communities	Central to supporting Ramsar values of site

Table 3.3: Critical Ecosystem Services at PWOL, supporting components and processes and the importance for the ECD (cont.).

Supporting services (cont.)

Ecosystem service type	Ecosystem service at PWOL	Components and processes to support service	Importance for ECD
Maintenance of biodiversity (cont.)	Supports a range of ecological communities including fish, saltmarsh vegetation, invertebrates of saltmarsh, intertidal flats and benthic environments	Estuarine environment Climate River flows Tidal flow and volume of exchange Sediment supply, distribution, resuspension & deposition Invertebrate communities Vegetation communities	Central to supporting Ramsar values of site
	Supports extensive and diverse area of a threatened non-forest vegetation community - saltmarsh	Estuarine environment Climate River flows Tidal flow and volume of exchange Sediment supply, distribution, resuspension & deposition	Supports Ramsar value
	Supports a number of nationally and locally threatened species	Estuarine environment Climate River flows Tidal exchange Geomorphology and habitat diversity Vegetation communities Invertebrate communities	Central to supporting Ramsar values of site

3.1.3 The context for description of components and processes

The PWOL system has been subject to human impacts since the time of settlement. The estuary is considered ‘substantially modified’ on an Environmental Index and ‘significantly impaired’ on a biota index (Norris 2001, cited in Mount *et al* 2005). The catchments have been subject to clearance and development for agriculture while residential settlements have grown at Midway Point and Sorell. Intensive cultivation demanding use of fertilizers and water for irrigation has led to increase inputs of sediments and nutrients. Flow of the river systems have been reduced and seasonal patterns of flow modified. Stormwater and effluents from sewage treatment plants contributed to increased nutrient levels and at times, high coliform levels.

The greatest impacts on the system at the time of listing resulted from artificial barriers in the form of two causeways constructed across the estuary. The causeways were built in the late 19^{th} century to provide rail, then road, access to the east coast and Tasman Peninsula. A bridge section in each causeway allowed for tidal movement between the open basin and the mouth of the estuary. The partial closure changed patterns of tidal movement and sediment redistribution, particularly in the bay now known as Orielton Lagoon.

The critical components and processes described in this ECD refer to evidence about this modified system. Despite the lengthy period over which catchment and hydrological modification has been occurring, data sets on which to determine a baseline condition are limited. This is especially true for Orielton Lagoon which has been subjected to several significant interventions with time scales too brief for the system to stabilise. For some components and processes, a historical perspective or landscape context is provided to better enable interpretation and appreciation of the nature of that component or process.

The terminology used for areas of the site follows that used in common local parlance (see Figure 2.2). Areas of Pitt Water are referred to as ‘Upper Pitt Water’ for that part of the estuary above the Causeway to the mouth of the Coal River and ‘Lower Pitt Water’ for the extensive basin south of the Causeway. Orielton Lagoon forms a distinct entity, largely isolated from the normal estuarine processes of Pitt Water.

3.2 Hydrology

3.2.1 Pitt Water

The total catchment area of Pitt Water is approximately 890 sq km (Figure 2.3). The catchments are subject to variable annual rainfall (Figures 2.9, 2.10) and flow rates and flood events vary considerably during the year. The Coal River is ephemeral for its entire length and is usually dry during summer (Gurung and Dayaratne 2003). Peak flows are highly dependent on easterly weather patterns bringing moist air to the catchment (Gurung and Dayaratne 2003). No flow data are available for the smaller catchments but rainfall patterns are similar in the catchment areas and thus the volume and behaviour of these streams may be assumed to mirror those of the Coal River.

Limited data are available for gauging stations in the Coal River and collections of flow data downstream at Richmond only commenced in 1995. Daley (1999) plotted available data up to 1997 (Figure 3.2). These data demonstrate a close relationship between stream flow and rainfall. Annual flow is very variable, with very low flow periods occurring in 1972/1973 and 1979/1980 coinciding with periods of drought (Figure 3.2 and Figure 2.10). Note that these flow data are indicative only as there were differences in recording methods and gaps in data. Low flows from 1983 can be attributed to the construction of an instream dam, Craigbourne Dam. The impacts of the Craigbourne dam are discussed in Section 6 Changes since listing.

During winter and spring baseflows are continuous while during summer and autumn flows are very low and supplemented by groundwater contributions (Davies *et al* 2002). The contribution of groundwater is thought to be significant – over half of the flow – but as yet not measured (D.Leaman pers.comm. 22/06/09). High flow events and flooding could occur during winter or spring or even early summer (Daley 1999). Such events are highly variable in magnitude and timing, occurring at different months in the year (Water Information Systems of Tasmanian WIST http://www.water.dpiw.tas.gov.au/wist/ui, consulted 23 May 2009). During December to April, flows were usually very low to nil and for some years the consecutive no-flow days could last between three and six months (Daley 1999, Gurung and Dayaratne 2003).

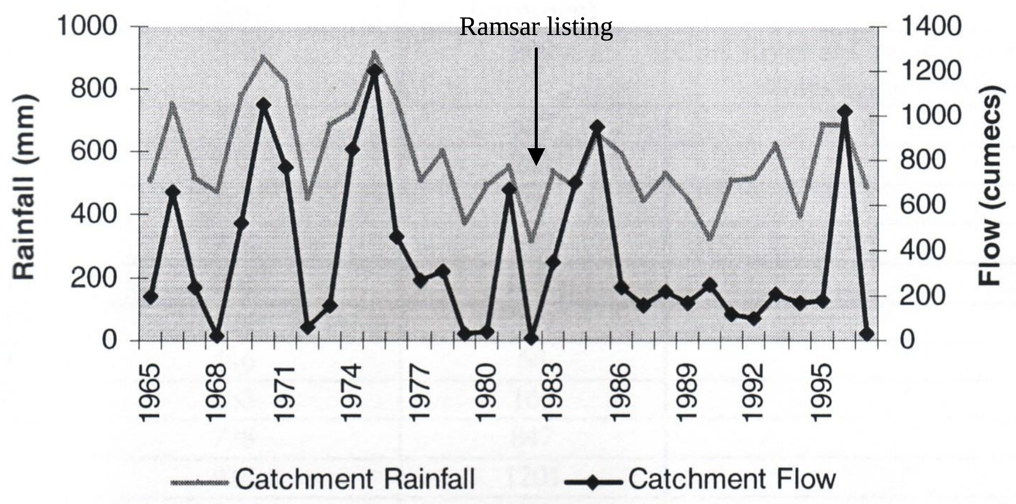


Figure 3.2: Annual catchment rainfall and flow in the Coal River 1965 - 1997 (Source; Daley 1999)

The hydrology of Pitt Water is dominated by marine influence. The estuary has a massive tidal flow with a tidal prism of ~ 23.4 gigalitres (~ 23.4 million cubic meters) (Mount *et al* 2005) and a high exchange rate (Crawford and Mitchell 1999). Flushing time for the entire estuary is approximately 4.36 tidal cycles and about one quarter of the total high-water volume of the estuary (~101.8 gigalitres) moves in and out on each tidal cycle (Mount *et al* 2005). The tidal range is about 1.4m, with flows between upper and lower Pitt Water influenced by the causeway and bridge.

Marine waters exchanged in the estuary follow consistent flow paths marked by hard sand (Figure 3.3), the incoming tides flowing in deeper channels to the west of Woody Island while ebb tides tend to flow to the eastern side of the island. An earlier flood tide current map (Harris 1968) confirms that the current patterns in the Pitt Water estuary have been unchanged since the time of listing (Figure 3.4). Surface water movements show some skirting of the southern side of the Sorell Causeway by both incoming and outgoing tides (Figure 3.5).

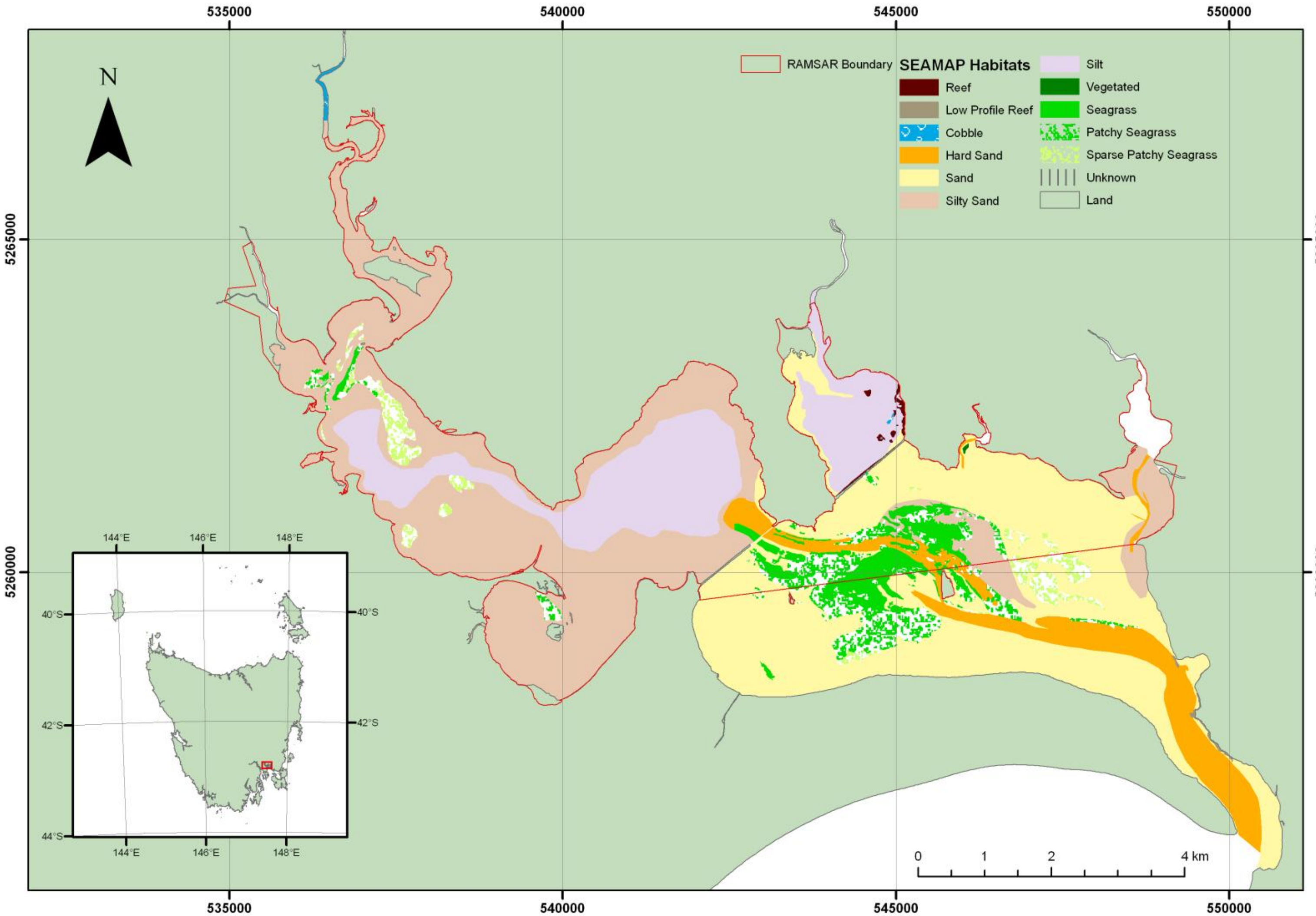


Figure 3.3: SEAMAP habitats for PWOL, showing locations of tidal currents, benthic environments and seagrass. (Source: M.Morffew, Centre for Spatial Information Sciences, School of Geography and Environmental Studies, University of Tasmania 2009, using SEAMAP undertaken by Tasmanian Aquaculture and Fisheries Institute, Hobart 2008.)

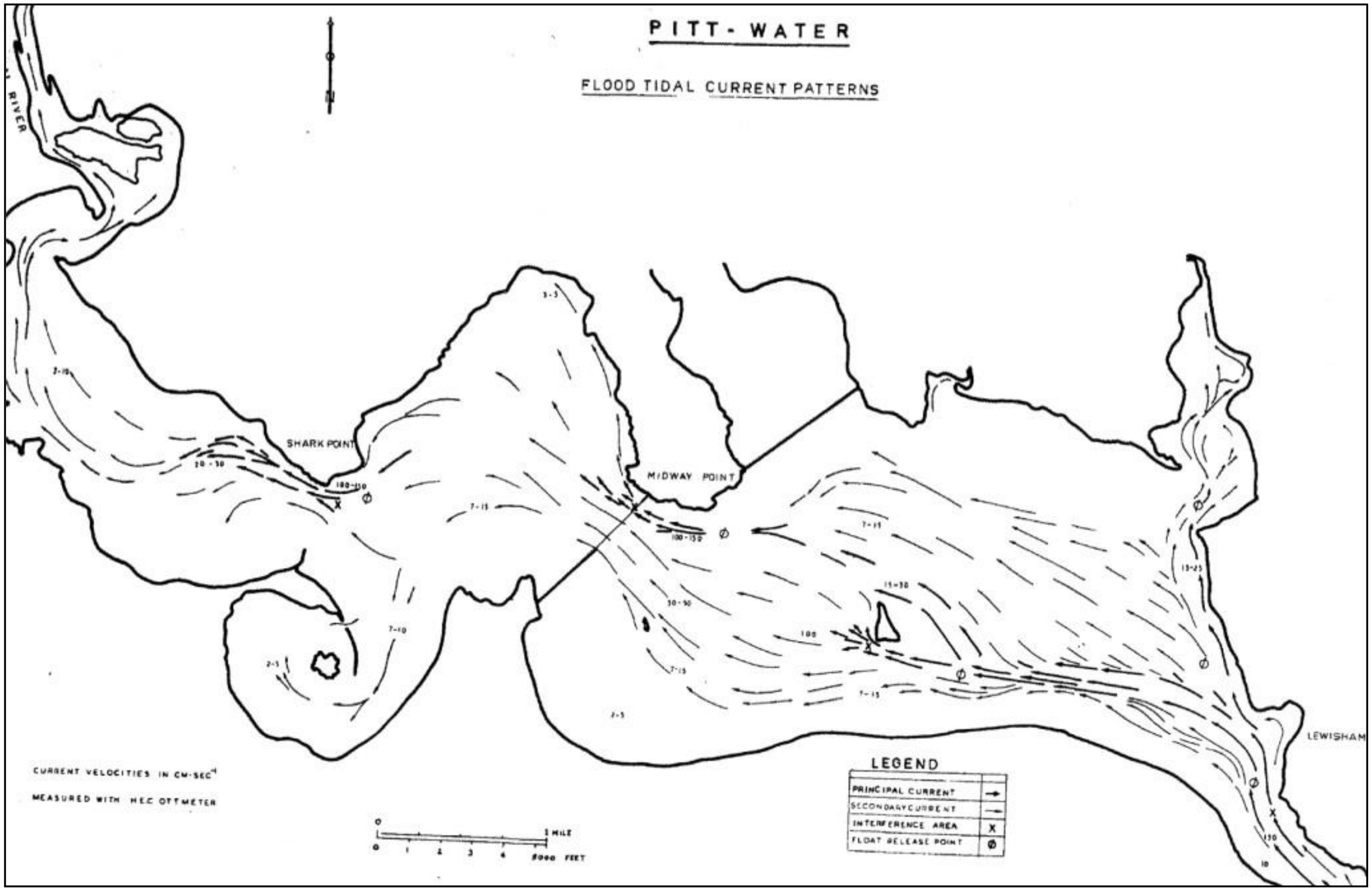
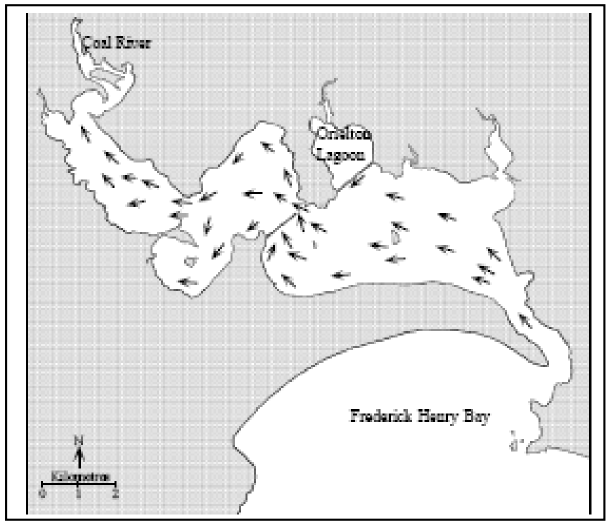


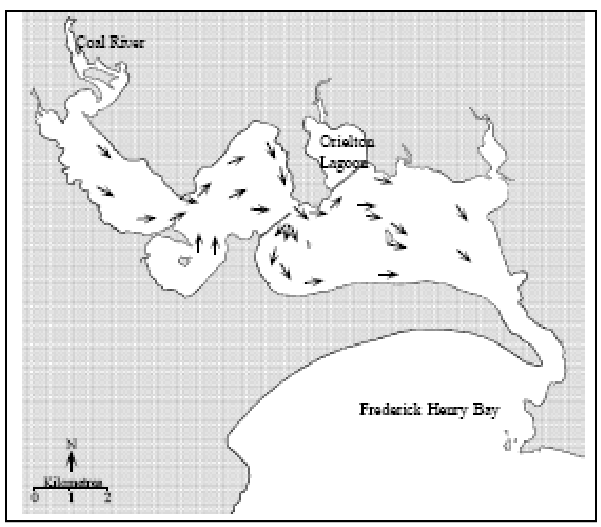
Figure 3.4: Flood tidal current patterns at Pitt Water, 1967. (Source: Harris 1968).

Principal currents shown in bold, secondary currents in normal type. Note the scale is in miles.

Figure 3.5 illustrates the effects of the causeways on tidal movements in their immediate area. Flood tide flows westwards along the 2nd causeway while ebb tides flow eastwards. The bridge section in the first causeway creates an interface area.



(a) Flood tide



(b) Ebb tide

Figure 3.5: Surface currents at flood (a) and ebb (b) tide in Pitt Water estuary. (Source: Crawford and Mitchell 1999).

Good mixing of the waters is ensured, homogenising temperature, salinity and nutrient levels within the main Pitt Water estuary. Flow rates control the sediment distribution and hence disposition and composition of substrates characterising the estuary habitats.

The hydrology of Pitt Water may be summarised as:

- Low but variable flows enter the estuary from the Coal River
- Periods of low to nil freshwater input extend from December to April, higher flows in winter months
- Flows are reliant on rainfall, no data on groundwater contribution though this is thought to be significant (<50%)
- Peak freshwater flow is limited until the major dam spills
- Massive tidal flow and high exchange rate in marine waters
- Tidal range in the main body of the estuary of 1.4m, influenced in upper reaches by the causeways, particularly in Orielton Lagoon.

3.2.2 Orielton Lagoon

Orielton Lagoon has been severely impacted by human intervention in the tidal movements, agricultural runoff and sewage disposal. A brief history of intervention and its consequences provides a context to the hydrology, water chemistry and sediments existing at the time of Ramsar listing.

Human intervention in the hydrology of Orielton Lagoon

Orielton Rivulet and a smaller tributary Frogmore Creek, feed into the Lagoon. These are ephemeral streams with generally no flow in summer months. Closure of this wide bay of Pitt Water took place with the construction of the causeway in 1874. The causeway was some 1372m long with a bridge of 195m at the Sorell (eastern) end. Early in the 20th century, the single bridge was replaced by a series of three bridges with approximately the same opening to Pitt Water. By 1953, the bridges had to be replaced and the cheaper option of a filled causeway was adopted. Culverts of 1.7m diameter and 36m in length were established halfway along the causeway with the crest level of the spillways to correspond to average high tide mark. This significantly limited tidal exchange and created a shallow lagoon with maximum depth of about 1.25m and 265ha in area. It was reported (Buttermore 1977) that that 'maladorous mudflats' were eliminated by the effective closure.

In the 1960s severe and extended flooding occurred, reducing the salinity and raising the water level in Orielton Lagoon. The water exceeded the height of the culverts and spilled over the causeway. The extensive area of saltmarsh at the head of the Lagoon was inundated, killing much of the vegetation which was intolerant of freshwater. A few years later, consideration was given to turning the lagoon into a freshwater lake by raising the baffles in the culverts and experiments were conducted to introduce brown trout as sport fishery. In 1963 it was officially named 'Orielton Lagoon', prompted by a suggestion from the Inland Fisheries Commission.

Land clearance and development for agriculture occurred in the catchment of the lagoon from the early days of settlement. With land clearance came an increase in sediment in the creeks, along with nutrients from fertilizers such as superphosphate (G. Robertson pers.comm.) and animal waste. Stormwater drainage from nearby housing development fed into the lagoon. In 1969 a sewage treatment plant was established at Midway Point, discharging primary treated waste into Orielton Lagoon.

Limited tidal flushing occurred and, over the years, the lagoon became eutrophic. Fish kills were reported and aquatic plants and algae flourished and decomposed, giving rise to ongoing complaints of odours.

The hydrology of Orielton Lagoon in 1982

The lagoon has an area of around 270ha, a mean depth of about 1.30m and a water volume of about 2×10^6 m^3 (Steane 1975). Orielton Rivulet has a catchment of 60ha and lies in an area of low and variable rainfall (Figure 3.6). The river usually ceases to run in the summer months and flows vary from year to year (Figure 3.7).

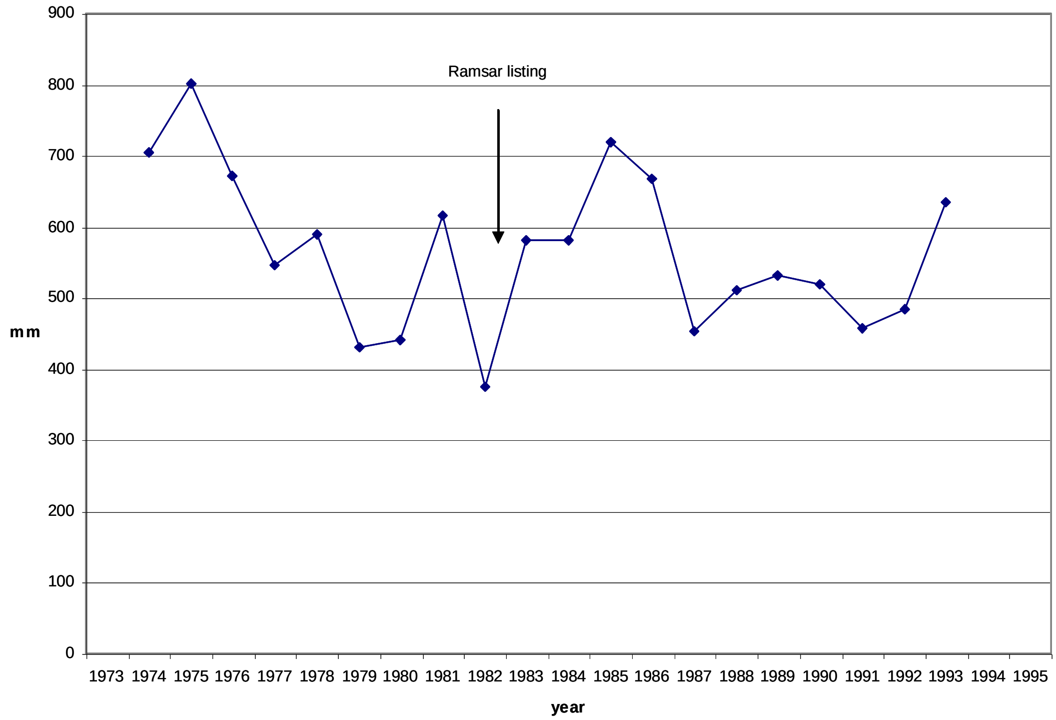


Figure 3.6: Annual rainfall at Orielton Road 1973 -1995. (Source BoM)

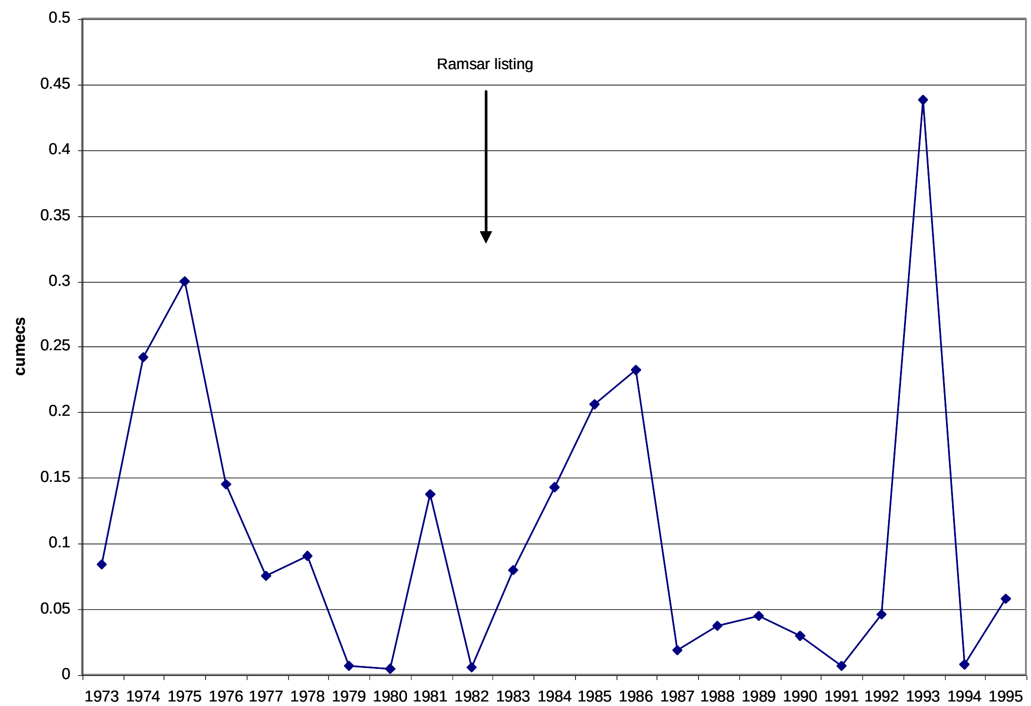


Figure 3.7: Mean annual flow in Orielton Rivulet at Brinktop Road 1973-1995. (Source: WIST)

Flow from Orielton Rivulet captures 70% of the catchment of the lagoon, the remaining freshwater input comes from drainage of immediate surrounding area and direct input of rainfall (Kinhill 1993). The shallow basin is exposed to evaporation. Two studies provide some insights into the water balance in Orielton Lagoon.

An estimate of water balance in the lagoon undertaken in 1975 (Steane 1975) concluded that there was a net loss of water of $260m^3 \times 10^3$ during the period of study. This was based on the gain from inputs of (i) flows in Orielton Rivulet, (i) tidal inflow and (iii) direct rainfall compared with outputs of (i) outflow through the culverts (ii) evaporation and (iii) seepage. Once the level of the water had fallen to the level of the culvert sill, it continued to fall regardless of the limited tidal inflow. Thus, without direct rainfall or flow from Orielton Rivulet, the level of the lagoon gradually fell under this regime. Taking into account the total volume of the lagoon, this represented a drop in level of 0.048m over 21 days. Loss from evaporation accounted for approximately 18% of total loss of water from the lagoon. Net evaporative loss (the difference between evaporation and rainfall) occurred through eight months of the year (Kinhill 1993).

Using data from 1991, when the factors influencing hydrology of the lagoon were the same as those applying at the time of listing, Brett (1992) estimated that turnover of water within the lagoon only occurred during the winter months, the only significant turnover being during August (23%). The net effect of the height of the culvert sills was to prevent effective flushing of lagoon waters. Evaporation and seepage exacerbated the problem by further reducing water levels.

Tidal patterns follow those of the main estuary but the culverts restrict flow and a lag in reaching high tide may be up to four hours. As flood tide continues to flow into the lagoon, the turn of the tide in the large body of Pitt Water leads to a simultaneous competing ebb tide (G Robertson Pers Comm.).

In summary, in 1982 the hydrology of Orielton Lagoon was controlled by

- limited tidal movement and exchange of marine waters through culverts at the centre of the causeway, set to average high tide mark

- ephemeral flows from Orielton Rivulet and Frogmore Creek, with occasional flood flows
- direct rainfall into the lagoon
- evaporation over the high surface-volume ratio
- seepage below the causeway.

3.2.3 Water quality

No data are available on water quality entering the estuary from the Coal River, Sorell Rivulet and Iron Creek in 1982. It is likely that nutrients would be carried in these waters given that they flow through land developed for agriculture. The water is naturally saline (D.Leaman pers.comm. 22/06/09). The influence of the freshwater flow is probably limited to Upper Pitt Water given the volumes and tidal flows.

The Pitt Water estuary is characterised by normal marine salinity (Crawford and Mitchell 1999).

The water quality in Orielton Lagoon up to and at the time of listing in 1982 was known to vary depending on climatic conditions. Since tidal exchange was limited, the lagoon could become almost fresh water under heavy rainfall conditions. At other times, evaporation could create hypersaline conditions. The effects of rainfall exacerbated fluctuating nutrient levels.

By the mid 1970s, Buttermore (1975) reported levels of total nitrogen in the lagoon exceeded that of Pitt Water throughout the year (0.012 – 5.70 pmm compared with 0.018 – 0.781 pmm). After heavy rains, total ammonia nitrogen levels were higher upstream in the lagoon than at the sewage outfall, while the converse was the case for nitrate and nitrate nitrogen, suggestive of the different inputs (agricultural run-off and sewage) and the anoxic conditions in the lagoon sediments which would result in conversion of nitrate-nitrite compounds to ammonia (Buttermore 1977). Phosphate levels were low across the entire lagoon and did not vary by season. Phosphate levels were not limiting for plant growth (Buttermore 1977).

Over the year, salinity in the lagoon ranged from fresh (2 ppt) to fully marine (33 ppt) and turbidity and suspended solid levels were high (210 mg/l and 83 JTU respectively). The lagoon is too shallow and its wave climate too energetic to allow thermal stratification and temperatures follow seasonal patterns ranging from 8°c in winter to 25 °c in January (Buttermore 1977, Brett 1992). Figures 3.8 (a) and (b) show the relationship between salinity, rainfall and temperature over a period of one year. Salinity falls to near freshwater after winter/spring rainfall and temperature follows seasonal patterns with rising temperatures through spring and summer and cooler in autumn and winter.

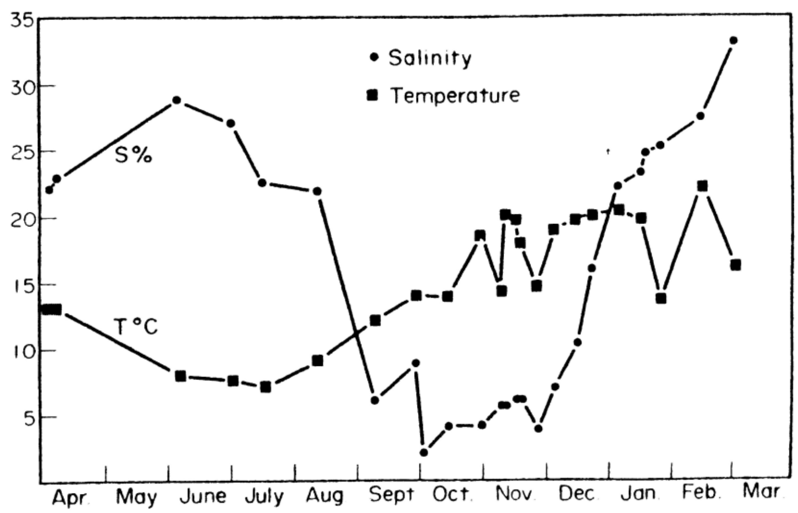


Figure 3.8: (a). Salinity and temperature in Orielton Lagoon April 1975-March 76. (Source: Buttermore 1977)

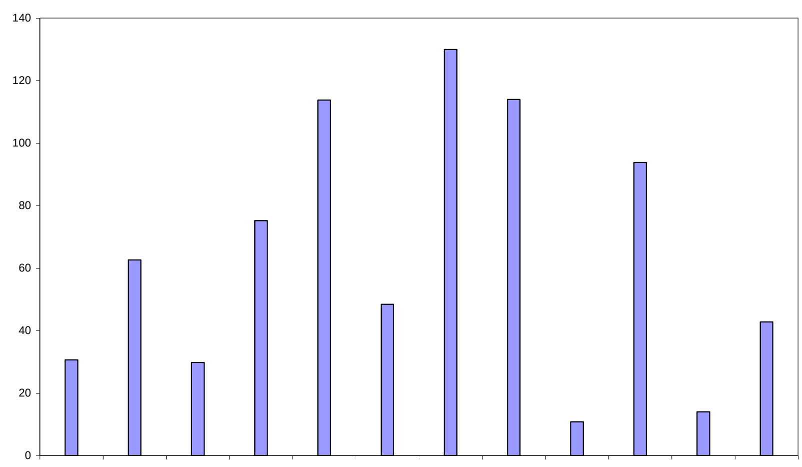


Figure 3.8: (b) Rainfall for Orielton Lagoon April 1975 – March 1976. (Source: BoM)

Turbidity of the lagoon also showed seasonal variation (Brett 1992) peaking in April with a sharp decline to May. Turbidity started to rise again in September and reached a peak in December. While turbidity varied between sites, it was consistently higher than in Pitt Water (usually about 20 FTU and up to 157 FTU compared with Pitt Water at 2 – 5 FTU).

Chlorophyll levels varied widely through the year (Brett 1992), all sites showing a peak in April in the order of 40 μg/L and a larger peak in December up to 80 μg/L. These figures contrast with values for Pitt Water ranging between 0.01 and 1.6.μg/L.

In summary, in 1982 the water quality of Orielton Lagoon was seasonally variable and subject to discharge from agricultural activities and human waste.

- Salinity varied from fresh to hypersaline
- Nitrogen levels could be high, depending on heavy rainfall and temperature
- Phosphate levels low but sufficient for plant growth
- Chlorophyll levels are high throughout the year with peaks in late spring and autumn
- Nutrient levels lead to periodic noxious algal blooms.

3. 3 Physical form and geomorphic environments

3.3.1 Landscape setting

The PWOL estuary is located in a downthrown block developed in the trailing edge of the Tasman Sea rift. Rifting was active in the early Tertiary (between 80 and 40 million years ago), and led to the development of a wide structural valley in Jurassic dolerite with Triassic sandstone and Permian mudstone. This was partially filled with sand to clay-sized sediment in the late Tertiary. Fluctuations of sea-level and climate through the Quaternary (last two million years) have periodically incised these soft sediments and deposited terrace sequences along major streams. The estuary is a drowned valley, excavated during the last glacial stage (approximately 20,000 years ago) and flooded by postglacial sea-level rise.

The geology of the area is shown in Figure 3.9. The immediate area surrounding PWOL is dominated by Holocene river alluvium, silt, fine sand, dune and windblown sand with pockets of Tertiary basalt and inliers of Triassic sandstone and shale. Sediments are washed through the rivers, eroded from the shorelines and brought in by the tides, forming and re-forming the present-day geomorphic features of the estuary.

The landscape context provides a key component of the ecological character through creation of the low-lying topography that allowed the estuarine features to develop and in the nature of the sediments contributed from the catchment. It is not included as a critical component per se as it is unlikely to change within the 100 year time-frame.

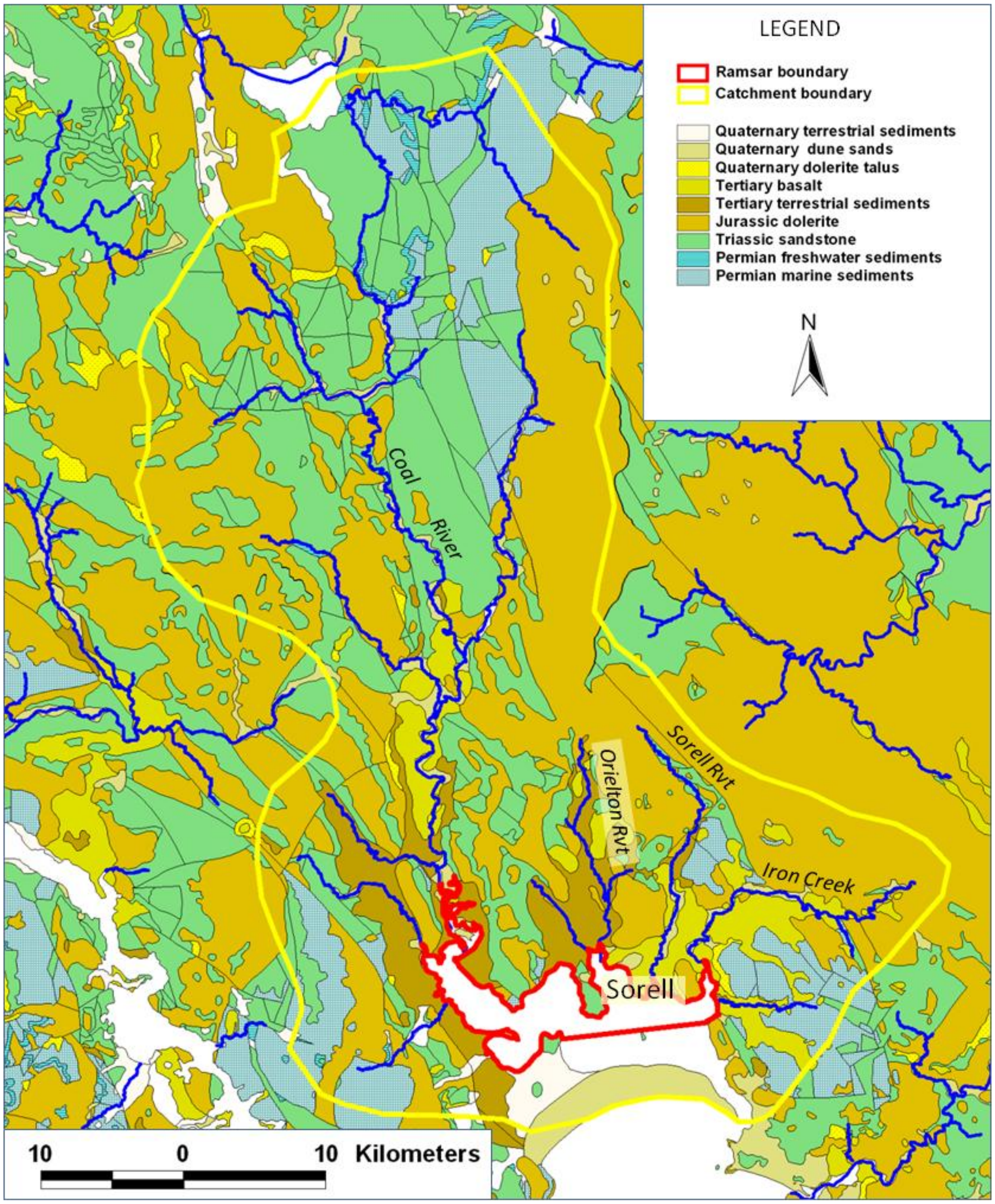


Figure 3.9: Geology of the Coal River valley and other PWOL catchment areas. (Source: Prepared by I Houshold DPIW 2009)

3.3.2 Physical form and geomorphic environments

Pitt Water is a large wave-dominated estuary of about 43 km^2. It was formed by the development of a mid bay spit resulting from sea level rise some 10 000 years BP (before present). This spit almost closed off the mouth of the Coal River. Flooding of the surrounding low-lying land occurred as sea level rose and created the wide but very shallow estuary. The estuary has a series of secondary basins, including Orielton Lagoon, Barilla Bay and Sorell Creek bay.

The coastal barrier, its southward edge forming Seven Mile Beach, controls the mouth of the Pitt Water estuary, leaving a tidal inlet some 0.5km in width at Dodges Ferry. The configuration of Upper Pitt Water is partly controlled by outcrops of Triassic sandstone at Midway Point and tertiary basalt at Sorell. Before the construction of the causeways, the area that is now Orielton Lagoon was a broad open embayment fully contiguous with the open estuary. It now functions as a highly modified estuary with very limited interchange with the main body of the estuary. As shown in Figures 2.1 and 2.2, only a small part of Lower Pitt Water lies within the Ramsar boundary and includes small estuaries and intertidal areas on the eastern shoreline. The components and processes within the entire estuary are important for describing and understanding the ecological character of the PWOL Ramsar site. Although the mid-bay spit lies outside the site boundary, it and the associated flood tide delta determine the ecological character of the site. Within the area captured by the Ramsar boundary, landforming energetics are, in order of dominance, tidal, fluvial and waves.

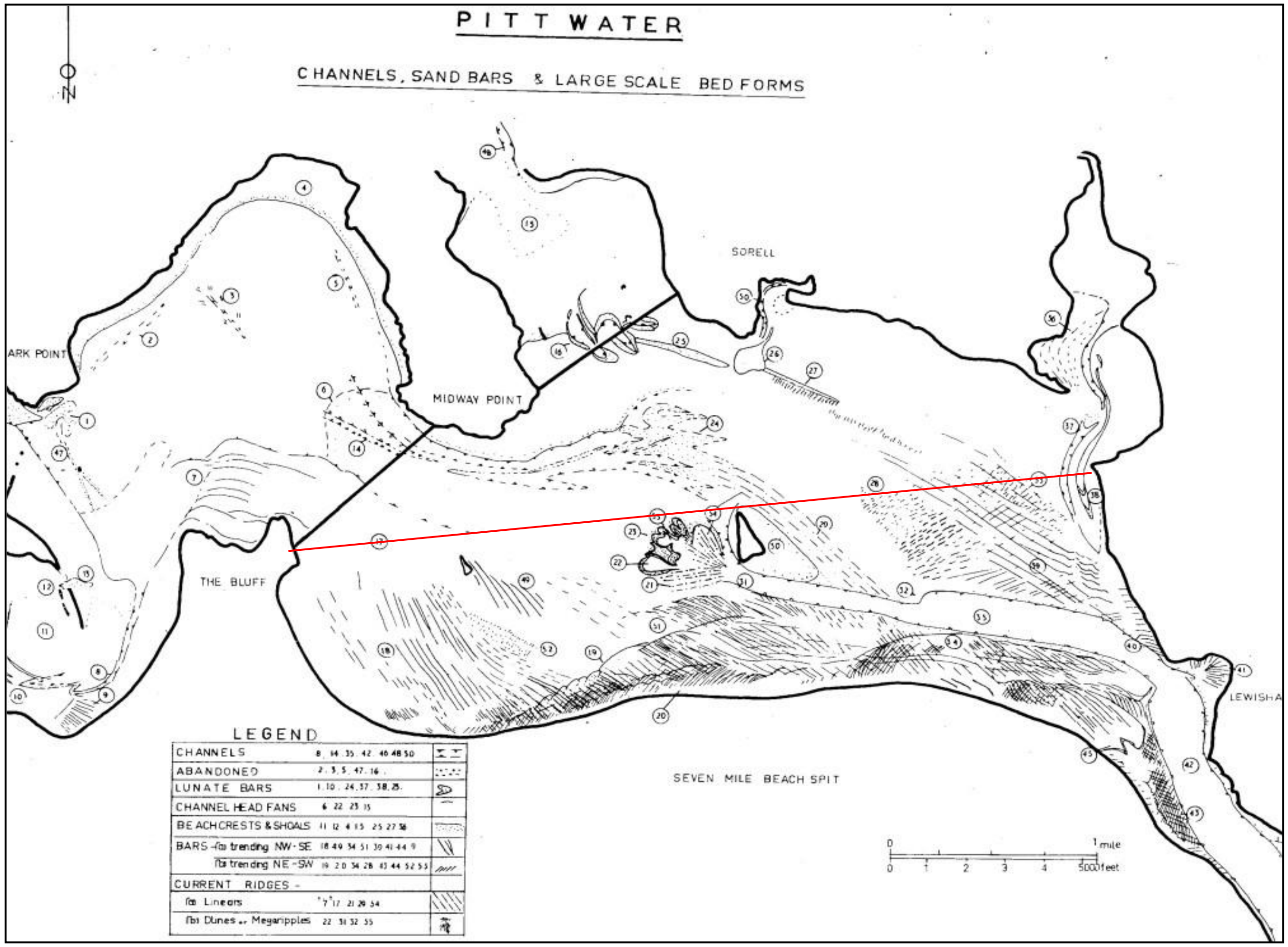
The Pitt Water estuary is generally shallow, reaching greatest depths of about 8m in the main channels (Mount *et al* 2005). Extensive areas of the estuary are very shallow with considerable exposure of intertidal flats at low tide. Further up the estuary, the width of the estuary narrows and it becomes sinuous as it reaches the upper limit of tidal influence at Richmond. Evidence of past meanders is seen in the disposition of saltmarshes on the eastern bank of the upper estuary.

Bays and secondary estuaries with associated geomorphological features feed into the central basin. The natural tidal flows, freshwater flows and sediment processes have been altered by two principal anthropogenic factors: catchment development and the construction of causeways that act as solid barriers across most of the open mouths of the two major bays, the Coal River and Orielton Lagoon.

The first causeway, between Pitt Water Bluff and Midway Point, has a lengthy bridge sited at the eastern end, in the approximate location of the original deeper channel marking the former river bed. The second causeway, also known as the Sorell Causeway, had, until 1953, a similar open bridge structure allowing quite free flushing between what was later known as Orielton Lagoon and the main body of the estuary. In 1953 the conversion of that bridge to a causeway across the open bay turned it into a coastal lagoon, breached only by 1.7m diameter culverts. Later modification of the culverts allows Orielton Lagoon to function as a highly modified barred estuary. The lagoon is only about 1 – 1.5m deep with a uniform bed of silty sand.

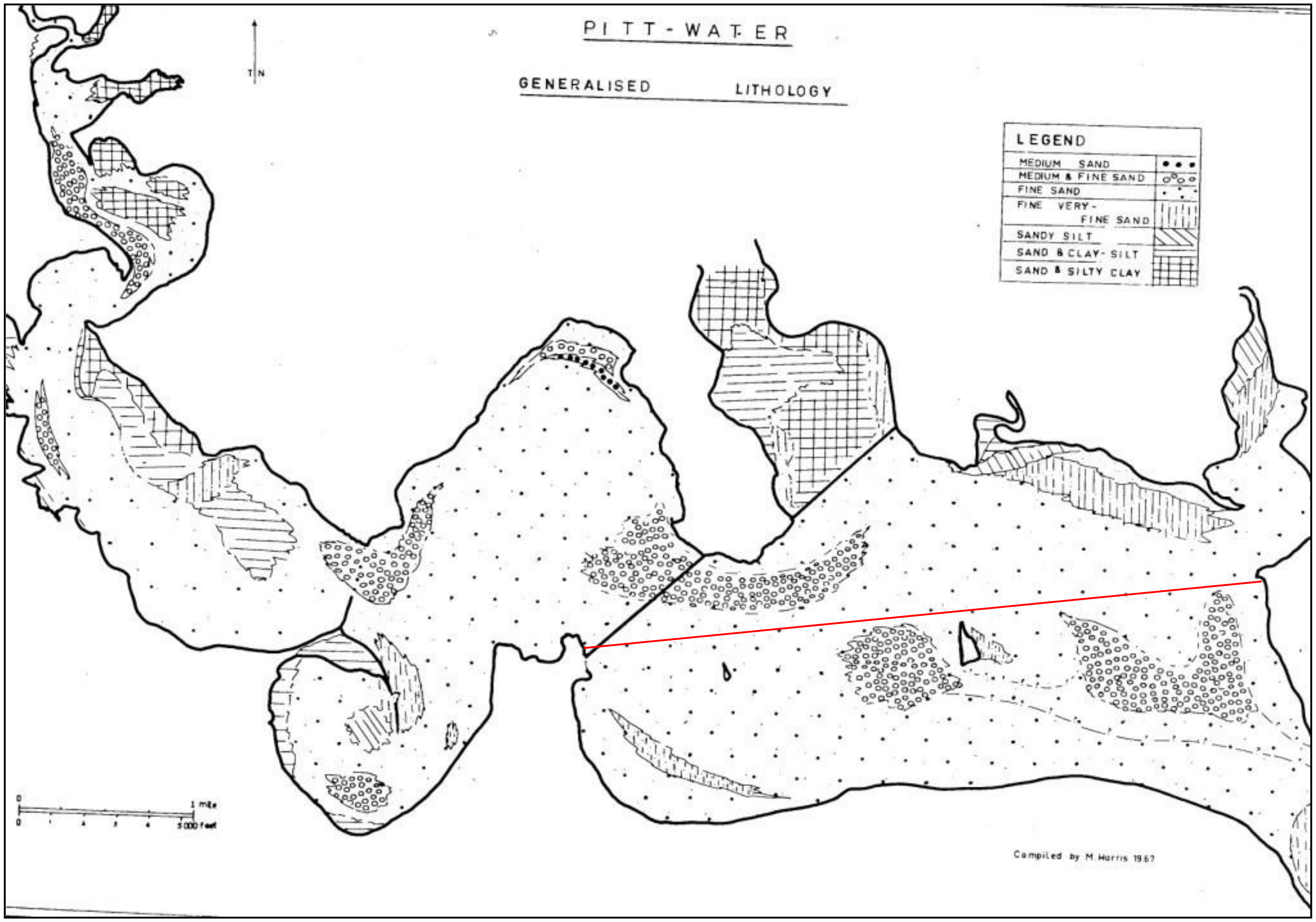
The bed-forms and sedimentology (Figure 3.10) of the estuary were described by Harris (1968). These show the effects of tidal movements in the wave-dominated estuary resulting in typical features such as beaches and shoals, current ridges, channels and bars. A significant head fan (or parabolic flood tide delta lobe) is developed where the main flood tide channel deposits sediments as it loses energy (Mount *et al* 2005).

Figure 3.11 shows the generalised lithology of the Pitt Water estuary (Harris 1968). Sandy sediment and silt carried by the Coal River or blowing overland into Upper Pitt Water has settled over the alluvial material that once formed the land surface prior to inundation. The main sediment of the waterway is fine sand. The deeper channels where there are active tidal flows are sorted to medium sand. The water is generally shallow (around 5m) except for the main channels. The open sandy bottom is often shaped into ridges caused by currents with harder sand in the scoured channels. In places, the softer sediments are clothed with areas of seagrass. In the upper reaches of the estuary there is evidence of clay and silt deposited by river flows. These are areas of particularly active sediment movement likely to be affected by changes in hydrology.



Note scale in miles. Seaward limit of Ramsar boundary

Figure 3.10: Bedforms at Pitt Water Estuary showing main channels, beach crests, bars and shoals in 1967. (Source: Harris 1967).



Note scale in miles.

Seaward limit of Ramsar boundary

Figure 3.11: Generalized lithology of the Pitt Water Estuary and Orielton Lagoon 1967. (Source: Harris 1967).

The shoreline bordering the estuary is generally low-lying with sediments varying from sand and coarse gravel to silt and mud. At several points rocky outcrops create low cliffs, along the eastern and western coastlines of Orielton Lagoon and near Shark Point in Upper Pitt Water. Higher bluffs at Pitt Water Bluff, Midway Point and Sorell 'anchor' the two causeways. Several small rocky islands and reefs occur within the Ramsar site, including Woody Island and Barren Island in lower Pitt Water and Susie Islet in Orielton Lagoon. An extended rocky shoreline has been artificially created at the foot of both causeways.

The sandy beds of much of the estuary can be attributed to abundant sand-sized sediment supply and active estuarine processes winnowing more readily suspendable finer material. The low-lying land surrounding Pitt Water and Orielton Lagoon is composed of beach deposits or wind-blown sand. The soils of the surrounding catchments of Pitt Water and Orielton Lagoon are clay or clayey loam (Kinhill 1993). Extensive land and forest clearing in the 19th and 20th century resulted in erosion and sediments entering the watercourses (Kinhill 1993). Lewis (2006) found, using analysis of foraminiferan and ostracods remains in sediment cores, that the recent seafloor environments had changed considerably since the late 19th century, mainly as a result of human activities.

At the time of listing, the channels had settled their somewhat modified courses below the causeways. In Upper Pitt Water the main channel more or less follows the original line of the channel, in Orielton Lagoon the original channel flow may have been on the Sorell side of the 'lagoon', the chosen location for the first bridge. In 2009, Orielton Lagoon was connected to the estuary by five (adjacent) 3.6m x 1.8m box culverts in the mid-point of the 2nd causeway and a pair of smaller (1.5m diameter) drainage channels towards the Sorell end.

No precise mapping of the extent and distribution of benthic and intertidal habitats was undertaken at the time of listing. Recent habitat mapping (Figure 3.3) illustrates recent interpretation of sediments.

3.3.3 Coasts, bedforms and sediments in Orielton Lagoon

Low sandstone cliffs mark the seaward entrance to Orielton Lagoon and low sandstone cliffs and rocky shores occur on the eastern side of the lagoon. Much of the remaining shoreline is comprised of sandy or muddy shores grading into intertidal flats. An extensive area of saltmarsh and saline flat fills the northern end around the mouth of Orielton Rivulet. A small island, Susie Islet, near Sorell marks an area with scattered rocky reefs in the eastern part of the lagoon. Silt and clay have deposited over most of the basin of Orielton Lagoon. Extensive intertidal flats occur south of the saltmarsh and continuing around the western shoreline. Sandy flats are also exposed on the both sides of the causeway at Midway Point and Sorell Point.

In the catchment of Orielton Lagoon, Kinhill (1993) noted significant gully and sheet erosion and streamside erosion due to unrestricted stock access. Fine silt was washed into Orielton Lagoon, much of it depositing on the consolidated sands of the lagoon bed. In most areas, the unconsolidated surface sediments were only a few centimetres thick, suggesting limited deposition since the lagoon closure (Kinhill 1993). Areas where more sediment accumulation had occurred were in the South-west corner of the Lagoon and along the western side of the lagoon (5-10cm and 8cm respectively). The deepest unconsolidated sediment was in the Orielton Rivulet itself (30 -35cm). When high river flows bring sediment into the lagoon, much of it is flushed through the lagoon, even at the time when the culvert openings were limited in size and height (Kinhill 1993). The superficial sediments of the lagoon tend to be slightly coarser (silt to coarse sand) around the perimeter shorelines than in the central basin (clay to medium sand) (Harris 1976) (Figure 3.10). The most significant sources of sediment supply are likely to be derived from shoreline erosion (I Houshold pers comm.). Saunders *et al* (2007), using sedimentation core analysis, estimated a sedimentation rate for Orielton Lagoon of 0.2cm yr^{-1}.

The 1948 aerial image, taken while the bridges still existed in the 2nd Causeway, shows the main channel of Orielton Rivulet sweeping down the eastern side of the large wedge of saltmarsh with sediment deposition at the end - a feature known colloquially as 'the boot'. The three bridge spans are clearly evident in the channels flowing between the lagoon and Pitt Water (Figure 3.12).

Figure 3.12: Aerial image of OL in 1948 showing main channel in the lagoon, three channels under the causeway and intertidal flats. (Source: DPIW)

All bridge openings were closed in 1953, leaving only two culverts with limited tidal exchange. The old abandoned channels and deposition of sand below the causeway are evident in mapping of bedforms and lithology done in 1967 (Figure 3.10). The result of the closure of channels, leaving only the two centrally located culverts, is seen in the aerial image taken in 1981 (Figure 3.13).

Figure 3.13: Aerial image of OL in 1981 showing remnants of channels and flow through central culvert. (Source DPIW)

3.3.4 Geomorphic features and processes

Critical geomorphic features and processes determining the ecological character of PWOL are listed below. Conceptual models illustrating the key geomorphic components and processes and their relationship with hydrology and biology of PWOL are provided in Section 4.

The features and processes of the whole estuary define the character of that area of Pitt Water encompassed within the Ramsar boundary. They also demonstrate the characteristic features of a wave-dominated estuary.

The types of features lying within the listed area are clearly shown in Figures 3.3, 3.14 and 3.15. The list of natural geomorphological processes highlights the dynamic nature of the system that must be factored into understanding the ecological character of PWOL and the challenges in proposing appropriate limits of acceptable change. Human intervention in the environment also generates (or exacerbates) geomorphological processes. Such processes are operating in PWOL and these are listed below.

Typical features of a wave-dominated estuary

- Fluvial bay-head delta
- Central basin
- Intertidal flats
- Flood and ebb-tide deltas
- Barrier
- Tidal channels
- Tidal sandflats.

Features of a recent estuarine environment with low freshwater inputs (‘negative’ estuary)

- Extensive tidal channels
- Well-developed spits, often resulting from local long-shore drift

- Lateral and mid-channel bars
- Beach ridges
- Current ridges, including linear ridges, dunes and mega-ripples.

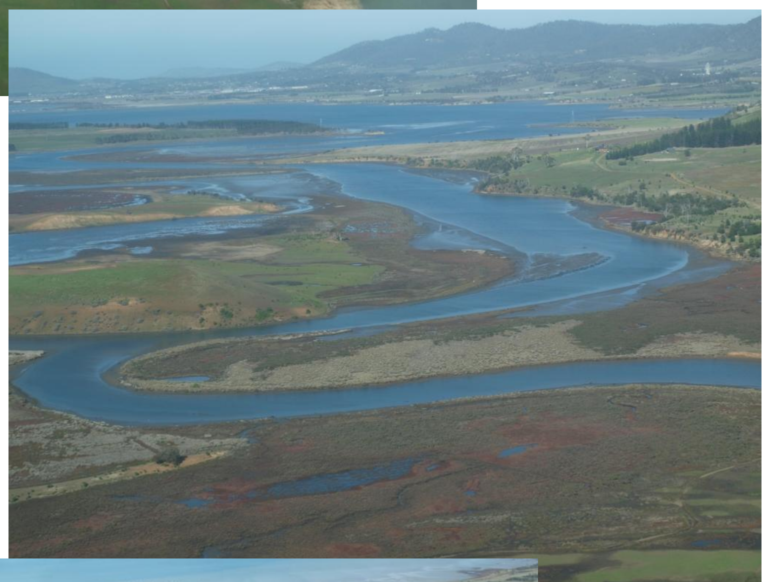
Ongoing natural geomorphological processes

- Sediment input from catchment streams
- Sediment input from shore erosion
- Deposition in intertidal flats, bars, fans, deltas, beaches, sandbanks
- Migration of tidal channels
- Export and import of marine sediment through the estuary mouth
- Import of aeolian sediment
- Re-working of bed sediments by wind waves.

Geomorphological processes that are a consequence of human intervention

- Decrease in fluvial sediment supply due to catchment flow regulation, abstraction from catchment, irrigation dams and farm dams
- Increase in sediment supply from unregulated agricultural catchments
- Increase in shoreline erosion (particularly in soft Tertiary sediments)
- Deposition of fine sediments in sheltered low-energy environments
- Increased depth of fine sediments in upper estuary due to lack of flushing flows
- Deposition behind artificial barriers (causeways)
- Erosion of shorelines and intertidal flats seawards of causeways (due to lowered sediment supply and sea level rise).

(a) Coal River estuary looking upstream to Richmond - bars, current ridges



(b) Coal River estuary looking downstream to Pitt Water – fluvial bay head delta

(c) Saltmarsh and intertidal flats at Orielton Lagoon

Figure 3.14: Some geomorphic features and evidence of geomorphic processes of Upper Pitt Water and Orielton Lagoon. (Images: I Houshold 2009).

(a)

(a) Pitt Water showing central basin, main beach spit, narrow tidal entrance and tidal flats

(b) Iron Creek spit

(c) Lower Pitt Water

(b)

(c)

Figure 3.15: Some geomorphic features and evidence of geomorphic processes of Lower Pitt Water. (Images: I. Houshold 2009)

3. 4 Seagrass and other aquatic primary producers

3.4.1 Seagrass

Seagrass is an important component of estuarine habitats and plays an important role in providing habitat and feeding areas for invertebrates, fish and wading birds (Aquenal 2000). The principal species of seagrass occurring in PWOL is *Zostera muelleri* which colonizes the intertidal flats and shallower bays. *Heterozostera tasmanica* is less tolerant of exposure and low salinities, so is limited to the deeper channels that generally lie in Lower Pitt Water outside the Ramsar boundary (Aquenal 2000). *Ruppia* sp is a perennial grass which may be found in areas with more freshwater influence such as the head of the estuary and Orielton Lagoon.

Estimated distribution of seagrass in 1970 and 1990 is shown in Figure 3.16. The extent and distribution was estimated from aerial imagery (Rees 1993), but poor image quality made interpretation difficult. Nevertheless, it has been confidently concluded that there was a significant decline in seagrass coverage from approximately 1276ha in 1950 to 75 ha in 1990 (Prestedge 1996, Aquenal 2000). Seagrass beds were reported to be extensive in about 1970 close to the main tidal channel in Lower Pitt Water, near the mouth of the Coal River in Upper Pitt Water, in the embayment at Barilla and in smaller patches on the eastern boundary of the Ramsar site (Prestedge 1996). Prestedge (1996) noted that there were extensive beds of *Zostera* in Lower Pitt Water including intermittent beds in the intertidal zone and following the shoreline in the region of Sorell Rivulet/Iron Creek.

Although no mapping was done for the year of Ramsar listing in 1982, declines were recorded by Prestedge (1996) in the 1970s and 1980s, with the seagrass becoming overgrown with epiphytes and covered with silt. Seagrass under these conditions loses the capacity to photosynthesize and dies off. By 1979, Prestedge (1996) observed that the growth of the seagrass was thinning out, and that from time to time filamentous green and brown algae were becoming widespread on the foreshores.

In Orielton Lagoon, Buttermore (1975) had reported that in the early 1970s beds of *Ruppia maritima (=R. polycarpa)*, *Lepilaena preissii*, *Zostera muelleri* and *Stuckenia* (= *Potamageton) pectinata* parallelled the shoreline, occupying less than 5% of the area of the lagoon[1]. At the time of listing in 1982, Prestedge (1996) suggested the seagrass in Pitt Water had declined to a few very small (i.e. less than 30 sq m) patches. The assessment of seagrass by aerial imagery circa 1970 by Rees (1993) confirmed levels of seagrass in the lagoon to be below the scale for mapping.

At the time of listing, seagrass was still an important component of the PWOL ecosystem, albeit less extensive than in earlier decades. Losses of seagrass have been attributed to increases in turbidity and nutrient levels, and sedimentation (Aquenal 2000). All these factors are likely to have occurred in PWOL, leading to reduction in photosynthesis by reducing light reaching the leaf blades or growth of epiphytic algae. In Orielton Lagoon, an additional factor affected the health of the seagrass. In the period when the site was listed, there was very limited tidal exchange resulting in the lagoon becoming almost freshwater during period of high rainfall. Seagrasses are intolerant of such conditions and declined, leaving only very limited patches within the lagoon.

There have been no systematic studies of the algae of PWOL, though these have been of some interest in Orielton Lagoon due to odour problems. After closure of the lagoon in 1953, the extensive beds of *Zostera muelleri* died off, salinity levels dropped and nutrient levels increased. Filamentous green algae such as *Enteromorpha intestinalis* and *Chaetomorpha linum* flourished (Kinhill 1993). Prestedge (1996) reported that from about 1975 at the same time as the seagrass beds declined, in Lower Pitt Water beds of the alga *Codium* which had fringed the islands and mudflats disappeared. The changing patterns of algal species and seagrass before, and since, listing in 1982 demonstrate the responses of the marine plant life to changes in environmental conditions in PWOL.

[1] Prior to the reconstruction of the causeway in 1953, *Zostera* was dominant and grew throughout the lagoon.

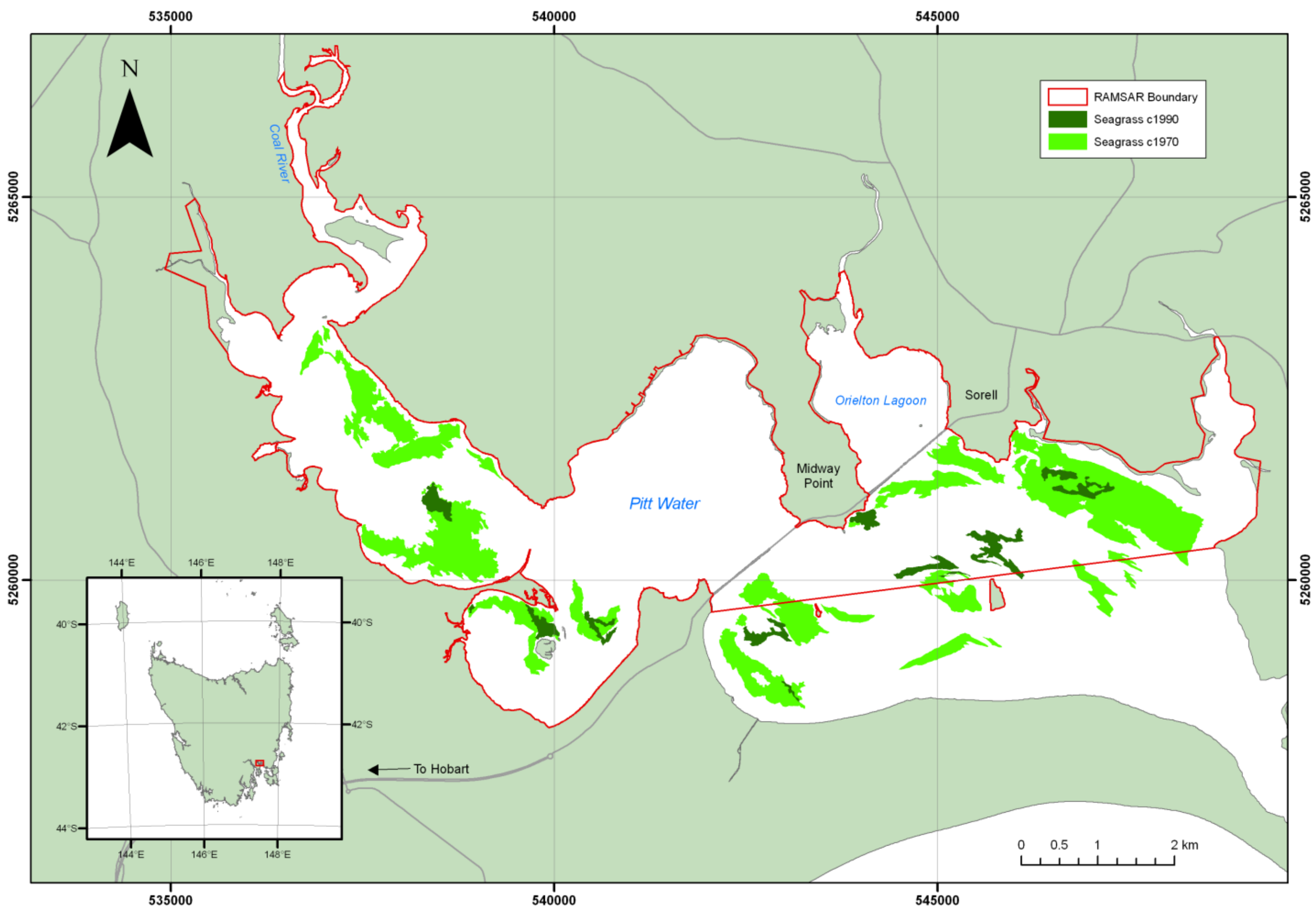


Figure 3.16: Seagrass distribution in PWOL 1970 and 1990. (Source: M.Morffew, Centre for Spatial Information Sciences, School of Geography and Environmental Studies, University of Tasmania 2009. Based on data in LIST, DPIW Tasmania).

3.4.2 Diatoms

Data on the phytoplankton of PWOL are limited (Crawford and Mitchell 1999). Phytoplankton plays an important role in the nutrient dynamics of estuarine systems and is a useful indicator of ecosystem health and nutrient balance. Oversupply of nutrients causes algal blooms that can be a nuisance or even of toxic significance, while algae also need to be available as a food source for filter feeders and grazers. Diatoms form a major source of food for oysters and the commercial production of oysters is a notable provisioning ecosystem service in PWOL.

A survey of the plankton in the vicinity of oyster farms in Upper Pitt Water showed that diatoms and nannoplankton (<20 micron flagellates) dominated the phytoplankton (Hallegreaff and Tyler 1987). The diatom species *Asterionella glacialis, Chaetocerus* spp., *Nitzschia closterium* and *N. pungens* reached bloom proportions in short spells in summer and autumn. The Pitt Water phytoplankton communities were similar to those of Storm Bay (an open marine bay further south in the Derwent Estuary) although the Pitt Water community was characterised by a low abundance of larger dinoflagellates and a high percentage of benthic diatom species resuspended from bottom sediments.

Limitation of silica can shift the balance from diatoms to dinoflagellates (Davies *et al* 2002). Estuarine systems tend to gain silica from riverine inflows, although in southern Tasmanian estuaries including Pitt Water, nutrient –rich waters from the Southern Ocean are an important contributor, especially in winter months (C.Crawford pers.comm.).

3. 5 Fish communities

Fish communities are a critical component of any estuarine ecosystem. In PWOL, Upper Pitt Water also provides nursery areas which are important for commercial shark species.

Long-term data on fish species, communities and abundance are very limited (Aquenal 2000). A systematic survey using seine netting techniques was undertaken by Last in the late 1970s (Last 1983) as part of a statewide study on estuarine fish communities. A summary of fish data by Aquenal (2000) indicates that full data are not readily available from this study, but analysis suggests that the fish fauna of Pitt Water consisted of species that are widespread, with no distinctive faunal communities (Edgar *et al* 1999). The species present were typical of estuaries in the south-east region of Tasmania (Edgar *et al* 1999).

Prestedge (1996) provides the most comprehensive list of species present in the estuary. This is based on anecdotal evidence collected over several decades while fishing or from local observation. Catches were frequently made from the bridge on the first causeway (Pitt Water Bluff to Midway Point). The full species list, along with comments on comparative abundance prior to 1975 and in 1995, is shown in Table 3.4. The majority of the fish listed in Table 3.4 are marine, with the exception of *Aldrichetta foresteri* (yellow-eyed mullet), *Mugil cephalus* (sea mullet) and *Torquigener glaber* (smooth toadfish) which may be classed as estuarine/marine (Aquenal 2000).

The wider range of species recorded by Prestedge (1996) reflects the different habitats within the estuary and the seasonal occurrence of some species. Seagrass provided specialised habitat for syngnathids (seahorses, pipefish) and the invertebrate fauna associated with seagrass provides an important food source for other fish species. Prestedge (1996) reported that September brought the annual run of Australian salmon, often accompanied by small barracouta. Early summer also saw increased numbers of mullet and flathead. Whitebait species undertake a ‘spring run’ migrating up rivers to breed in freshwater. School and gummy shark increased in the spring, summer and autumn and elephant fish were always plentiful. Patterns of fish species richness in Tasmanian are strongly correlated to summer surface salinities and to the presence of seagrass (Edgar *et al* 1999).

Several shark species migrate to the sandy bays of the Upper Pitt Water for breeding and sheltered habitat for the juveniles (CSIRO 1993, Healey 1996). Pitt Water is a key breeding area for school shark *Galeorhinus galeus* and gummy shark *Mustelus antarcticus*, the main target species for the southern shark fishery.

Table 3.4: Fish species recorded at PWOL. (Source: Aquanel 2000, based on data from Prestedge 1996).

SPECIES		**FREQUENCY**	
Scientific Mame	Common Name	Pre 1975	1995
Squalus acanthias	White-spotted dogfish	Frequent	Uncommon
Mustelus antarcticus	Gummy shark	Common	Frequent
Galeorhinus galeus	School shark	Common	Infrequent
Dasyatis brevicaudatus	Smooth stingray	Frequent	Uncommon
Myliobatis australis	Eagle Ray	Common	Frequent
Urolophus cruciatus	Banded stingaree	Frequent	Rare
Raja whitleyi	Whitely's skate	Common	Uncommon
Raja lemprieri	Thornback skate	Common	Uncommon
Callorhynchus milii	Elephant fish	Common	Common
Conger verreauxi	Southern conger eel	Common	Rare
Muraenichthys breviceps	Short-headed worm eel	Frequent	Rare
Pseudophycis bachus	Red cod	Common (winter)	Infrequent
Genypterus tigerinus	Rock ling	Frequent	Rare
Hyporhamphus melanochir	South Australian garfish	Common	Uncommon
Atherinosoma presbyteroides	Silverfish	Abundant	Frequent
Hippocampus sp.	Sea horse	Uncommon	Rare
Syngnathus sp.	Pipefish	Frequent	Rare
Gymnapistes marmoratus	Soldierfish	Frequent	Rare
Neosebastes scorpaenoides	Common gurnard perch	Not seen	Uncommon
Platycephalus laevigatus	Rock flathead	Frequent	Rare
Platycephalus bassensis	Sand flathead	Common	Common
Acanthopegasus lancifer	Sculptured sea moth	Rare	Rare
Caesioperca lepidoptera	Butterfly perch	Uncommon	Not seen
Latridopsis forsteri	Bastard trumpeter	Uncommon	Not seen
Sillago bassensis	School whiting	Common	Frequent
Pseudocaranx dentex	Silver trevally	Uncommon	Rare
Arripis trutta	Eastern Australian salmon	Abundant	Frequent
Aldrichetta forsteri	Yellow-eyed mullet	Common	Infrequent
Mugil cephalus	Sea mullet	Abundant	Frequent
Thyrsites atun	King barracouta	Frequent	Rare
Rhombosolea tapirina	Greenback flounder	Common	Frequent
Ammotretis elongatus	Elongate flounder	Rare	Not seen
Diodon nicthemerus	Globefish	Common	Frequent
Haletta semifasciata	Blue rock whiting	Uncommon	Not seen
Heteroclinus sp.	Weedfish	Frequent	Not seen
Gobiidae species	Goby	Common	Frequent
Pictiblennius tasmanianus	Blenny	Common	Infrequent
Chelidonichthys kumu	Red gurnard	Uncommon	Rare
Torquigener glaber	Smooth toadfish	Frequent	Rare
Cyttus australis	Silver Dory	Not seen	First record 1997

Amongst a large number of sites in Tasmania surveyed for shark pups, the most significant numbers of juvenile school sharks were found in Pitt Water (Aquenal 2000). The pregnant school sharks move into shallow waters in late spring-early summer to give birth in shallow sandy bays near Shark Point. The presence of seagrass is considered important as feeding and shelter for the newborn sharks. Healey (1996) suggests that other shark species, including elephant fish *Callorhinchus milii*, have somewhat different and less restrictive requirements for breeding and no significant pupping grounds for gummy shark were located in a CSIRO study (Aquenal 2000).

Catch rates of shark in Pitt Water declined from the time of earliest observations in the 1950s and 1960s (Aquenal 2000) and numbers of school shark pups also declined (Prestedge 1996). The decline was considered to be the result of overfishing, seagrass decline and possibly other environmental changes in Pitt Water (Aquenal 2000). Pitt Water was declared a shark nursery area in 1990 under the *Living Marine Resources Management Act 1995*.

3.6 Invertebrates

Invertebrates are a critical component of the ecological character of PWOL as a food source for fish and birdlife. Invertebrates of the intertidal flats rework sediments, releasing organic matter and enabling microbial activity.

There is little information available about invertebrates of PWOL at the time of listing in 1982. Prestedge (1996) recorded aquatic species that he observed over several decades but location or distribution data are not reported. His observations and later research into the vulnerable live-bearing seastar *Parvulastra (=Patiriella) vivipara* provide evidence of distribution and frequency of this species at the time of listing. Information about other invertebrate species and communities may be inferred from later studies. These data provide some evidence of the invertebrate fauna of PWOL, although in most cases sampling was limited temporally and spatially.

3.6.1 Invertebrates of Saltmarshes

Wong *et al* (1993) surveyed 63 saltmarshes around Tasmania in 1991. Only one of these sites, Railway Point, lies within the Pitt Water – Orielton Lagoon area. At Railway Point, a total of four species of crustaceans and five molluscs were recorded (Table 3.5). These species were typical of the Tasmanian saltmarsh fauna and the diversity fell around the mean diversity for this type of ecosystem.

Table 3.5: Invertebrates of the Railway Point saltmarsh, 1991. (Source: Wong *et al* 1993)

Crustacea	**Molluscs**
5-dentate beachflea (Amphipod)	*Hydrococcus tasmanicus*
Deto marinus (Isopod)	*Mytilus* spp (mussel)
Porcellio scaber (Isopod) (introduced)	*Ophicardelus australis*
Paragrapsus gaimardii (crab)	*Salinator solida*
	Tatea rufilabris

The saltmarsh at Railway Point was largely vegetated with succulent marsh dominated by *Sarcocornia quinqueflora* and *Sclerostegia (=Tectocornia) arbuscula.* It was also recorded as having suffered impacts from grazing, tracks and landfill or drainage. These impacts may have affected the diversity of saltmarsh fauna. Wong *et* *al* (1993) used only hand collection from surface quadrats on a single occasion to provide a comparative snapshot of surface saltmarsh fauna at sites across Tasmania

The diversity of saltmarsh vegetation around PWOL is likely to provide habitat for a range of crustaceans and molluscs. In addition, the structural vegetation is known to host a number of species of spider (Figure 3.17) and other more mobile invertebrates.

Figure 3.17: Invertebrate habitats in saltmarsh at Duckhole Rivulet. (Source: H.Dunn 2009)

Saltmarshes in PWOL provide habitat for the saltbush blue (or chequered blue) butterfly *Theclinesthes serpentata lavara*, listed in Tasmania as rare under the *Threatened Species Protection Act Tasmania 1995*. The distribution of this species in Tasmania is restricted to coastal habitats (P.McQuillan pers.comm. 19/1/09). The saltbush blue larva feeds on *Rhagodia* and similar saltmarsh plants in the upper zones of saltmarshes.

3.6.2 Invertebrates of the intertidal flats

Invertebrates of the intertidal flats are of critical importance as a food source for shorebirds. However, detailed or long-term data on these communities is lacking. The first systematic survey of the fauna of the intertidal flats at PWOL was undertaken by Aquenal (2008c) as part of a development proposal for nearby Ralphs Bay. The sites within PWOL at Orielton Lagoon, Barilla Bay and, for the purpose of the initial pilot project, at the mouth of Iron Creek and Sorell Rivulet, were for the purpose of comparison and assessment of prey resources in the surrounding areas of Ralphs Bay and the Derwent estuary system.

The intertidal areas of the wider Derwent estuary, PWOL and beyond, showed considerable variation in prey diversity and abundance (Table 3.6). Orielton Lagoon had the lowest species richness amongst the sites (51 species) and the lowest density of all prey species (Aquenal 2008c). Barilla Bay falls midway in the range of sites with respect to species diversity and abundance, while using only limited sampling data, the intertidal flats at the mouth of Iron Creek and Sorell Rivulet appear to support invertebrate communities with high diversity, moderately high numbers and low dominance value (Aquenal 2008c).

The fauna at Orielton Lagoon and at Barilla Bay was dominated numerically in winter by the bivalve *Anapella cycladea* and in summer by polychaete worms. Orielton Lagoon showed significant seasonal differences in community composition although this may be partly explained by the low numbers of organisms and the inclusion of additional sites in subsequent phases of the survey. Barilla Bay had a much greater abundance than at Orielton Lagoon in summer.

Sediment characteristics are an important factor determining the benthic infauna community composition (Aquenal 2008c). Sediments are very fine in Orielton Lagoon. This may partly account for the difference in invertebrate fauna which was distinct from all other sites in the wider Derwent survey. Grey mud or (silt) was recorded at the surface and in deeper sediments in Orielton Lagoon. Other possible factors influencing the invertebrate fauna include limited tidal exchange, nutrient inputs and occasional freshwater flows. Barilla Bay was also found to have some finer sediments at shallow depths and is also subject to occasional freshwater flows.

Despite the apparently lower availability of prey at Orielton Lagoon, it remains a favoured site for wading birds. This may partly be accounted for by the sampling procedure and analysis of available prey species, particularly smaller prey. Aquenal (2008c p 103) notes that ‘it appears likely that habitat utilization by intermediate and small waders is influenced by a range of environmental and ecological factors and cannot be predicted on the basis of main prey densities alone’.

Table 3.6: Dominant invertebrates of intertidal flats at sites in and near PWOL. (Source: Aquenal 2008c). Sites within PWOL highlighted.

L=Lauderdale, M=Mortimer Bay, S=South Arm, P=Pipeclay Lagoon, F=Five-Mile, B=Barilla Bay, O=Orielton Lagoon

Spring 2006 - Species	Taxonomic Group	B	F	L	M	O	P	S
Anapella cycladea	Bivalvia (Mollusca)	4.66	1.64	2.56	0.00	0.38	0.84	0.11
Katelysia scalarina	Bivalvia (Mollusca)	0.07	0.46	0.99	0.85	0.00	0.25	0.32
Tellina deltoidalis	Bivalvia (Mollusca)	0.09	0.00	0.14	0.00	0.12	0.02	0.14
Eumarcia fumigata	Bivalvia (Mollusca)	0.05	0.00	0.03	0.05	0.00	0.00	0.00
Laternula tasmanica	Bivalvia (Mollusca)	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Wallucina assimilis	Bivalvia (Mollusca)	0.45	7.46	0.05	0.05	0.00	1.59	0.00
Soletellina biradiata	Bivalvia (Mollusca)	0.02	0.00	0.01	0.00	0.00	0.02	0.00
Nephtys australiensis	Polychaeta (Annelida)	1.07	0.14	1.40	1.35	2.92	1.52	2.30
Leitoscoloplos normalis	Polychaeta (Annelida)	2.25	3.14	1.85	1.75	0.04	1.44	0.32
Olganereis edmonsi	Polychaeta (Annelida)	0.05	0.04	0.04	0.00	0.00	0.31	0.18
Paragrapsus gaimardii	Decapoda (Crustacea)	0.00	0.04	0.05	0.05	0.00	0.02	0.00
Mictyris platycheles	Decapoda (Crustacea)	0.00	0.36	0.00	0.00	0.00	0.34	0.00
Salinator fragilis	Gastropoda (Mollusca)	1.02	1.89	3.01	1.60	0.23	0.61	1.43
	Total	9.75	15.18	10.13	5.70	3.69	6.95	4.80
Summer 2007 - Species	**Taxonomic Group**	**B**	**F**	**L**	**M**	**O**	**P**	**S**
Anapella cycladea	Bivalvia (Mollusca)	6.89	1.43	3.08	0.00	0.12	0.66	0.07
Katelysia scalarina	Bivalvia (Mollusca)	0.05	0.14	1.29	0.80	0.00	0.09	0.43
Tellina deltoidalis	Bivalvia (Mollusca)	0.23	0.00	0.08	0.00	0.00	0.00	0.02
Eumarcia fumigata	Bivalvia (Mollusca)	0.07	0.00	0.44	0.00	0.00	0.89	0.05
Laternula tasmanica	Bivalvia (Mollusca)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wallucina assimilis	Bivalvia (Mollusca)	0.27	7.64	0.20	0.00	0.00	2.41	0.00
Soletellina biradiata	Bivalvia (Mollusca)	0.00	0.00	0.09	0.00	0.00	0.00	0.00
Nephtys australiensis	Polychaeta (Annelida)	1.16	0.11	3.90	6.40	2.27	1.83	6.20
Leitoscoloplos normalis	Polychaeta (Annelida)	0.25	3.18	1.04	0.95	0.00	0.84	0.61
Olganereis edmonsi	Polychaeta (Annelida)	0.70	1.50	5.91	12.90	0.08	9.34	8.98
Paragrapsus gaimardii	Decapoda (Crustacea)	0.02	0.00	0.09	0.00	0.00	0.03	0.05
Mictyris platycheles	Decapoda (Crustacea)	0.00	0.32	0.03	0.00	0.00	0.13	0.05
Salinator fragilis	Gastropoda (Mollusca)	0.64	2.43	9.85	5.85	0.12	3.08	2.77
	Total	10.27	16.75	25.98	26.90	2.58	19.30	19.23
Winter 2007 - Species	**Taxonomic Group**	**B**	**F**	**L**	**M**	**O**	**P**	**S**
Anapella cycladea	Bivalvia (Mollusca)	5.72	2.71	3.68	0.28	5.39	0.70	0.45
Katelysia scalarina	Bivalvia (Mollusca)	0.26	1.50	2.29	1.30	0.03	0.41	0.75
Tellina deltoidalis	Bivalvia (Mollusca)	0.06	0.00	0.14	0.03	0.44	0.00	0.07
Eumarcia fumigata	Bivalvia (Mollusca)	0.04	0.00	0.03	0.00	0.00	0.00	0.00
Laternula tasmanica	Bivalvia (Mollusca)	0.00	0.00	0.00	0.00	0.19	0.00	0.00
Wallucina assimilis	Bivalvia (Mollusca)	0.26	5.79	0.15	0.05	0.00	2.31	0.05
Soletellina biradiata	Bivalvia (Mollusca)	0.00	0.04	0.07	0.05	0.00	0.00	0.02
Nephtys australiensis	Polychaeta (Annelida)	1.44	0.29	4.81	7.35	2.30	2.28	8.30
Leitoscoloplos normalis	Polychaeta (Annelida)	0.76	1.29	0.71	0.55	0.03	0.67	0.36
Olganereis edmonsi	Polychaeta (Annelida)	0.44	0.39	3.59	9.53	0.72	8.52	7.48
Paragrapsus gaimardii	Decapoda (Crustacea)	0.02	0.07	0.07	0.00	0.00	0.02	0.00
Mictyris platycheles	Decapoda (Crustacea)	0.00	0.29	0.01	0.00	0.00	0.02	0.02
Salinator fragilis	Gastropoda (Mollusca)	0.70	2.18	4.69	2.48	0.02	2.22	2.14
	Total	9.70	14.54	20.25	21.60	9.11	17.14	19.64
	Mean total per season	9.91	15.49	18.78	18.07	5.13	14.46	14.55

3.6.3 Pelagic and benthic invertebrates of the open water

Invertebrates of the open water and benthos are key elements of the food chain of estuaries, providing food sources for fish and larger invertebrates as well as a range of bird species. No systematic sampling of pelagic invertebrates at PWOL has been undertaken and little information is available. In a one-off state-wide sampling program of estuarine benthic habitats, a total of 35 species of invertebrate were recorded in Pitt Water (Edgar *et al* 1999). Of these, 10 species were crustaceans, 8 gastropod molluscs, 10 bivalve molluscs, 6 polychaete worms and one other. None was restricted only to Pitt Water. State-wide, the species richness was very variable with Pitt Water at 35 species being at the lower end of 'moderate' diversity. The benthic invertebrates at Pitt Water were dominated by the gastropod *Hydrococcus brazierii* and two bivalves *Notospisula trigonella* and *Cyanomacron mactroides* (Edgar *et al* 1999).

The observations of Prestedge (1996) over many years and across all habitat types, indicates a wide variety of invertebrates inhabit PWOL. In his detailed list of species (cited in Aquenal 2000) he lists 29 gastropod species, 20 bivalves, 2 cephalopods, 7 chitons, 24 decapod crustacean, 12 amphipods, 7 isopods, 4 barnacles, 19 echinoderms (including starfish and urchins), 54 polychaete worms, 4 ascidians, and 8 species from various other groups, a total of 190 species.

3.6.4 Invertebrates of the rocky foreshores

Several short sections of the shoreline are rocky and sandstone bluffs occur at Pittwater Bluff, Midway Point and Sorell Point. The most extensive section of rocky shoreline formed from the artificial shores of the causeways. These have been colonised by a typical range of invertebrate species, information about which was gathered as part of a study for the planned replacement of the bridge section of the 1st causeway (Aquenal 2000).

A total of 54 species were recorded in the survey (Aquenal 2000). The fauna was dominated by molluscs and crustaceans. In the upper–mid littoral zone, the gastropods were the most common species as well as the isopod, *Ligia australiensis*. In the mid-littoral zone, crabs became more common along with ascidians. In the lower mid-littoral several species not adapted to extensive exposure occurred. The fauna of the northern side of the causeway was more diverse than the southern shore, averaging 20-28 species for each northern transect compared with 15–22 species for the southern transects. More species were restricted to the northern side (10 species) than the southern side (4 species). Aquenal (2000) concluded that this indicated a larger zone of more suitable and diverse habitats in the littoral zone. The species and communities are typical of sheltered estuarine or marine rocky shorelines.

One species of the rocky shoreline that is of critical importance is the endemic viviparous seastar, *Parvulastra vivipara (= Patiriella vivipara)*. This seastar is listed as vulnerable on the *Threatened Species Protection Act 1995*, Tasmania and was listed in June 2009 as 'vulnerable' on the *EPBC Act*. It is a tiny seastar, maximum radius 15mm (Figure 3.18). This species has a very limited distribution in southern Tasmania and its stronghold is considered to be in PWOL (K.Parsons pers.comm. 2009). Its preferred habitats are the mid-littoral zone of rocky shorelines at the base of the sandstone cliffs and bluffs. It has also been recorded along other parts of the shore towards Shark Point (Prestedge 1998). Small to medium size rocks on the more sheltered aspects of the causeways were more favoured. Because of its live-bearing reproductive behaviour, it lacks ability to use tides and currents for widespread dispersal. The PWOL population is reported to have greater reproductive productivity than other sites (Byrne 1996).

At the time of listing the PWOL area was one of only six known population of this species. Although further sites have now been identified, PWOL is habitat for a significant proportion of the total population (K.Parsons, pers.comm. 25/05/2009) http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=66767

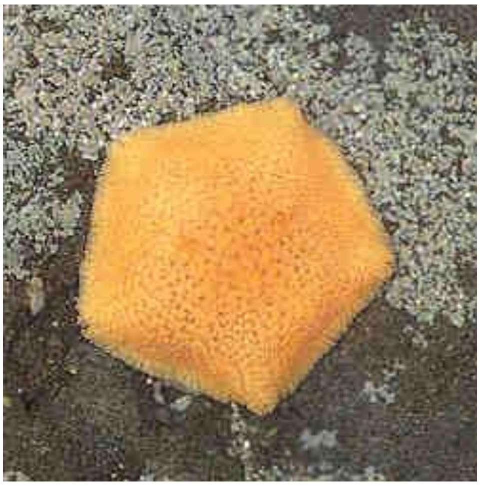


Figure 3 18: Endemic and vulnerable live-bearing seastar *Parvulastra vivipara*.
(Source: Edgar 1997 viewed on the website of the Woodbridge Marine Discovery Centre, Tasmaniahttp://www.woodbridge.tased.edu.au/mdc/Species%20Register/class_asteriodea.htm).

3. 7 Birdlife

The numbers and variety of birdlife are distinctive features of the Pitt Water – Orielton Lagoon ecosystem and therefore a critical component of its ecological character. The area provides habitat for a range of birdlife including waterfowl, seabirds, resident and migratory shorebirds. A range of bushland birds, raptors and other species have been observed in the area. A full list of birds recorded in the area is provided in Appendix 3. The use of the area for migratory shorebirds during the (northern) winter and its role as a refuge for large numbers of waterfowl in times of drought contributed to the nomination and listing of the area under the Ramsar Convention. While no population of shorebirds occurs in internationally important numbers, 23 populations have been recorded (Table 3.7). Orielton Lagoon is the most southerly site to be included in the Site Network of the East Asia-Australasian Flyway (EAAF) (http://www.eaaflyway.net). Orielton Lagoon is considered a priority site in the Bruny Marine Bioregion for beach nesting and migratory shorebirds (Bryant 2002).

PWOL provides a diversity of food sources including open water, shallow bays, intertidal flats, rocky and sandy shorelines, and saltmarshes. Rocky shorelines, saltmarshes, shrubby headlands and islands provide nesting and roosting areas.

Different bird species visit the area at different seasons. Late spring and summer is marked by the arrival of migratory shorebirds and waterfowl such as ducks and swan arrive in summer or move into the area in times of drought. Other seasonal or infrequent visitors include cormorants, grebes, pelicans and occasionally spoonbills. Some shorebirds and seabirds are year-round residents of the site, using the coast and islands for nesting and the readily available food of the estuary. Species of birds usually associated with marine habitats such as gulls feed, nest and roost in PWOL.

Weather conditions play a part in the presence and use of the area by different bird species. Information on presence and numbers of individual species reflects the birdlife of the extensive areas of the entire Derwent estuary system, for the birds move around the entire area in response to daily weather conditions. Prevailing winds turn from north-west to south-west during the day in summer as a seabreeze moderates temperatures (Figure 2.7). The diversity of the habitats and aspects in PWOL, Lower Pitt Water and the Derwent estuary complex offers shelter and roosting sites suitable for a range of weather and tidal conditions.

3.7.1 Migratory shorebirds of the East Asian-Australasian Flyway

Species that have been recorded in PWOL are shown in Table 3.4.

Table 3.7: Migratory shorebirds of the EAAF recorded in PWOL and their listing on international agreements. (Source: PWS data)

Common name	**Scientific name**	**JAMBA**	**CAMBA**	**ROKAMBA**
Latham's Snipe	*Gallinago hardwickii*		✓	✓
Ruddy Turnstone	*Arenaria interpres*	✓	✓	✓
Eastern curlew	*Numenius madagascariensis*	✓	✓	✓
Whimbrel	*Numenius phaeopus*	✓	✓	✓
Common greenshank	*Tringa nebularia*	✓	✓	✓
Common sandpiper	*Actitis (=Tringa) hypoleucos*	✓	✓	✓
Great knot	*Calidris tenuirostris*	✓	✓	✓
Marsh sandpiper	*Tringa stagnatilis*	✓	✓	✓
Red knot	*Calidris canutus*	✓	✓	✓
Little Stint	*Calidris minuta*			✓
Red-necked stint	*Calidris ruficollis*	✓	✓	✓
Curlew sandpiper	*Calidris ferruginea*	✓	✓	✓
Sharp-tailed sandpiper	*Calidris acuminata*	✓	✓	✓
Pectoral sandpiper	*Calidris melanotos*	✓		✓
Buff-breasted sandpiper	*Tryngites subruficollis*	✓		✓
Ruff	*Philomachus pugnax*	✓	✓	✓
Grey-tailed tattler	*Heteroscelus (=Tringa) brevipes*	✓	✓	✓
Pacific golden plover	*Pluvialis fulva*	✓	✓	✓
Lesser sand plover	*Charadrius mongolus*	✓	✓	✓
Double-banded plover	*Charadrius bicinctus*			
Greater sand plover	*Charadrius leschenaultia*	✓	✓	✓
Grey plover	*Pluvialis squatarola*	✓	✓	✓
Double-banded plover	*Charadrius bicinctus*			
Bar-tailed godwit	*Limosa lapponica*	✓	✓	✓
Black-tailed godwit	*Limosa limosa*	✓	✓	✓
Little Tern	*Sterna albifrons*	✓	✓	
White-winged black tern	*Chilidonias leucopterus*	✓	✓	✓
White-throated needletail	*Hirundapus caudacutus*	✓	✓	✓
Cattle egret	*Bubulcus ibis (Ardea ibis)*	✓	✓	
Great egret	*Egretta alba (Ardea alba)*	✓	✓	

Regular summer visitors to PWOL include: red-necked stint *Calidris ruficollis,* the endangered Eastern curlew *Numenius madagascariensis,* common greenshank *Tringa nebularia,* bar-tailed godwit *Limosa lapponica,* curlew sandpiper *Calidris ferruginea* Pacific golden plover *Pluvialis fulva* and sharp-tailed sandpiper *Calidris acuminata.*

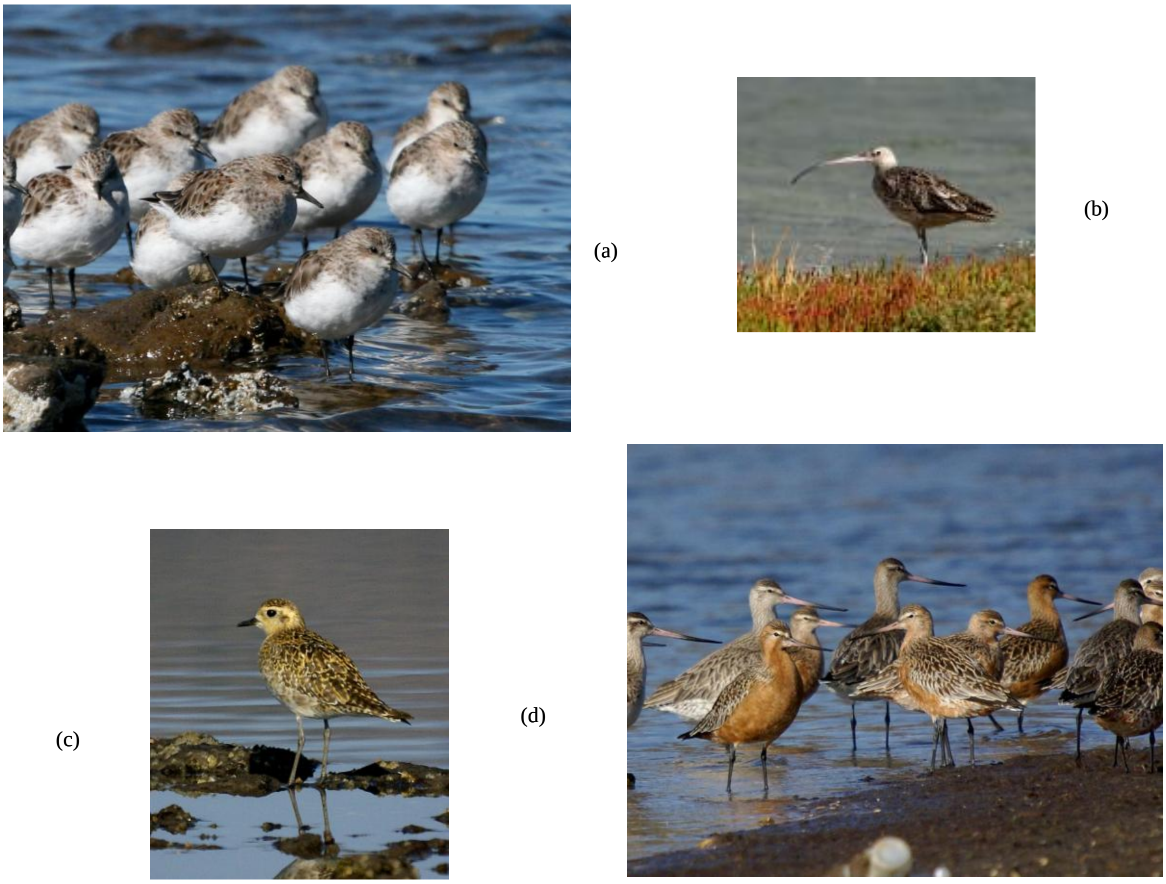


Figure 3.19: Migratory shorebirds at PWOL. (a) Red-necked stint (b) Eastern curlew (c) Pacific golden plover (d) Bar-tailed godwit. (Source: Alan Fletcher)

Figure 3.20 shows the numbers of eight species of migratory shorebirds that most commonly occur in the summer months in PWOL. These records are the sum of the two major sites within PWOL, Barilla Bay and Orielton Lagoon. Since counts are done simultaneously, these figures represent the total numbers visiting the area on the day of the official count.

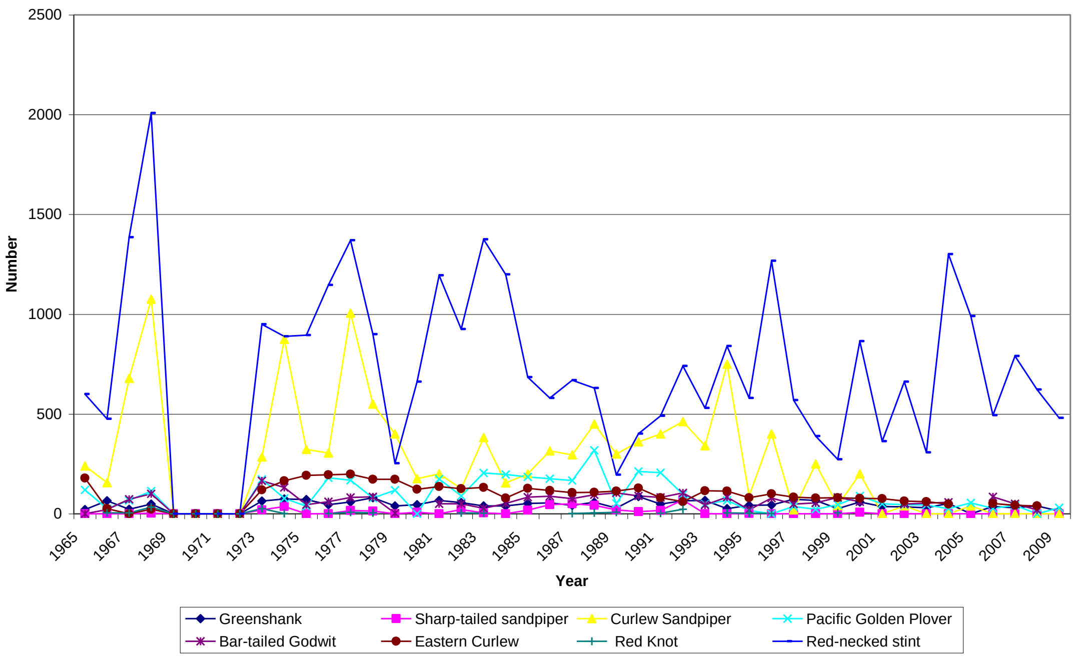


Figure 3.20: Numbers of eight species of migratory shorebirds most commonly occurring at PWOL 1965 – 2009. (Source: Birds Tasmania (2009) Unpublished survey data, Pitt Water Orielton Lagoon Ramsar site, 1964-2009).

Another migrant, the double-banded plover *Charadrius bicinctus*, is a trans-Tasman migrant, breeding in New Zealand in summer and migrating to eastern Australia to over-winter. The double–banded plover occurs in PWOL, using similar areas of the site as the other migratory shorebirds but largely during the winter months.

The shorebirds use several areas within PWOL depending on tidal movements and weather conditions (Figure 3.21, 3.22). They also utilise sites in the wider areas of the Derwent estuary, and movement between PWOL and suitable sites to the southern Derwent estuary is well-established (Aquenal 2008a, c, d; P.Park pers.comm.). No species of bird reaches the numbers threshold of 1% of total population to meet Ramsar Criterion 6. However, Orielton Lagoon has been identified as a priority site for migratory shorebirds for Tasmania and is the most important in the Bruny Marine Bioregion (Bryant 2002).

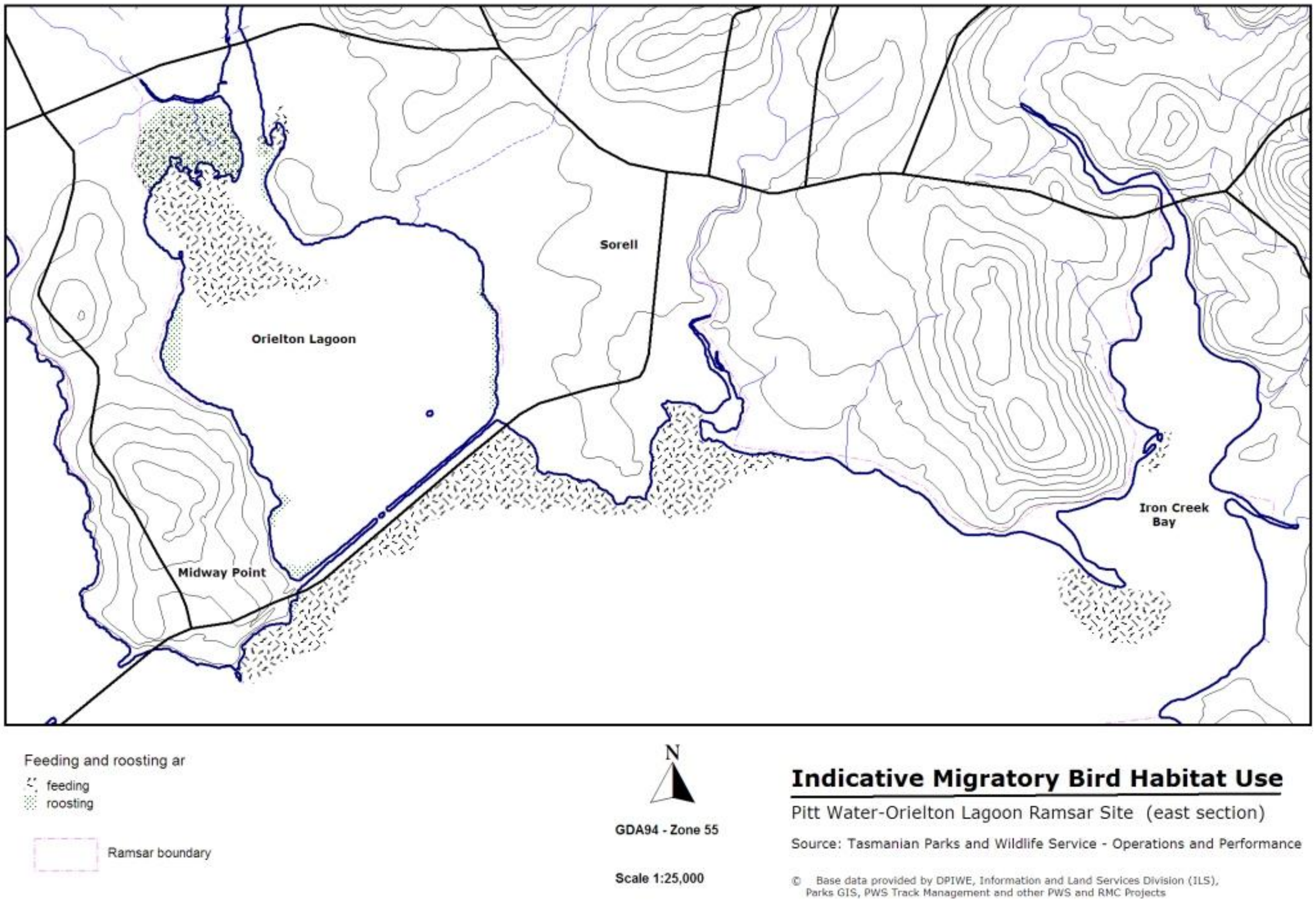


Figure 3.21: Eastern area of PWOL showing indicative areas used by migratory birds. (Source: PWS 2009).

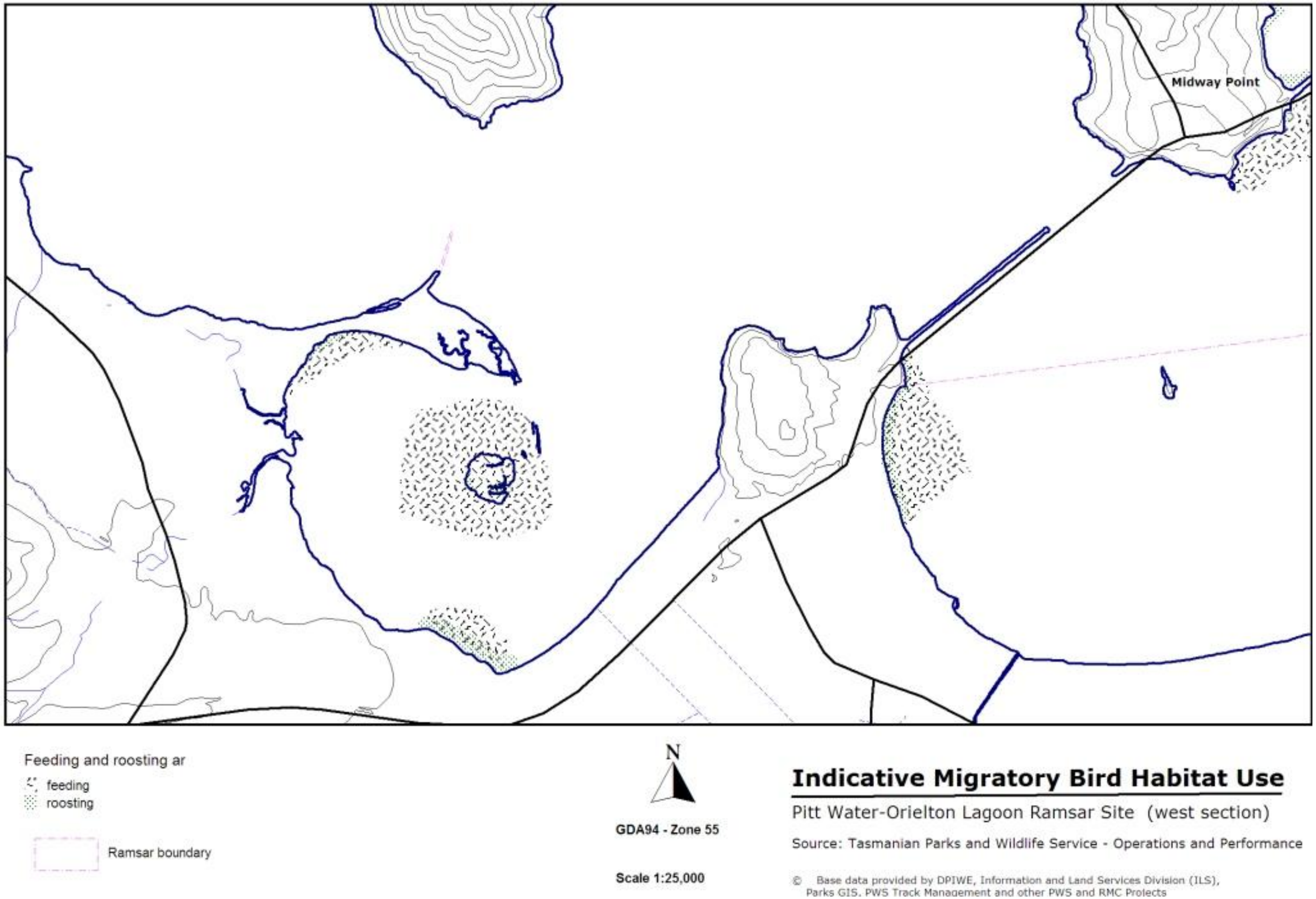


Figure 3.22: Western area of PWOL showing indicative areas used by migratory birds. (Source: PWS 2009).

Several key areas within the Ramsar site, where intertidal flats are exposed at low tide are used by the shorebirds for feeding. Weather and tidal conditions may influence the choice of a feeding site at any given time. At high tide they retreat to roost in sheltered and undisturbed locations, mainly at the head of Orielton Lagoon and corners of Barilla Bay.

Different species favour different areas for feeding and roosting at high tide and these locations have been identified over some 40 years of observation and recording (P Park pers.comm). The commonest migratory species is the red-necked stint, which occurs in both the eastern (Orielton Lagoon) and western (Barilla Bay) areas within PWOL. Three species mostly use the Orielton Lagoon area: the bar-tailed godwit, the endangered eastern curlew and red knot. Red-necked stint exploit the food resources in several areas – the tidal mudflats of Iron Creek, the extensive intertidal flats south of the second causeway at Sorell, Orielton Lagoon and Barilla Bay, especially around the saltmarsh island at the centre of Barilla Bay. Eastern curlew, the largest of the migratory shorebirds, also uses several areas of PWOL including the flats at the spit at the entrance to Iron Creek and the mouth of Sorell Rivulet, as well as throughout Orielton Lagoon. Pacific golden plover and common greenshank tend to be more restricted to Orielton Lagoon intertidal areas while the bar-tailed godwit uses both Orielton Lagoon and Barilla Bay. During winter, a few of the shorebirds of the EAAF, particularly juveniles, remain to feed and roost in PWOL, while double-banded plovers arrive to overwinter in the same general areas.

In summary, Iron Creek is used by red-necked stint and eastern curlew and Sorell Rivulet estuary by eastern curlew. The tidal flats south of the causeway at Sorell are popular for red-necked stints, and other species are reported to gather there from other areas prior to their return migration (P.Park, pers. comm.). Orielton Lagoon attracts all wader species across the intertidal flats around the perimeter and at the head of the bay adjacent to the saltmarshes on both sides of the outflow of Orielton Rivulet. Common greenshanks prefer the western side and southwest corner of the lagoon. Barilla Bay is especially favoured by eastern curlew and red-necked stints (P.Park pers.comm.).

Various sites around the perimeter of PWOL are used for roosting at high tide, the different species tending to have preferential areas and roost in uniform flocks. Common greenshanks occupy the saltmarsh fringe on the unnamed bay on the western side of Orielton Lagoon. Bar-tailed godwits seek out sheltered sandstone slabs which outcrop at Midway Point. Double-banded plovers roost in the south-west corner of Barilla Bay, while Pacific golden plovers roost on fingers of rock extending from the shores on the south-east side of Orielton Lagoon. Many eastern curlew roost on a small spit extending into the lagoon from the shoreline below the sewage treatment plant, along with other species. This is probably a sheltered site under a range of weather conditions.

Shorebirds have somewhat different food preferences (Aquenal 2008c; Harrison 2008). The eastern curlew use its large curved beak to prey on the crab *Paragrapsus gaimardii*, although it also feeds on other types of prey, notably in Orielton Lagoon where *Paragrapsus* was not recorded in the Aquenal survey (Aquenal 2008c). Bar-tailed godwit and other intermediate size waders[2] such as curlew sandpiper (Fig 3.23), greenshank, whimbrel and grey-tailed tattler largely consume polychaetes, although they also take shrimps, crabs and bivalves (Table 3.8). High consumption rates by bar-tailed godwit at Orielton Lagoon suggest that the polychaetes may be small in size compared with other intertidal flats in the PWOL/Derwent estuary area (Harrison 2008).

Figure 3.23: Migratory shorebirds feeding in shallows at Orielton Lagoon: curlew sandpipers and a single red-necked stint (Source; Image by Alan Fletcher)

[2] The term 'shorebirds' is the generally preferred term. However, 'wader' is also commonly used in Tasmania and is adopted where used in cited references to avoid confusion.

Figure 3.24: Red-necked stint feeding on the exposed intertidal flats, Orielton Lagoon. (Source: Image by Alan Fletcher)

The smaller shorebirds, including red-necked stint (Fig 3.24) and the double–banded plover (winter migrant) feed on prey around 5mm in size (Harrison 2008). Such small prey was largely unidentified (possibly Crustacea) but also included amphipods and polychaetes. The invertebrate prey distribution is discussed in Section 3.6.2.

Data from the prey species survey (Harrison 2008c) do not provide a complete picture of potential prey sources for waders and other birds. Crustacea were eliminated from the analysis because the focus of the study was for prey species of oystercatchers. Davies *et al* (2006) found that amphipods dominated the benthic invertebrate community at Orielton Lagoon, although this sampling was undertaken in 1999, after the improvements in tidal flow. Amphipods were found in large numbers in the benthic surveys and are potentially important for small shorebirds (K.Parsons pers.comm). Microscopic animals in the substrate biofilm are another potential food source for small waders (Elner *et al* 2005).

Feeding habits, preferred prey groups and habitats of shorebirds are complex to describe. Within site differences in abundance and diversity of shorebirds may suggest a relationship with prey density and type (Spruzen *et al* 2008) but there is not sufficient evidence to demonstrate such relationships at PWOL.

Table 3.8: Percentages and minimum and maximum sizes of prey consumed by each species of wader in the PWOL and Lauderdale areas. (Source: Harrison 2008 p 67)

	# of surveys	Total # prey	Prey type	% of total prey	Min.(mm)	Max.(mm)
Eastern Curlew	16	70	*P. gaimardii*	97.1	20.0	60.0
			Fish sp.	2.9	100.0	150.0
Bar-tailed Godwit	37	312	Polychaete spp.	90.4	10.0	120.0
			S. biradiata	3.2	19.8	28.8
			Fulvia sp.	1.9	13.8	22.6
			P. gaimardii	2.2	20.0	40.0
			Shrimp sp.	1.3	30.0	40.0
			Fish sp.	0.3	40.0	150.0
			Unknown	0.6	30.0	30.0
Red-necked Stint	22	180	Amphipod	15.6	5.0	5.0
			Unidentified	83.9	5.0	6.0
			Polychaete spp.	0.5	70.0	70.0
Red-capped Plover	18	59	Polychaete spp.	23.7	10.0	30.0
			Amphipod spp.	49.2	5.0	10.0
			M. platycheles	8.5	5.0	5.0
			P. gaimardii	1.7		
			Fly sp.	16.9	5.0	5.0
Sooty Oystercatcher	23	340	Polychaete spp.	73.2	10.0	110.0
			A. cycladea	5.3	10.0	24.0
			K. scalarina	2.1	20.0	20.0
			S. biradiata	3.2	20.0	45.5
			T. deltoidalis	0.3	30.0	30
			M. platycheles	3.8	20.0	20
			S. fragilis	7.7	8.0	15
			M.galloprovincialis	1.5	30.0	30
			Ascidian	2.7	20.0	20
			P. gaimardii	0.3	30.0	30
Double-banded Plover	2	13	Polychaete spp.	38.5	15.0	80.0
			Amphipod spp.	38.5	5.0	5.0
			P. gaimardii	23	8.0	15.0
Curlew Sandpiper	1	2	Polychaete spp.	100	60.0	80.0
Greenshank	1	2	*P. gaimardii*	100	30.0	30.0
Grey-tailed Tattler	3	4	Polychaete spp.	75		
			P. gaimardii	25	20.0	20.0
Whimbrel	3	8	Polychaete spp.	75	50.0	100.0
			P. gaimardii	25	25.0	25.0

3.7.2 Resident shorebirds

PWOL is an important habitat for resident shorebirds, notably pied oyster catchers and red-capped plovers, both of which are listed as 'marine' under the EPBC Act. Pied oyster catchers use a wider range of sites than the generally smaller migratory species. They nest in shorelines on the eastern side of Orielton Lagoon, in the bay north of Shark Point in Upper Pitt Water, on the spit at Railway Point in Barilla Bay and in the north-east and south-west corners of Orielton Lagoon (P Park pers. comm.). Pied oyster catchers also nest in more exposed areas around the site including around Iron Creek estuary and south of the first causeway at Pitt Water Bluff. The adjacent shorelines and intertidal flats provide a food supply and roosting areas (Figs 3.25, 23.26).

Figure 3.25: Pied oyster catchers feeding. (Source: Image by Alan Fletcher)

Figure 3.26: Pied oyster catcher nesting on upper shoreline. (Source: Image by Alan Fletcher)

Red-capped plovers, Fig 3.27 (a), are recorded from Barilla Bay and Orielton Lagoon in all seasons. Red-capped plovers select sheltered sites at Barilla and the northern end of Orielton Lagoon for nesting, roosting and feeding. Masked lapwings, Fig 3.27 (b), are common throughout the site.

(a)

(b)

Figure 3.27: Resident shorebirds of PWOL (a) Red-capped plover (b) Masked lapwing. (Source: Images of Alan Fletcher).

Figures 3.28 and 3.29 show the use of PWOL by resident shorebirds and other non-migratory species. Figure 3.28 shows Orielton Lagoon as being used for widespread feeding for a range of birds, including not only resident shorebirds but also duck, swan, gulls, cormorants and other marine species. Preferred roosting and nesting sites for pied oystercatchers are shown in red.

Resident shorebirds numbers fluctuate between years (Figure 3. 30 and 3.31). These data are counts for Barilla Bay and Orielton Lagoon combined. There appears no correlation between seasonal numbers for any year. Seasonal and annual variations may be influenced by factors beyond the site, particularly for masked lapwing which use a wide range of types of habitat beyond the immediate marine environment.

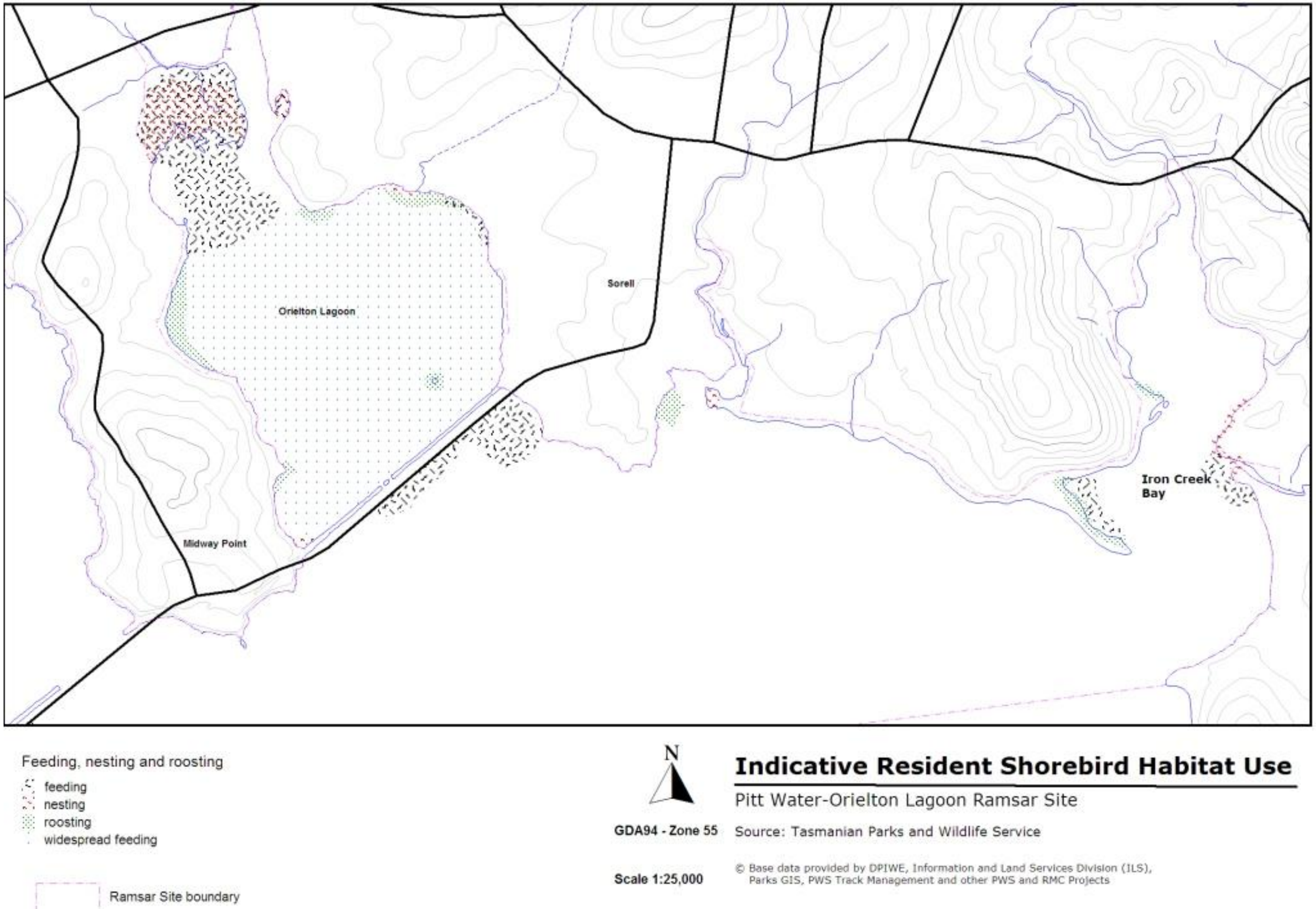


Figure 3.28: Eastern area of PWOL showing indicative areas used by resident shorebirds and others. (Source: PWS 2009).

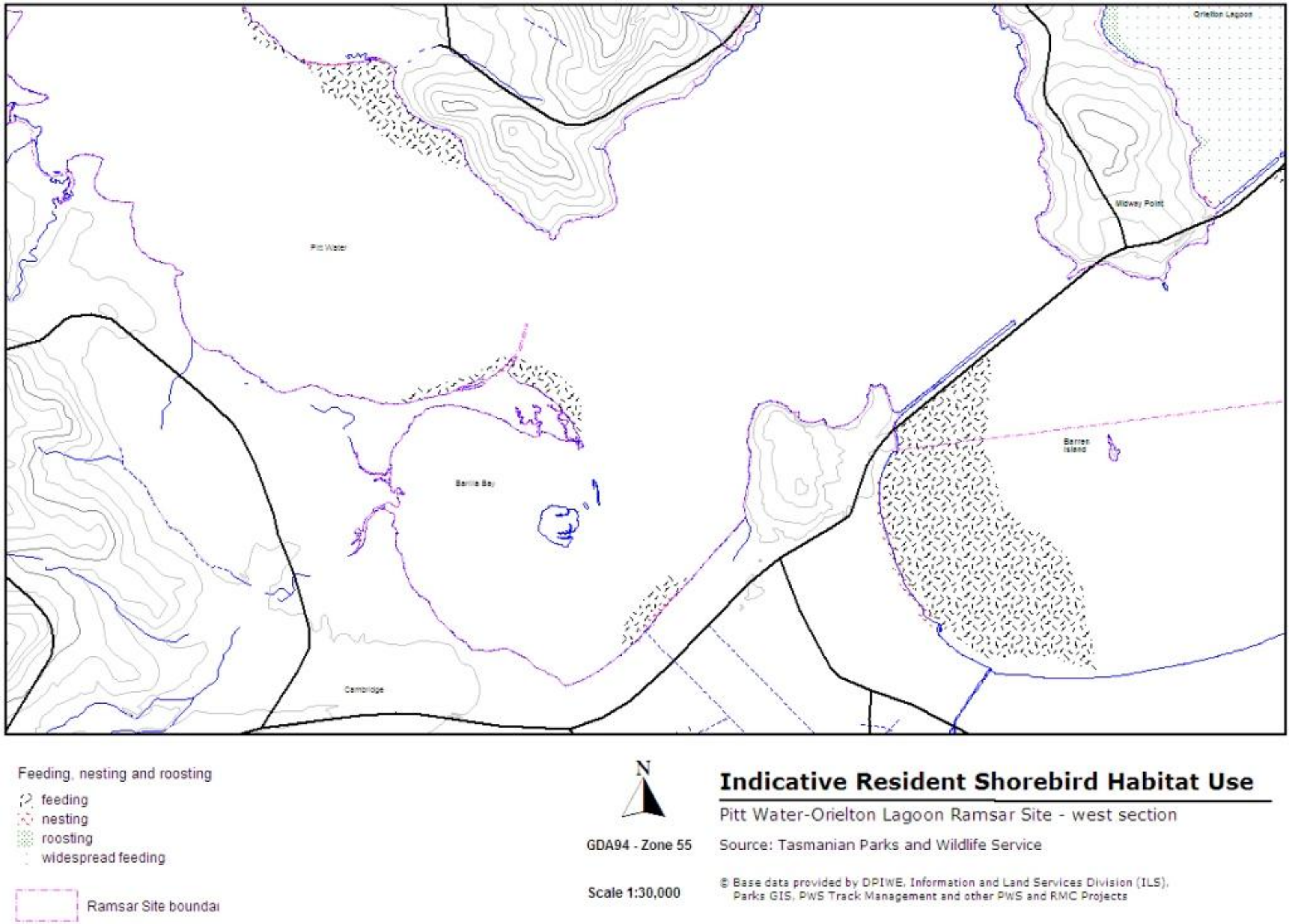


Figure 3.29: Western area of PWOL showing indicative areas used by resident shorebird and others. (Source: PWS 2009).

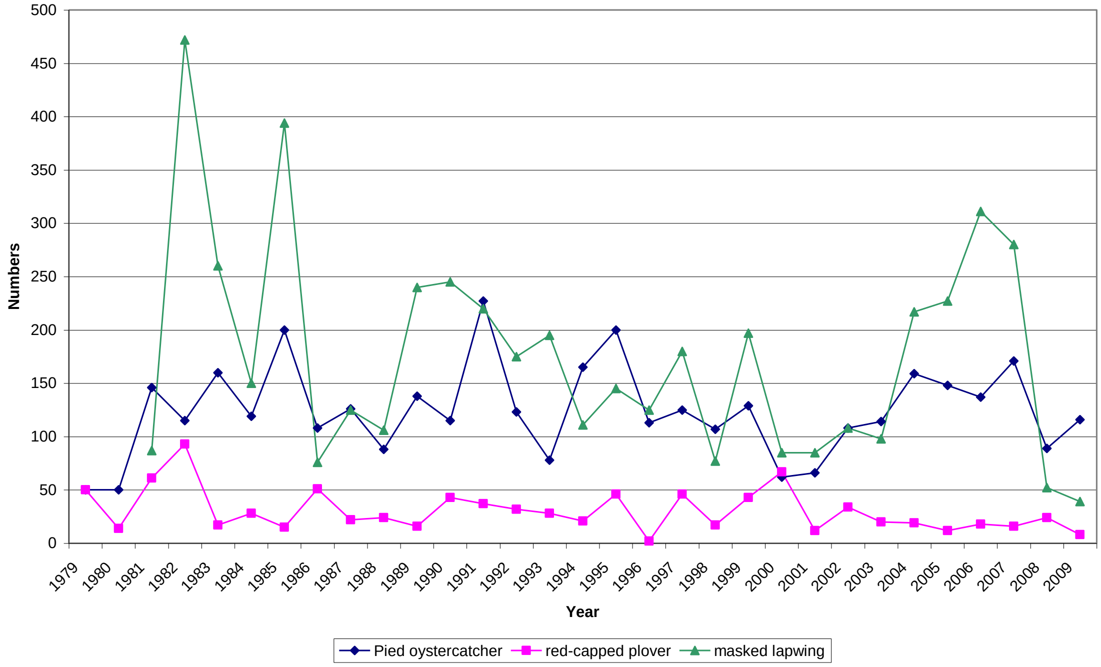


Figure 3.30: Annual counts of resident shorebirds in PWOL – Summer counts 1973 - 2009. (Source: Source: Birds Tasmania (2009) Unpublished survey data, Pittwater Orielton Lagoon Ramsar site, 1964-2009).

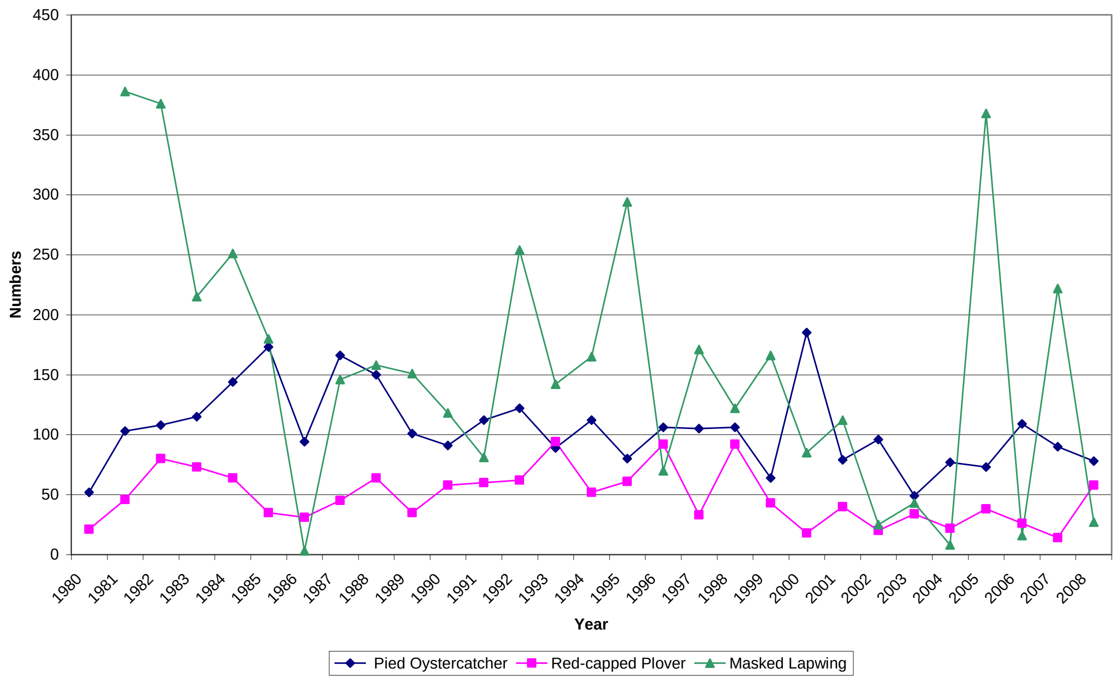


Figure 3.31: Annual counts of resident shorebirds in PWOL – Winter counts 1973 -2009. (Source: Source: Birds Tasmania (2009) Unpublished survey data, Pittwater Orielton Lagoon Ramsar site, 1964-2009).

3.7.3 Waterfowl

In some years, large numbers of ducks and swans apparently use POWL as a refuge at times when dry conditions prevail elsewhere. Orielton Lagoon and the upper estuary around Duckhole Rivulet and Lands End are favoured localities. Numbers vary considerably from year to year. No systematic recording took place prior to Ramsar listing in 1982, though anecdotal evidence suggested that black swan *Cygnus atratus* sometimes nested on Orielton Lagoon and found a rich food source in the seagrass (P.Park pers.comm). Chestnut teal and mountain duck were the most numerous ducks. Figure 3.32 shows numbers of waterfowl from 1985 -2009 collated from annual duck counts (DPIW data, Blackhall pers. comm.).

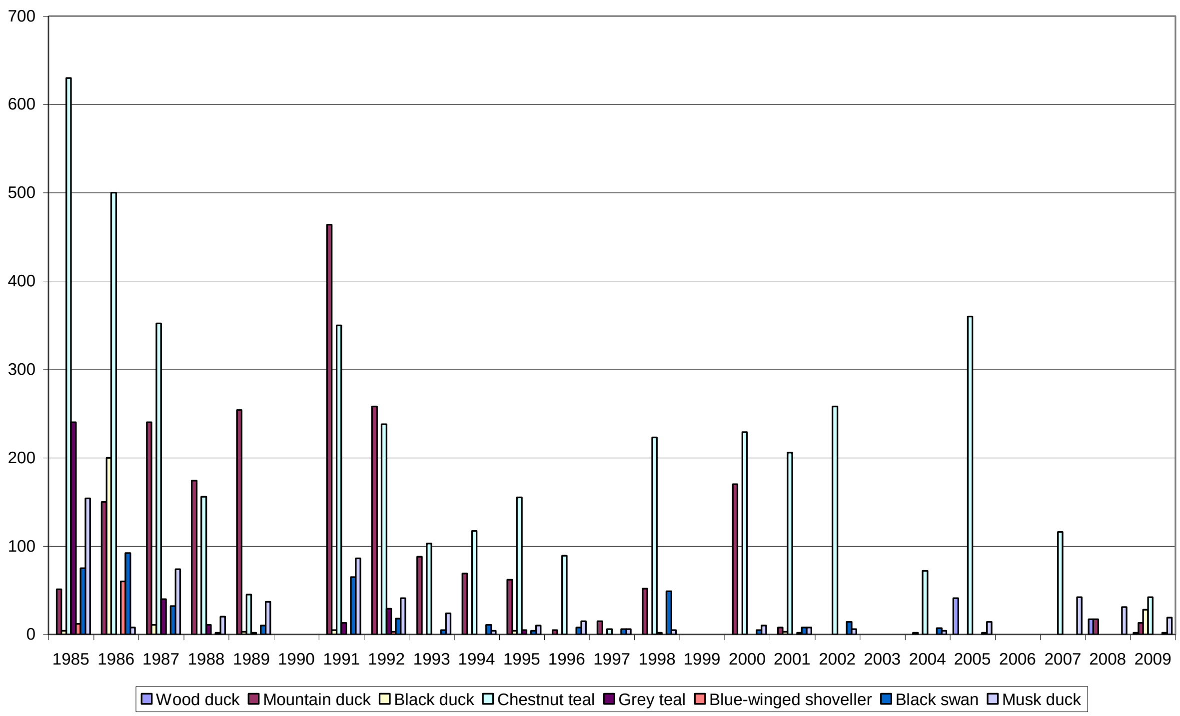


Figure 3.32: Waterfowl counts at PWOL 1985 -2009. (Source: S Blackhall, DPIW annual counts)

Numbers and species vary from year to year. The commonest waterfowl in the area were chestnut teal. The upper reaches of Orielton Lagoon and in the Upper Coal River estuary are important sites for chestnut teal and black swan. Musk duck are more common in the more open water areas of the lagoon near the causeway. Swans nested in considerable numbers on Orielton Lagoon up to the 1970s (P.Park. pers.comm.) But as the seagrass *Zostera* declined with declining water quality, swans no longer used that area.

3.7.4 Seabirds and other species of special interest

Eighteen species of birds listed as 'marine' under the EPBC Act occur within PWOL. Such species are protected in Commonwealth water under the provisions of the Act although they do not constitute values under Ramsar criteria. Listed marine species found at PWOL include: birds of open water near the coasts, such as silver, Pacific and kelp gulls, cormorants and pelicans; birds of the shorelines such as red-capped and double-banded plovers, and birds that range widely across the landscape such as brown goshawk, musk duck, southern boobook and black-faced cuckoo shrike. The swift parrot is EPBC Act and TSPA listed endangered and also noted as 'marine'. This species, which has been recorded at PWOL, breeds in Tasmania close to the coast, migrating to mainland Australia in autumn to over-winter (http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=744).

Three species of gulls are common in PWOL: the Pacific gull *Larus pacificus,* kelp gull *Larus dominicanus* and silver gull *Larus novaehollandiae*. At the time of listing, silver gulls occurred in numbers approximately ten times that of the other two species combined (E.Woehler, pers.comm. Birds Tasmania data June 2009). Silver gulls nest on natural rocky shorelines, islands and the man-made shorelines of the causeways. Kelp gulls, Fig 3.33, have become more numerous in recent years. Cormorants are common, roosting on rocky islands and outcrops. Pelicans and spoonbills are occasional visitors.

Figure 3.33: Kelp gulls. (Source: Alan Fletcher).

The hoary–headed grebe *Poliocephalus poliocephalus* and great crested grebe *Podiceps cristatus* use the Orielton Lagoon area in particular in time of drought, feeding in the intertidal areas and shallow water. The great crested grebe (Figure 3.34) is listed as vulnerable in Tasmania under the *Threatened Species Protection Act 1995*.

Figure 3.34: Great crested grebe at Orielton Lagoon 2009. (Source: Image by Alan Fletcher)

PWOL is an important locality for red-capped plovers. This species feeds on the shores and intertidal flats at similar locations to the migratory species. It nests on the upper shorelines.

The double-banded plover (Figure 3.36) is a migratory species which is the only east-west migratory species in PWOL, nesting in New Zealand and over-wintering in Australia. It occupies similar habitats and uses similar food resources as the other migratory shorebirds during their absence in the winter months. The preferred feeding and roosting areas for double-banded plovers are the intertidal flats and open saltmarshes at the head of Orielton Lagoon and the sheltered bays surrounding Barilla Bay where tidal exposure offers an expanse of mudflat. A few were recorded in summer months in the 1970s but since 1980 numbers have fallen to less than ten in any year. Most of the observations are made in the winter months (Figure 3. 35). Numbers vary from year to year and the total number is generally falling, with few counted in Barilla Bay in the last ten years.

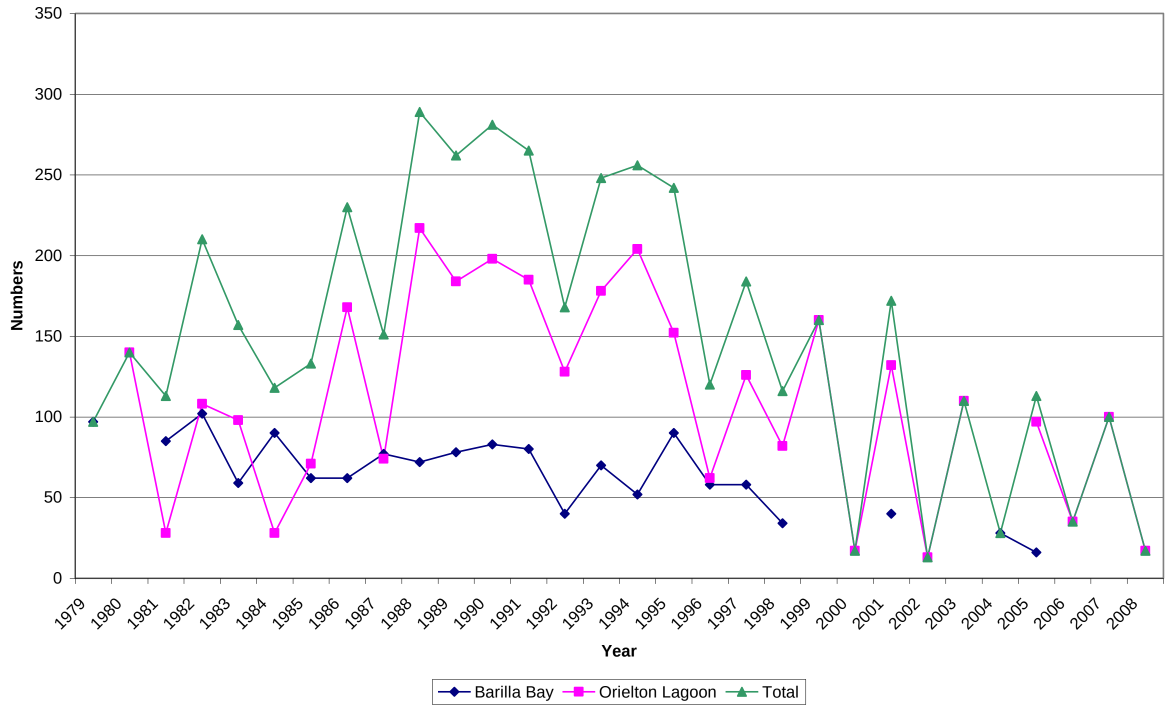


Figure 3.35: Double-banded plover counts for PWOL (winter) 1979 – 2008. (Source: Birds Tasmania (2009) Unpublished survey data, Pittwater Orielton Lagoon Ramsar site, 1964-2009).

Figure 3.36: Double-banded plover. (Source: Image by Alan Fletcher)

Figure 3. 37: Migratory shorebirds at PWOL. Eastern curlew (top) Red-necked stint (below). (Source: Image by Alan Fletcher)

3.8 Saltmarshes

3.8.1 Saltmarsh vegetation communities

Saltmarshes are typical fringing vegetation communities along the shorelines of wave dominated estuaries. These communities are an important connection or bridge between the aquatic and terrestrial environments and exhibit tolerance to fluctuation in salinity and degrees of exposure and dehydration. Saltmarshes form a critical component of PWOL, not only for their biological values but also in the roles which they play in sedimentary processes and hydrology of the shoreline.

Areas of saltmarsh occur extensively around the shoreline of Pitt Water estuary and Orielton Lagoon (Figure 3.38). Marshes line the shoreline of the estuary towards the mouth of the Coal River but being above high water mark, they lie outside the Ramsar boundary. However, the entire suite of marshes demonstrates and contributes to the ecological character of the PWOL estuarine wetland ecosystem. Several marshes and two marshy islands lie within the Ramsar boundary (Figure 2.13).

Detailed mapping of the saltmarsh communities of Pitt Water undertaken in the 1970s (Glasby 1975, Kirkpatrick and Glasby 1982) provides a likely picture of those saltmarsh communities within the PWOL Ramsar site near the time of listing in 1982. Details of the survey, including the full legend of vegetation communities, are given in Appendix 4. Figures 3.39 – 3.43 show the vegetation communities for some saltmarshes lying within the Ramsar boundary.

The saltmarshes exhibit different floristic community facies controlled by topography, salinity, inundation, hydrology and drainage patterns. Some saltmarsh units are dominated by low-growing succulent saltmarsh species (*Sarcocornia* spp), a few are largely shrubby dominated by *Tecticornia arbuscula* (formerly *Sclerostega arbuscula).* Species tolerant of low salinity such as *Juncus krausii* may fringe the landward edge of saltmarsh or on a saltmarsh dune face. Such communities also extend on the shoreline at the upper limits of the estuary near Richmond. Saltmarshes within the site boundary include two islands, one in the mouth of the Coal River (Samphire Island), the other an unnamed island in Barilla Bay.

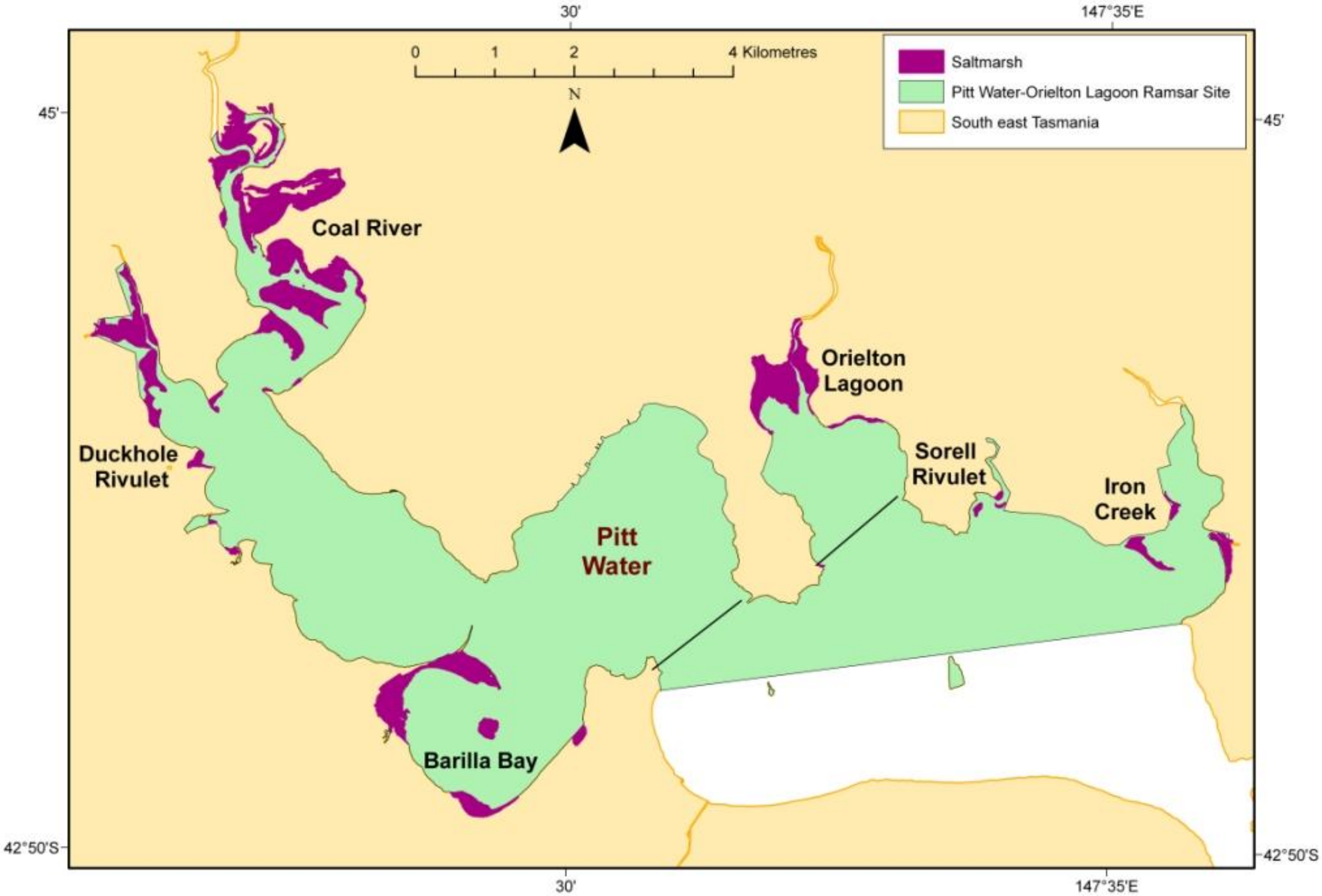
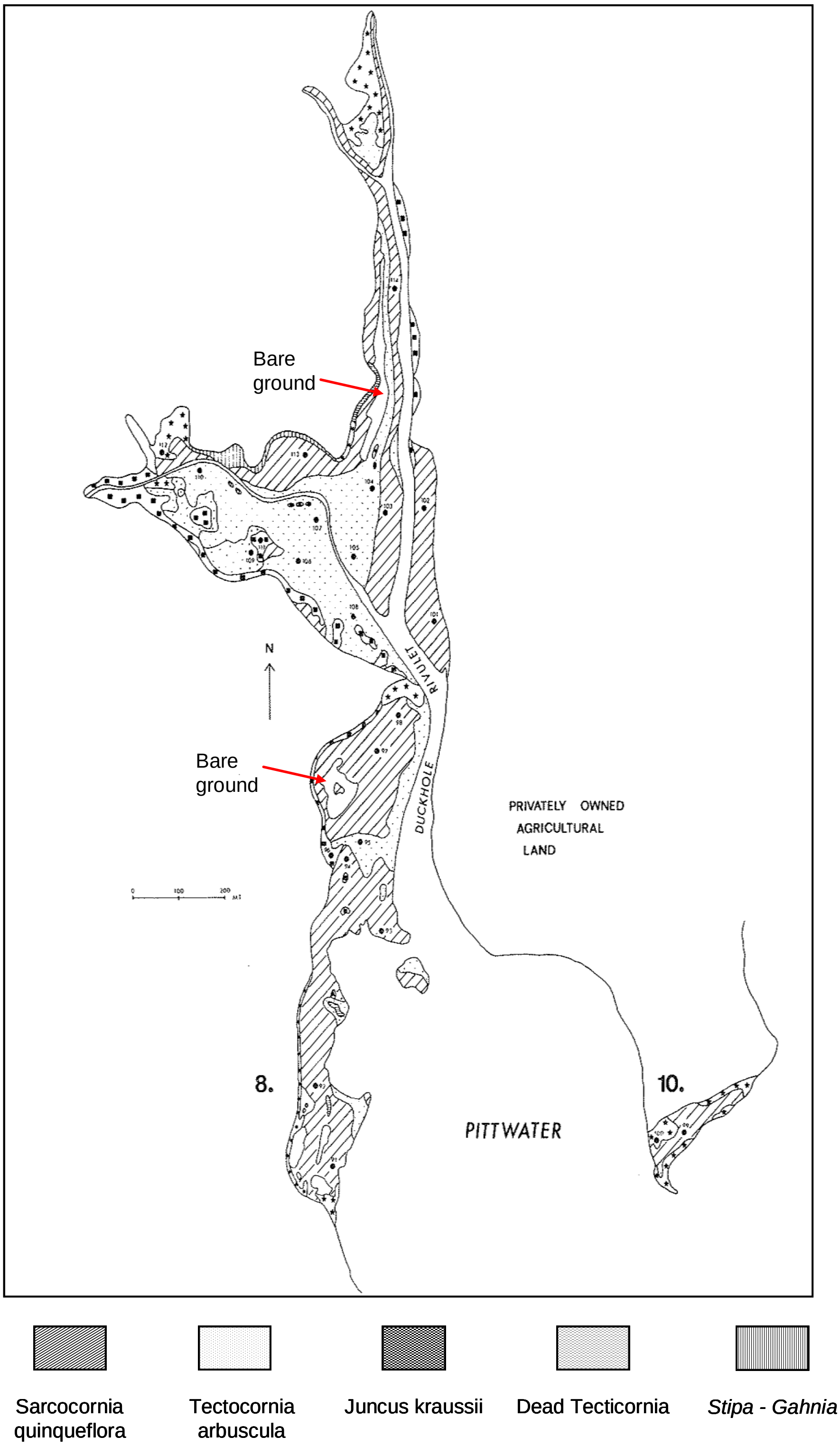


Figure 3.38: Saltmarshes within the Pitt Water estuary system. (Source: Datum GDA94 UTM Zone 55, created by V.Prahalad, University of Tasmania, based on LIST).



Note: Complete key to vegetation communities provided in Appendix 4

Figure 3.39: Dominant vegetation communities at Duckhole Rivulet. (Source: After Kirkpatrick and Glasby 1981)

(a)

(b)

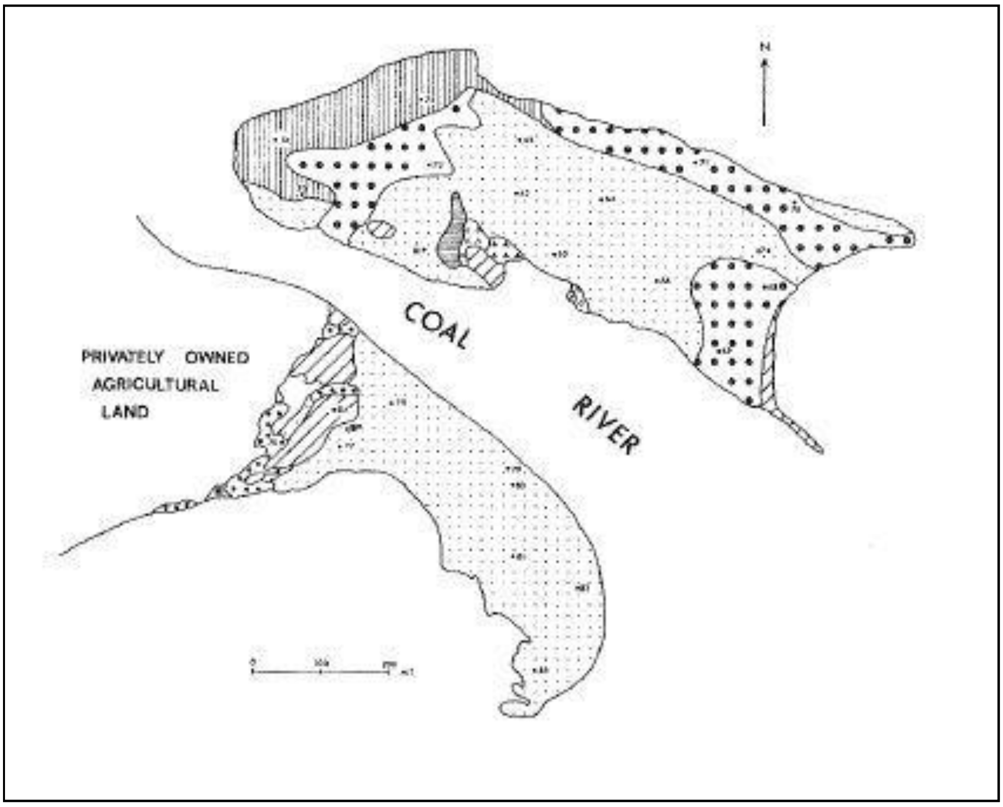
(c)

Figure 3.40: Duckhole Rivulet saltmarshes (a) aerial oblique looking north west (b) *Sarcocornia* community (c) *Tectocornia* community. (Source: (a) Hydro Tasmania Consulting 2006, (b) and (c) H.Dunn April 2009)

Saltmarshes (Figure 3.39) line the shorelines of Duckhole Rivulet and other small creeks on the western bank of Upper Pitt Water. The vegetation is mostly disposed in zones dominated by *Tecticornia* or *Sarcocornia* with *Juncus kraussii* on the landward edges.

Two areas of bare ground are noted. Such salt pans occur where saline groundwater, poor drainage and compaction inhibit vegetation growth. Figure 3. 40 shows the general features of this saltmarsh.

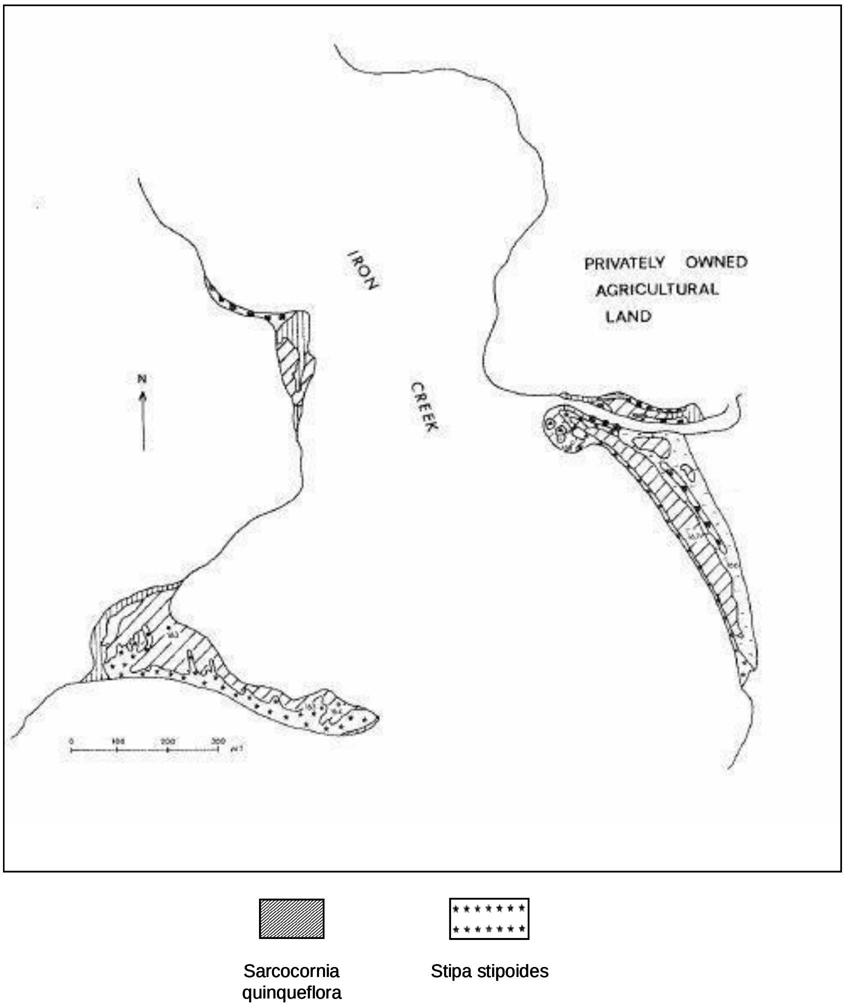
Samphire Island lies in the channel of the Coal River towards the head of the estuary. The outer areas of the island are dominated by saline sedges and rushland species which are less tolerant of high salinity and tidal influences whereas the central and southern shore (downstream) are shrubby saltbushes *Tecticornia* (Figure 3.41). The island in Barilla Bay is almost entirely vegetated with *Tectocornia*.



Key – See Figure 3. 39 above.

Figure 3.41 Saltmarsh communities on Samphire Island and Stinking Point. (Source: Kirkpatrick and Glasby 1981)

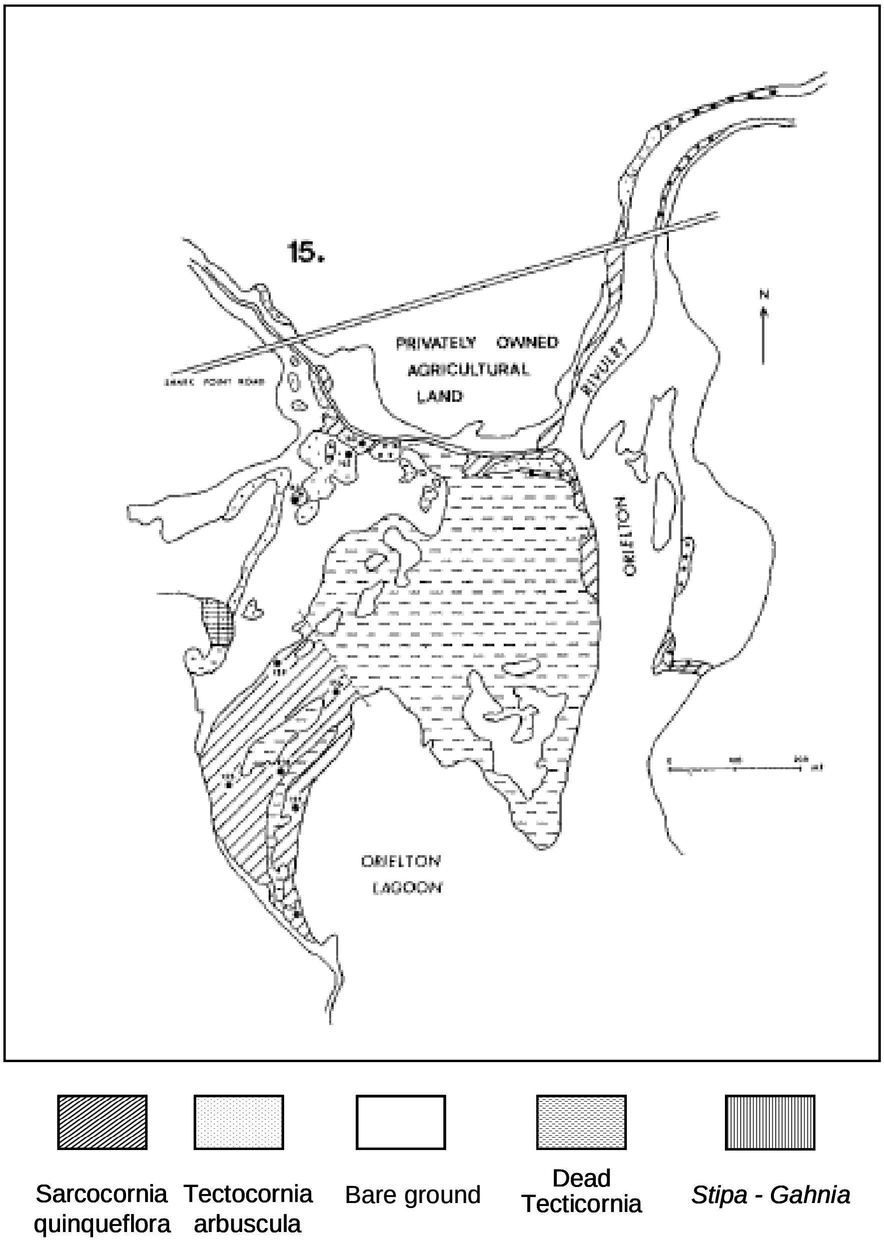
The saltmarshes at the mouth of Iron Creek (Figure 3.42) face in a southwesterly direction and are more exposed to winds and tides. The spit has a stand of *Austrostipa stipoides* on the leading face where sand has built up on the shoreline. Behind this, *Sarcocornia* dominates the low groundcover.



Note: See Figure 3.39 for key to other vegetation communities

Figure 3.42: Saltmarshes at the mouth of Iron Creek. (Source: Kirkpatrick and Glasby 1981).

The largest area of saltmarsh within PWOL lies at the head of Orielton Lagoon (Figure 3.43). At the time of Glasby's survey, this saltmarsh was in a poor condition as a result of manipulation of the lagoon's hydrology. Much of the area was open bare ground, the result of freshwater inundation a few years earlier. Lasting a period of around two weeks, this was sufficient to kill off the *Tecticornia* with which the marsh had previously been covered. Further damage ensued when the area was fired.



Note: See Figure 3.39 for key to other vegetation communities

Figure 3.43: Saltmarsh communities at Orielton Lagoon. ((Source: Kirkpatrick and Glasby 1981).

3.8.2 Critical rare and threatened saltmarsh flora

At the time of listing, five species of plants of the saltmarsh or saltmarsh fringes were considered threatened in Tasmania. The daisy known as the lemon beauty-head *Calocephalus citreus* is listed as rare under the *Threatened Species Protection Act 1995* (TSPA). It is found in dry grasslands and extends onto the landward edges of graminoid saltmarshes, notably at Orielton Lagoon and Duckhole Rivulet as well as other sites around PWOL. The silky wilsonia *Wilsonia humilis* (TSPA – rare) is a true saltmarsh species, forming extensive mats of a rather woody creeper on better drained but saline areas at Iron Creek, Duckhole and Barilla Bay (Figure 3.44). There are also significant populations of sea lavender *Limonium australe* (TSPA– rare) present in the upper areas of the marsh.

Figure 3.44: Saltmarsh species of conservation value at PWOL. (Source: H.Dunn 2009).

Two more aquatic species, slender water-mat *Lepilaena preissii* and fennel pondweed *Stuckenia pectinata* (both listed as rare under the TSPA) have been recorded from Orielton Lagoon. These two species are characteristically found in slightly brackish sites. It is not clear if the present hydrology of the lagoon still provides suitable habitat for these species.

Salt lawrencia *Lawrencia spicata* was also present in 1981 and was being considered for listing under the TSPA at the time. It is now known to be widely distributed although localised throughout coastal areas of the state.

Other species listed as rare under the TSPA which are known from sites adjacent to the Ramsar boundary and are likely to occur within it in marginal saltmarsh areas are *Austrostipa scabra*, *Cynoglossum australe*, *Vittadinia gracilis* and *Vittadinia muelleri*.

3.8.3 The significance of the PWOL saltmarshes

The region contains one of the most significant areas of saltmarsh in Tasmania (Kirkpatrick and Glasby 1981). The saltmarshes are critical components of the ecological character of the site. There are extensive and diverse areas of saltmarsh, of which several locations are relatively isolated from human disturbance. Most of the saltmarsh communities and species of Tasmania occur in the Pitt Water area and all but one of the poorly reserved saltmarsh species is abundant within the Ramsar site.

Pitt Water Nature Reserve is the only formal public reserve in which *Wilsonia humilis* occurs. It occurs in a number of private conservation covenants. *Lepilaena preissi* is found in at least five reserves and *Stuckenia pectinata* (syn. *Potamogeton pectinatus*) and *Limonium australe* are each found in only three reserves in Tasmania. All but one of the poorly reserved saltmarsh species in Tasmania occur in abundance within the reserve. Six species of threatened bryophytes also occur within the reserve.

Saltmarshes host a diverse invertebrate fauna. They provide cover, roosting areas and food for foraging birds and even small mammals. The saltmarshes of PWOL have particular significance for the migratory and resident shorebirds which forage and roost in these areas.

Section 4 Summary of critical components and processes and conceptual models

This section provides models of the Pitt Water estuary to demonstrate the hydro-geomorphic context for the areas within the Ramsar boundary. Critical components and processes are then summarized in tabular form and in conceptual diagrams for Upper Pitt Water and Orielton Lagoon. The relationship between critical ecosystem services and critical components and processes was summarized in section 3.1.2, Table 3.3.

4.1 Conceptual models for the Pitt Water estuary

These models are based on templates provided in Ryan *et. al* (2003). Process descriptions related to the graphic conceptual models have been modified to reflect conditions in the PWOL Ramsar site.

Characteristics of the Pitt Water - Orielton estuary

- A diverse range of both marine and brackish, sub-tidal, intertidal and supra-tidal estuarine habitats are supported.
- Narrow entrance restricts marine flushing, but a high water volume is exchanged at each tide.
- River flow generally low. Since construction of Craigbourne Dam, very few flushing events occur in Pitt Water, from the Coal River. Orielton Rivulet floods periodically, however this has little flushing effect on the estuary, as Orielton Lagoon backfills due to narrow culverts in the causeway.
- Turbidity, in terms of suspended sediment, is naturally low except during high wind or fluvial runoff events.
- Central basin is an efficient 'trap' for terrigenous sediment and pollutants.
- Long sediment residence time encourages trapping and processing (e.g. denitrification) of terrigenous nutrient loads (however inputs from the Coal River are now minimal).
- 'Semi-mature' in terms of evolution: morphology will change over time due to infilling (particularly in Orielton Lagoon) resulting in shallowing of the central basin and on-going terrestrialisation of littoral flats. In Pitt Water the major sediment source has changed

from the Coal River catchment to more local sources associated with tunnel erosion depositing sediment on the shoreline and bank erosion of the foreshore.

Key processes in hydrodynamics, sediment dynamics and nutrients are described below.

PITT WATER-ORIELTON LAGOON WAVE-DOMINATED ESTUARY: HYDRODYNAMICS (Negative conditions)

1. Freshwater enters from the catchment. Whilst inputs from the Coal River, Orielton Rivulet and Iron Creek are typically low, significant dilution of brackish water occurs in Orielton Lagoon due to backfilling above the causeway during floods. Little flushing now occurs from the Coal catchment since construction of Craigbourne Dam.

2. The volume of freshwater entering the estuary is often too low to cause significant stratification, however temporary stratification may occur following episodic flood events.

3. High evaporation rates result in moderately elevated salinity in Orielton Lagoon,; this is likely to be less pronounced in Pitt Water. This produces hyper-saline water that sinks beneath the intruding sea water. A small amount of mixing occurs between the stratified layers.

4. Exchange of sea water and estuarine water occurs through the entrance of the estuary, although this is reduced by the length of the entrance channel. In 'negative' wave-dominated estuaries, such as is usual here, the inflow of marine water exceeds the outflow of freshwater. In such cases, the hyper-saline water is usually exported to the ocean. The entrance of the estuary is continually open.

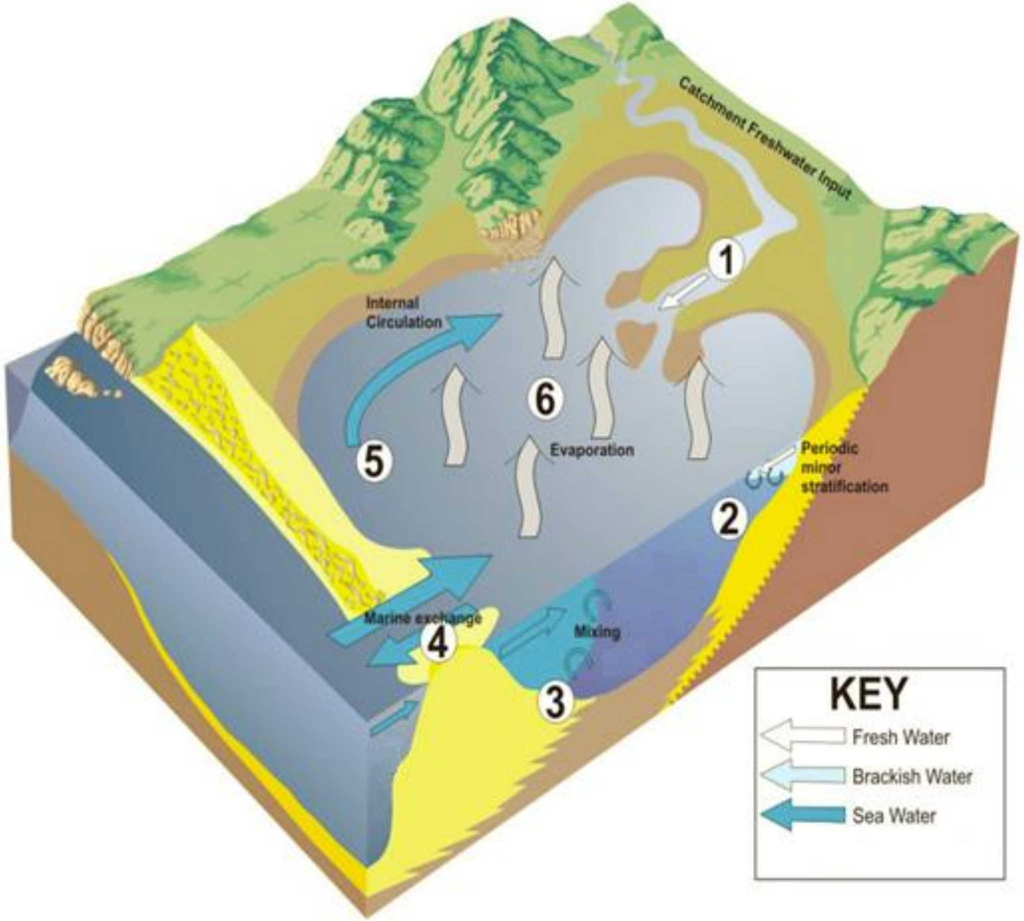


Figure 4.1: PWOL wave-dominated estuary: hydrodynamics. (Source I.Houshold modified from OzCoasts http://www.ozcoasts.org.au/conceptual_mods/geomorphic/wde/wde_neg_hydro.jsp)

5. Wind-induced currents affect internal circulation. Secondary circulations can be generated by tides. However, tidal ranges are small compared to those in the ocean. Internal circulation patterns are disrupted during high-flow events.

6. Evaporation is an important process, due to generally dry climatic conditions. Aridity and evaporation may vary seasonally, however in Pitt Water-Orielton Lagoon, evaporation is often greater than freshwater input. Residence time is long, as compared with tide-dominated estuaries.

PITT WATER-ORIELTON LAGOON WAVE-DOMINATED ESTUARY: SEDIMENT DYNAMICS

1. Fine sediment enters the estuary from Coal River, Orielton Rivulet and Iron Creek, although flows (and hence sediment flux) have decreased significantly since construction of Craigbourne Dam. As much of the catchment is underlain by Tertiary clays, little coarse material reaches the estuary from this source. Groundwater flows (enhanced by land clearance) may cause tunnel erosion in tertiary sediments and deposition of fine materials on tidal flats.

2. Fine sediment (i.e. silts and clays) is deposited at the head of the estuary forming a fluvial bay-head delta on the Coal River. Progradation is likely to have slowed significantly since dam construction. Terrigenous sediment from the Orielton catchment is mostly deposited in OL, due to backflooding caused by the causeway.

3. Fine sediment is eroded from foreshores, by both tidal and fluvial currents, and wind waves. Banks underlain by Tertiary sediments are particularly vulnerable. Subsequent deposition in these environments is aided by the baffling effects of vegetation such as saltmarshes. Biological activity and waves cause significant reworking of fine sediment on un-vegetated intertidal flats.

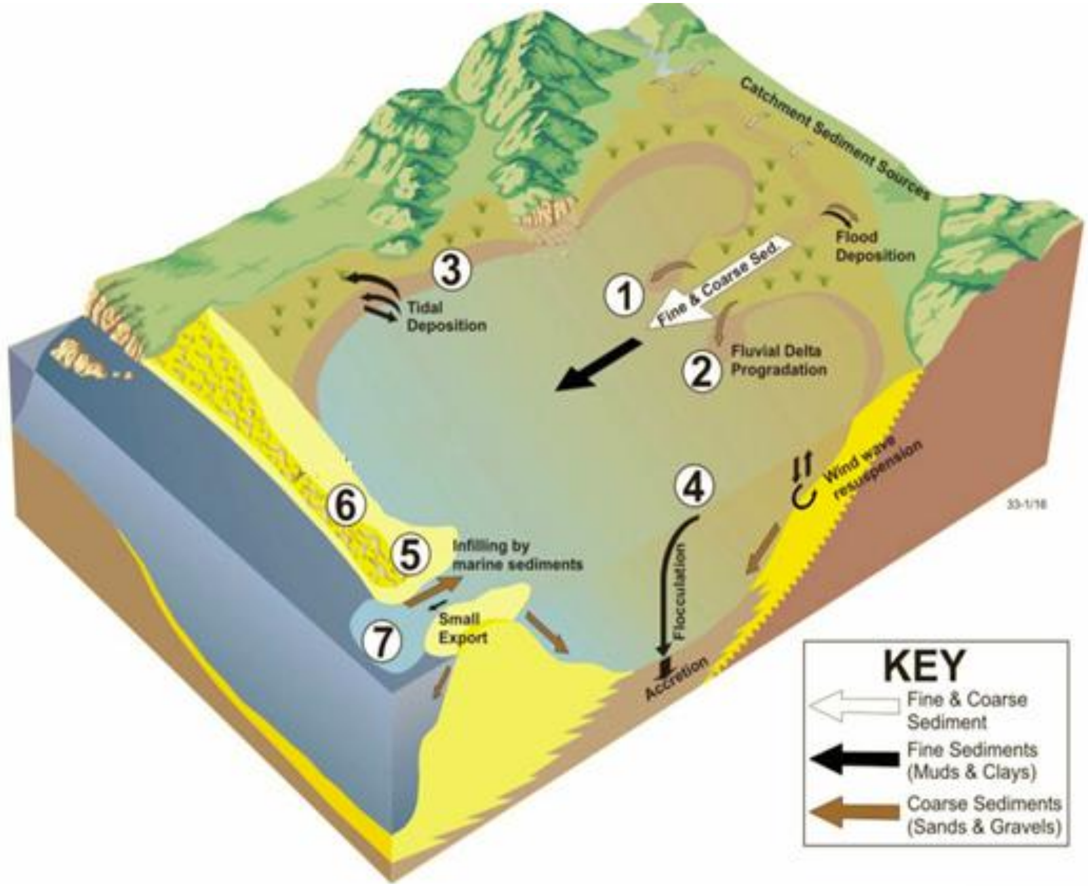


Figure 4.2: PWOL wave-dominated estuary: sediment dynamics. (Source I.Houshold modified from OzCoasts http://www.ozcoasts.org.au/conceptual_mods/geomorphic/wde/wde_sed_trans.jsp)

4. Suspended sediment is transported into the central basin, where it is deposited in a low energy environment. Deposition is most active in Orielton Lagoon. Flocculation is also an important process that allows fine particles to settle out from the water column. Benthic micro-algae (BMA) assist in the stabilisation of fine sediment. The low-energy conditions and large relative size of the central basin means that this region is the primary repository for fine material and particle-associated contaminants. Re-suspension of the fine sediment by wind-waves occurs in shallower margins, causing turbidity.

5. Tidal currents are locally accelerated in the constricted entrance, and form well-developed flood and ebb tidal deltas in Pitt Water. Sedimentary processes are dominated by the landward transport of coarse sediment derived from the marine environment. Sediment can be exported to the ocean through the inlet, particularly during spring tides and rare flood events.

6. Coarse marine sediment is driven along the coast by strong wave energy and is deposited as a supra-tidal (subaerial) barrier. Marine sediment is transported into the estuary by aeolian, tidal, and wave processes. The barrier at Seven Mile Beach is too high to allow any washover deposits to reach Pitt Water.

7. The sediment trapping efficiency of Pitt Water is moderately high, however Orielton Lagoon is a particularly efficient sediment trap, which may capture up to 80% of fine material. Infilling by marine sand transported through the entrance is moderately active, as shown by the large flood-tide delta in Pitt Water.

PITT WATER-ORIELTON LAGOON WAVE DOMINATED ESTUARY: NUTRIENT DYNAMICS

1. Nitrogen (both particulate and dissolved, or Total Nitrogen (TN)) enters the estuarine system from point and non-point sources, from within the catchment. Similar to other southern Tasmanian estuaries, significant nitrogen is also input from Southern Ocean sources, particularly in winter when the effects of the warm east Australian current are reduced. River flow and nutrient input vary seasonally and episodically. The input of catchment-derived nutrients into the estuary may be significant in Coal river floods due to intensive upstream agriculture, however these events are now rare.

2. Input of particulate N (PN) from atmospheric sources such as smoke and ash are probably low-moderate, due to isolation from forested areas.

3. Dissolved inorganic nitrogen (DIN) is transported into the central basin, with biological uptake by phytoplankton and macrophytes occurring along the way. The balance between planktonic and benthic primary productivity may depend on catchment nitrogen loads and connectivity with the estuary. Figure 3. 47: PWOL wave-dominated estuary: nutrient dynamics. (Source I.Houshold)

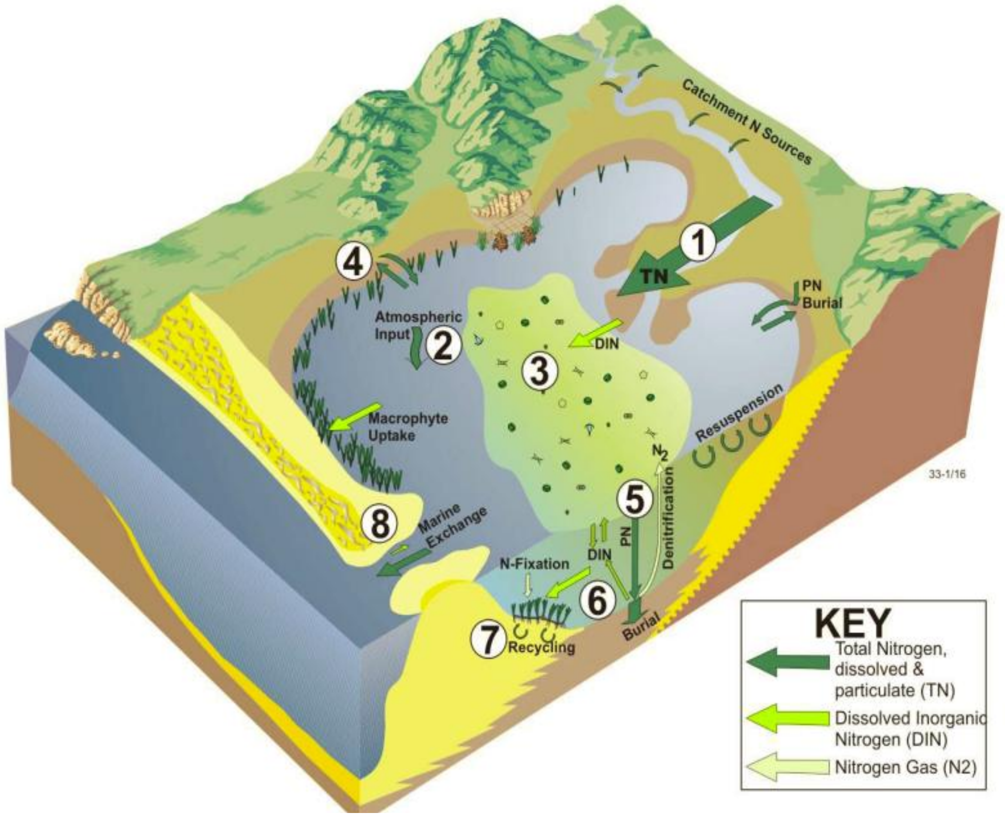


Figure 4.3: PWOL wave-dominated estuary: nutrient dynamics. (Source I.Houshold modified from Ozcoasts: http://www.ozcoasts.org.au/conceptual_mods/geomorphic/wde/wde_nit_dynamics.jsp)

4. Some deposition and burial of PN occurs on flanking environments, due to the baffling effect of saltmarsh vegetation. Burial and re-suspension of PN and DIN can also occur within intertidal flats. Some PN may be deposited and buried within the fluvial delta.

5. PN is deposited in the sediment as phytoplankton debris.

6. Decomposition of organic matter within the sediment produces DIN (potentially available for further plant/phytoplankton growth). Denitrification within the sediment converts nitrate (NO_3^{2-}) to N_2 gas, which escapes from the system to the atmosphere. Some of the particulate nitrogen (PN) deposited into the sediment of the central basin is buried.

7. Seagrasses take up DIN from the water column and from the sediment pore-waters. The pore-water DIN is derived from the metabolism of phytoplankton, seagrass and other organic matter debris. Seagrass debris is, therefore, in part "recycled" back to the plants. N-fixation (incorporation of atmospheric N_2 to form nitrogenous organic compounds) occurring in the root-zone contributes additional DIN to this pool. Denitrification is also an important process in seagrass meadows. Sandy sediment is permeable, hence can be ventilated by oxygen rich overlying waters resulting in efficient remineralisation of organic debris (mostly by denitrification) with little preservation of organic matter.

4.2 Critical components and processes

Table 4.1 summarises the critical components and processes for each of the two major areas of PWOL. These reflect the situation at the time of listing in 1982.

The conceptual models presented in Figures 4.1, 4.2 and 4.3 illustrate the hydrological and geomorphological components and processes of the Pitt Water estuary as a whole. This barred wave-dominated estuary, although not entirely enclosed within the Ramsar boundary, sets the environmental context in which all the components and processes of the Ramsar site function. The models show the features and processes of the estuary as it would have been under natural conditions, prior to the construction of the causeways in 1874. The artificial barrier to tidal exchange into the upper reaches of the estuary at the mouth of the Coal River and the embayment later known as Orielton Lagoon modified the natural estuarine processes. This factor, coupled with the effects of land clearance on sediments and flows in the inflowing streams and rivers, modified the natural estuary.

At the time of listing, the components and processes within the Ramsar boundary area of the Pitt Water estuary had been modified. Table 4.1 lists the key components and processes in each of two main areas of the site where these changes were likely to have had an impact. Some of these components and processes have been subject to change since listing (see Section 6). The components and processes are summarised in Figures 4.4. and 4.5.

Table 4.1: Summary of key components and processes at Upper Pitt Water and Orielton Lagoon.

<table>
<tr><th>Component</th><th>Sub-component</th><th>Features and processes</th><th>Features and processes</th></tr>
<tr><td></td><td></td><td>Upper Pitt Water</td><td>Orielton Lagoon</td></tr>
<tr><td>Climate</td><td>Rainfall</td><td colspan="2">Low and variable</td></tr>
<tr><td></td><td></td><td colspan="2">Cool temperate climate</td></tr>
<tr><td></td><td></td><td colspan="2">Exposed to NW and SW winds</td></tr>
<tr><td>Hydrology</td><td>Estuary type</td><td>Wave-dominated estuary</td><td></td></tr>
<tr><td></td><td></td><td>Shallow estuary with marked tidal channels</td><td>Shallow water body ,1.5m</td></tr>
<tr><td></td><td>Tidal exchange</td><td>Large tidal exchange</td><td>Limited tidal exchange</td></tr>
<tr><td></td><td>Freshwater inflow</td><td colspan="2">Low</td></tr>
<tr><td></td><td>Stream flow</td><td colspan="2">Often ceases in summer months</td></tr>
<tr><td></td><td>Groundwater inputs</td><td colspan="2">Low</td></tr>
<tr><td>Water quality</td><td>Salinity</td><td>Dominantly marine</td><td>Variable - near fresh to hypersaline</td></tr>
<tr><td></td><td>Nutrient levels</td><td>Low</td><td>High</td></tr>
<tr><td></td><td>Coliforms</td><td>Low</td><td>High</td></tr>
<tr><td></td><td>Chlorophyll levels</td><td>Low</td><td>High</td></tr>
<tr><td></td><td>Water temperature</td><td>Stable marine</td><td>Varies diurnally and seasonally</td></tr>
<tr><td>Geomorphology</td><td>Geomorphic type</td><td>Drowned valley</td><td>Artificially enclosed lagoon</td></tr>
<tr><td></td><td>Intertidal flats</td><td colspan="2">Extensive</td></tr>
<tr><td></td><td></td><td>Complex sandbanks, ridges and bars</td><td></td></tr>
<tr><td></td><td></td><td>Sediment movement controlled by tidal movement</td><td>Limited sediment movement</td></tr>
<tr><td></td><td>Sediment source</td><td colspan="2">Largely from shoreline erosion</td></tr>
<tr><td>Littoral vegetation</td><td></td><td colspan="2">Saltmarshes</td></tr>
<tr><td>Submerged vegetation</td><td></td><td colspan="2">Seagrass beds</td></tr>
<tr><td>Invertebrates</td><td></td><td colspan="2">Interstitial fauna of intertidal flats</td></tr>
<tr><td></td><td></td><td colspan="2">Saltmarshes</td></tr>
<tr><td></td><td></td><td>Benthic fauna</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Fauna of rocky shorelines</td></tr>
<tr><td>Fish</td><td></td><td>Estuarine fish community</td><td></td></tr>
<tr><td></td><td></td><td>Breeding area for shark</td><td></td></tr>
<tr><td>Birds</td><td></td><td colspan="2">Migratory shorebirds</td></tr>
<tr><td></td><td></td><td colspan="2">Resident shorebirds</td></tr>
<tr><td></td><td></td><td colspan="2">Waterbirds, seabirds</td></tr>
<tr><td></td><td></td><td colspan="2">Feeding areas, nest sites, roosting sites</td></tr>
<tr><td></td><td></td><td colspan="2">Refuges in timess of drought</td></tr>
</table>

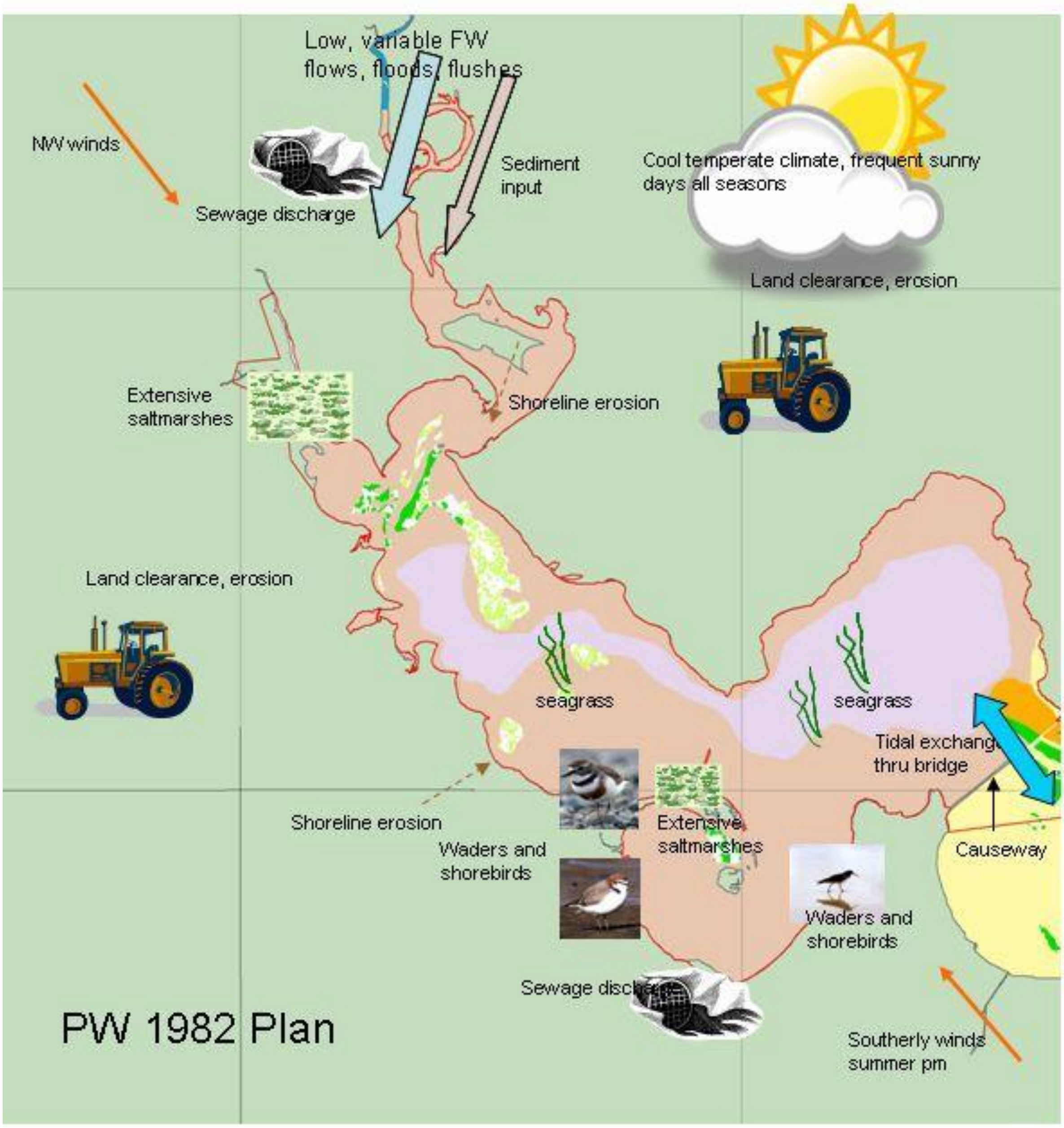


Figure 4.4: Conceptual model of Upper Pitt Water in 1982 - plan view.

In 1982, the Coal River estuary received variable and sometimes low freshwater flows carrying sediment from upstream. Land clearance had already stripped most of the immediate catchment and shorelines of natural vegetation cover, although saltmarshes are extensive in some areas. Free tidal exchange occurs through the bridge in the causeway. Seagrass occurs in several areas and is important as a shark nursery near Shark Point. Migratory waders and resident shorebirds use the area around Barilla Bay at the southern end of Upper Pitt Water and waterfowl are common further upstream. Two small sewage treatment plants discharge into the river at Richmond and Barilla Bay.

Figure 4.5: Conceptual model of Orielton Lagoon in 1982 - plan view.

In 1982, Orielton Lagoon received little tidal exchange and variable freshwater inputs. Accordingly the salinity was very variable and nutrient levels were high due to the contribution from the sewage treatment plant and drainage from adjacent area. Sediments and nutrients enter the lagoon from the Rivulet with extensive use of fertilizers. Shallow depth and warm conditions often led to algal blooms. Nevertheless, the lagoon was an important feeding area for migratory waders and resident shorebirds and ducks and swans were frequent and often numerous. The saltmarsh was in poor condition because of earlier inundation with freshwater and burning.

Section 5 Limits of Acceptable Change

Explanatory notes regarding limits of acceptable change:

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

Exceeding or not meeting limits of acceptable change 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 limits of acceptable change 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 ECD and define limits of acceptable change 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 limits of acceptable change 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 ECD 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.

5.1 Defining limits of acceptable change

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'. …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.'

This definition assumes that the range of natural variation is known for any parameter and that a sufficiently long term data set exists against which any change can be measured.

Limits of acceptable change may be set for components, processes, benefits or services. Specific measures or features may be classed as a component or process (eg tidal flow), a component or a benefit (eg shorebirds). Therefore no distinction between critical components, processes and services is made in the following summary. There is overlap and duplication in the quantifiable measures of components and services. The limits of acceptable change identified are quantifiable indicators relevant to critical components, processes and services.

5.2 Setting limits of acceptable change

PWOL was listed as a Ramsar site in 1982. This ECD describes the site as at that time where possible, and changes since listing are noted. Much of the information about the site has been collected during the 27 years since listing.

In accordance with the guidelines for preparing an ECD, the limits of acceptable change should refer to the ecological character of the site at the time of listing. That is, that baseline refers to the state of the components and processes of the ecological character as evident in 1982, and limits of acceptable change are based on those reference data. No data existed at the time of listing for some key parameters, such as marine water quality in Upper Pitt Water. In such cases, more recent information may be used to provide an appropriate baseline when evidence suggests that there has been no change in these parameters between 1982 and 2009.

At PWOL some positive changes in environmental condition have occurred, notably with the improvement in tidal exchange of marine waters in Orielton Lagoon. Where change is positive for the long-term maintenance of ecological character, present conditions provide a new baseline and limits of acceptable change can be considered against that benchmark.

The range of natural variation is problematic for a system that is both in a natural state of dynamic flux and a system still adapting to nearly 200 years of environmental change as a result of land clearance and modification of natural flows. This system has been impacted by both abstraction from inflow of fresh water for irrigation use and stock watering, and constraints on tidal flows after the construction of causeways. Orielton Lagoon has been subjected to various tidal regimes over some 7-8 decades and may be yet to achieve an equilibrium status in its ecological character under the most recent modifications.

Some critical components are subject to factors beyond the boundaries of the site, including levels of habitat protection on the EAAF, climate and weather, and the resources available in the wider estuarine system of the Derwent estuary.

Hale and Butcher (2008) suggest criteria that can be applied in identifying appropriate components and processes as the basis for setting limits of acceptable change. The components considered suitable are those:

1. for which there is adequate information to form a baseline against which change can be measured;
2. for which there is sufficient information to characterise variability;
3. that are primary determinants of ecological character;
4. that can be managed; and
5. that can be monitored.

In addition, the proposals for limits of acceptable change are chosen for both abiotic and biotic components covering a range of habitats.

Table 5.1 demonstrates selection of components as a basis for limits of acceptable change using the five criteria listed above. The components highlighted are those selected for further analysis. Table 5.2 provides a summary justification for each selected component in relation to the ecological character of the site.

Table 5.1: Selection of components to be developed with Limits of Acceptable Change using criteria of Butcher *et al* 2009.

	1	**2**	**3**	**4**	**5**
Physical components and processes					
Climate	✓	✓	✓		✓
Landscape context and geomorphology	✓	✓	✓	#	✓
Water quality/salinity	✓	✓	✓	✓	✓
Sediments			✓	✓	✓
Tidal regime	✓	✓	✓	✓	✓
River flows	✓	✓	✓	✓	✓
Habitats:					
Estuarine waters			✓		
Intertidal flats	✓	✓	✓	✓	✓
Saltmarsh	✓		✓	✓	✓
Seagrass beds	✓	✓	✓	✓	✓
Rocky shorelines	✓	✓		✓	✓
Supporting biological components					
Phytoplankton			✓		✓
Zooplankton			✓		✓
Invertebrates			✓		✓
Communities and species					
Saltmarsh communities & species	✓	✓	✓	✓	✓
Waterbirds and shorebirds	✓	✓	✓	#	✓
Fish	✓		✓		✓
Seastar	✓	✓	✓	✓	✓

# indicates use of area of intertidal flats as a measure amenable to management in support of shorebirds

Table 5.2: Selected components for Limits of Acceptable Change at PWOL

Component	Justification	Comments
Water quality/salinity	Water quality and salinity parameters are central to estuarine ecology. Data are quantifiable and readily measured.	Estuarine characteristics have been established in national programs http://www.ozcoasts.org.au/. Baseline values have identified for the Pittwater-Orielton system (Temby and Crawford 2008):
Tidal regime	Tidal regime is a critical process for maintaining the estuarine system. It determines the occurrence of critical intertidal and sub-tidal habitats and communities. Tidal movements ensure regulating services of the estuary and renewal of biotic components in the water column. The tidal regime of Orielton Lagoon has undergone significant modifications both before and since listing.	Tidal exchange in Orielton Lagoon is now managed to improve water quality. The results of changes in tidal regime on long-term water quality and intertidal zones may yet to reach a new stable state. The system will require monitoring to ensure that the expected outcomes are realised.
River flows	River inflows bring freshwater, sediment and nutrients to the estuary and are important triggers in the biology of some estuarine species. The Coal River, the major source of inflow, has been significantly modified by the construction of a large in-stream irrigation dam, the Craigbourne Dam, in 1986.	Recent dry years have exacerbated the problem of very reduced flow and reversal of peak flow season in the Coal River, altering the ecological character of the Site. The effects of a very wet year in 2009 do not necessarily return PWOL to its original character.
Intertidal flats	Intertidal flats are the key feeding area for shorebirds. Maintaining the area and condition of these habitats is crucial for migratory species.	Areas of these marine habitats can be measured. Surveys of invertebrates of these habitats would provide more information on the quality of the food sources but cost will limit such data collection.

Table 5.2: Selected components for Limits of Acceptable Change at PWOL (cont.)

Component	Justification	Comments
Seagrass beds	Seagrass beds are a typical and important component of estuaries. Seagrass is known to be affected by changes in water quality and provide an early indicator of decline in condition.	Data and mapping of seagrass beds in PWOL has shown an apparent decline in their area. Seagrass beds are naturally variable in extent and disposition. Decline in the area of seagrass was reported prior to Ramsar listing (Prestedge 1996) and this continued to less than 15% of the estimated original area (Aquenal 2000). Some changes in distribution are indicated (comparing Figure 2.13 and 3.16).
Saltmarsh communities & species	Saltmarsh communities can provide evidence of wider changes in the ecological character of PWOL as they respond to changes in tidal movements, freshwater inflow, sediment movement and sea level rise.	Detailed mapping of saltmarshes at the time of listing (Kirkpatrick and Glasby 1983) and a recent comparative survey (Prahalad 2009) provide a sound, reliable and replicable basis for monitoring change.
Seastar	The endemic viviparous seastar *Parvulastra (=Patiriella) vivipara* is listed as vulnerable under the EPBC Act & TSPA. Its occurrence within PWOL appears to have retreated (K. Parsons, pers.comm.).	The substrate in areas previously occupied by the seastar has been subject to increased siltation.

Table 5.3 summarizes the indicators to be used for each component, the baseline condition for each indicator and range of natural variation (where known). Limits of acceptable change are proposed for each indicator.

Table 5.3: Limits of acceptable change PWOL.

Critical components, processes, benefits and services	**Indicator**	**Baseline condition in 1982 and range of natural variation (NV) where known**	**Limits of acceptable change**
Water quality – upper Pitt water and Coal river	N P DO Salinity pH Turbidity Chl A Faecal coliforms	Not known for 1982. Data available in Temby and Crawford (2008): N =<.01 NOx with occasional peaks P =Soluble reactive phosphorus 3 -10 µg/L, occasional peaks DO >80% Naturally hypersaline 35-38ppt, occasional low salinity of surface layers under rainfall events in upper estuary 8.08 – 8.55 <5 NTU < 2.6 µg/L	Not exceed reference data range of Temby and Crawford (2008) Maintain low level, (occasional peaks acceptable) Maintain within range 3 -10 µg/L, (short-term peaks acceptable) Maintain >80% Salinity falls within acceptable range except for short-term natural perturbance Maintain neutral pH range 8.0 – 8.5 <5 NTU (occasional short-term increases under windy conditions acceptable) Not exceed 2.6 µg/L Not exceed EPA guidelines for primary contact
Water quality – Orielton Lagoon	N P DO Chl A Salinity Turbidity Faecal coliforms	Eutrophic (Brett 1992) 0.03 – 5.8 mg/L (Kinhill 1993) 0.04 – 0.198 mg/L (Kinhill 1993) >90% (Brett 1993) Range from 8.67 – 33.8 µg/L monthly mean Saline to hypersaline 38.1 – 38.8ppt 15 – 94 NTU (Brett 1992) Counts at STP 445 x10^3	Not exceed reference data range of Temby and Crawford (2008) - As above

Table 5.3: Limits of acceptable change PWOL (cont.)

Critical components processes, benefits and services	**Indicator**	**Baseline condition and range of natural variation (NV) where known**	**Limits of acceptable change**
Tidal exchange – Orielton Lagoon	Volume, lag Area of intertidal flat	Tidal patterns and predictions available for open estuary but not for impeded flow Mapping of tidal flats since culverts opened	Maintenance of sufficient tidal exchange and exposure of mudflats for shorebird habitat availability No loss in area of intertidal flats
Flow regime – Coal River below Richmond	Baseflow and flushing flows Months with no flow Peak flow interval and volume Magnitude and frequency of flushing flows	Baseline modelled from rainfall data (Davies *et al* 2002)	Maintenance of natural flow characteristics and flushing flows as recommended by Davies *et al* 2002, Table 5.1
Flow regime- Orielton Rivulet	As above	Not known. Poor quality rainfall and stream flow data and insufficient time series to establish modelled baseline Pattern or base flow and flushing flows should parallel that of Coal River	Maintenance of natural flow characteristics

Table 5.3: Limits of acceptable change PWOL (cont.)

Critical components, processes, benefits and services	**Indicator**	**Baseline condition and range of natural variation (NV) where known**	**Limits of acceptable change**
Intertidal flats	Area of intertidal flats	Area mapped as available for wader feeding in 2009	No loss in total area of intertidal flats
Seagrass	Area of seagrass beds Condition of seagrass	Mapped in 1970 and 1990. Loss of 90% estimated by 2004. Naturally variable but range of variability in Pitt Water not known. Considered a good indicator of ecosystem health	No further decline. Total area maintained at least 1990 level. Appears outside natural variation but does not appear to have lost further ground between 2004 and 2008
Saltmarsh	Total area in PWOL Total area in PWOL and Pitt Water estuary Vegetation communities Bare/hypersaline ground Damage by stock Invasion of weeds Rare and Threatened (R&T) flora and fauna species	Mapped area (Glasby 1975) Aerial images Mapped by Glasby (1975) Mapped by Glasby (1975) Noted by Glasby (1975) Weed species noted by Glasby (1975) Indicative mapping on Natural Value Atlas (DPIW)	No loss in total area of saltmarsh No increase in physical impacts of grazing or roads No net loss of vegetation communities No net increase in bare ground Reduce to zero areas accessed by stock No net increase in species or extent of introduced weeds No loss in distribution or abundance of R& T species: *Theclinesthes serpentata lavara* , *Wilsonia humilis, Calecephalus citreus, Limonium australe, Lepilaena preissi, Stuckenia pectinata* (syn. *Potamogeton pectinatus*)
Seastar	Distribution and	Habitat areas mapped and hot spots	Populations and habitats maintained within 10% of

	abundance in PWOL	(abundance) noted. NV not known.	original distribution

Section 6 Changes since listing

6.1 Overview

Some components and processes have undergone change since listing, the most significant of which are as the result of direct human intervention. Some interventions have had a positive effect on the condition of the site. Other changes or trends have been observed in the 27 years since listing. These changes may be weak signals of long term change, natural cyclical change or result of external factors.

Changes since listing include:

- Alteration of flow regimes in the Coal River
- Increasing tidal exchange and improvement of water quality in Orielton Lagoon
- Changes in sediment deposition
- Decline in abundance and diversity of birds, fish and invertebrates
- Decline in seagrass beds
- Change in saltmarsh flora and condition.

6.2 Observed changes since listing

6.2.1 Alteration of flow regimes in the Coal River

The Craigbourne Dam is an instream dam of 125,000 megalitre capacity constructed on the Coal River in 1986, some 25 kilometres upstream from Richmond and 4 kilometres downstream from Colebrook. It provides irrigation water for the expanding intensive agriculture, horticulture and viticulture industries of the Coal Valley. Water from the dam is released for direct abstraction from the downstream channel by irrigators (Davies *et al* 2002). Although flow from Craigbourne Dam is regulated, the exact amount extracted for irrigation is not known because of the large number of small dams and direct pumping from the river. The number of registered instream and offstream dams in the Coal River catchment is approximately 300, with a potential irrigation capacity of 35,500 ML, (Davies *et al* 2002).

Since construction of the Craigbourne Dam, flows in the river have declined and peak flow periods have reversed. The Coal River is now a highly regulated river with total and seasonal flows considerably altered (Davies *et al* 2002).

Data on stream flows at Richmond commenced only after the dam's construction, making firm comparisons difficult. Figure 3.2 shows a summary of stream flows in the Coal River catchment between 1961 and 1997, illustrating the highly variable flows. Since dam construction, capture of the significant contribution of upstream flow, together with an increase in drawdown for irrigation further downstream, has led to successive months of low flow at the Richmond weir gauging station (Figure 6.1). Recording at the Richmond weir station only commenced in 1995.

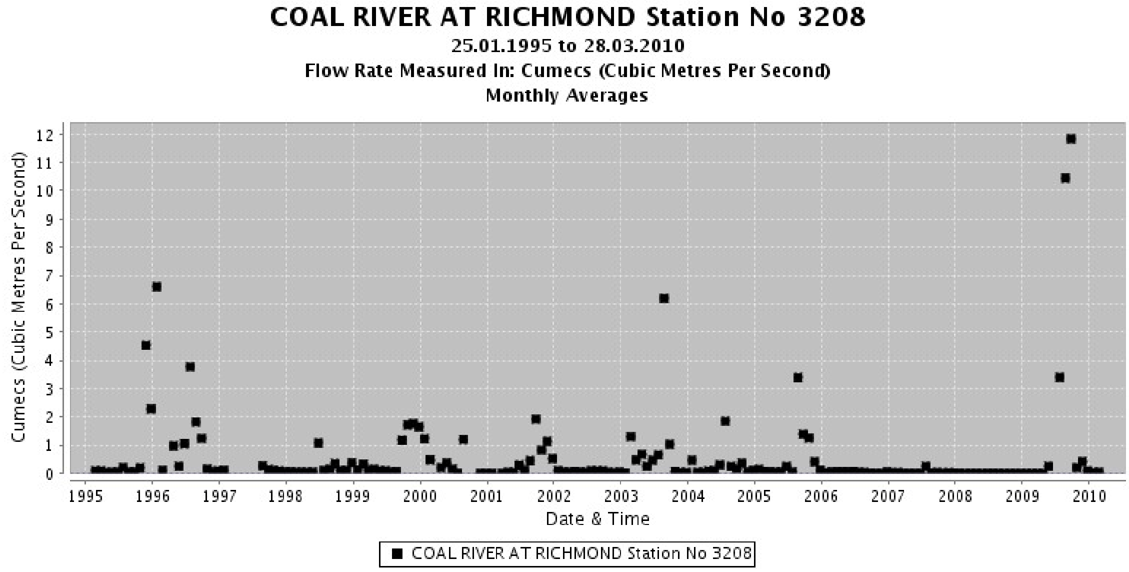


Figure 6.1: Average monthly flows at Richmond 1995 – 2009 (Source: WIST)
Note: Data missing for some months

Years with higher mean flows can largely be attributed to a single month with high flow, often the result of a single high rainfall event. Data from flows at gauging stations in the Pitt Water Coal River catchment are very patchy, discontinuous and frequently missing. However, both modelled data and widespread and consistent anecdotal reports provide clear evidence of change in the Coal River and its contribution to freshwater inputs to the estuary.

Manipulation of the flows in response to irrigation demands, abstraction downstream from the Craigbourne Dam and management of weirs have resulted in a highly altered regimen in the river and in the upper end of the estuary. Now the higher flows occur in summer when water is released for irrigation while during the winter, water flowing into the dam is captured for summer use. The changes in flow of the Coal

River are shown in Figure 6.2 where actual flows are compared with notional ‘natural’ flows derived from modelling. Figure 6.2 demonstrates the release of stored water from the dam between October, peaking in December and slowly falling away to a minimum in winter months. This contrasts with the modelled natural flow which peaks in August and shows very low flow in the summer. The situation at Richmond weir is shown in Figure 6. 3 where high natural flows occur between July and September, the flow augmented by contributions and tributaries downstream from Craigbourne Dam. Natural flows in summer months into the estuary are very low, whereas under conditions of dam release and irrigation, flows in summer months are higher. The flow regime in the Coal River was characterised by Davies *et al* (2002) as follows:

- Highly regulated flows
- Loss of natural seasonal pattern
- High baseflows during summer-autumn
- Reduced base-flows during winter-spring
- Reduction in flood size, frequency and duration
- Rapid level changes over periods of hours associated with irrigation water delivery.

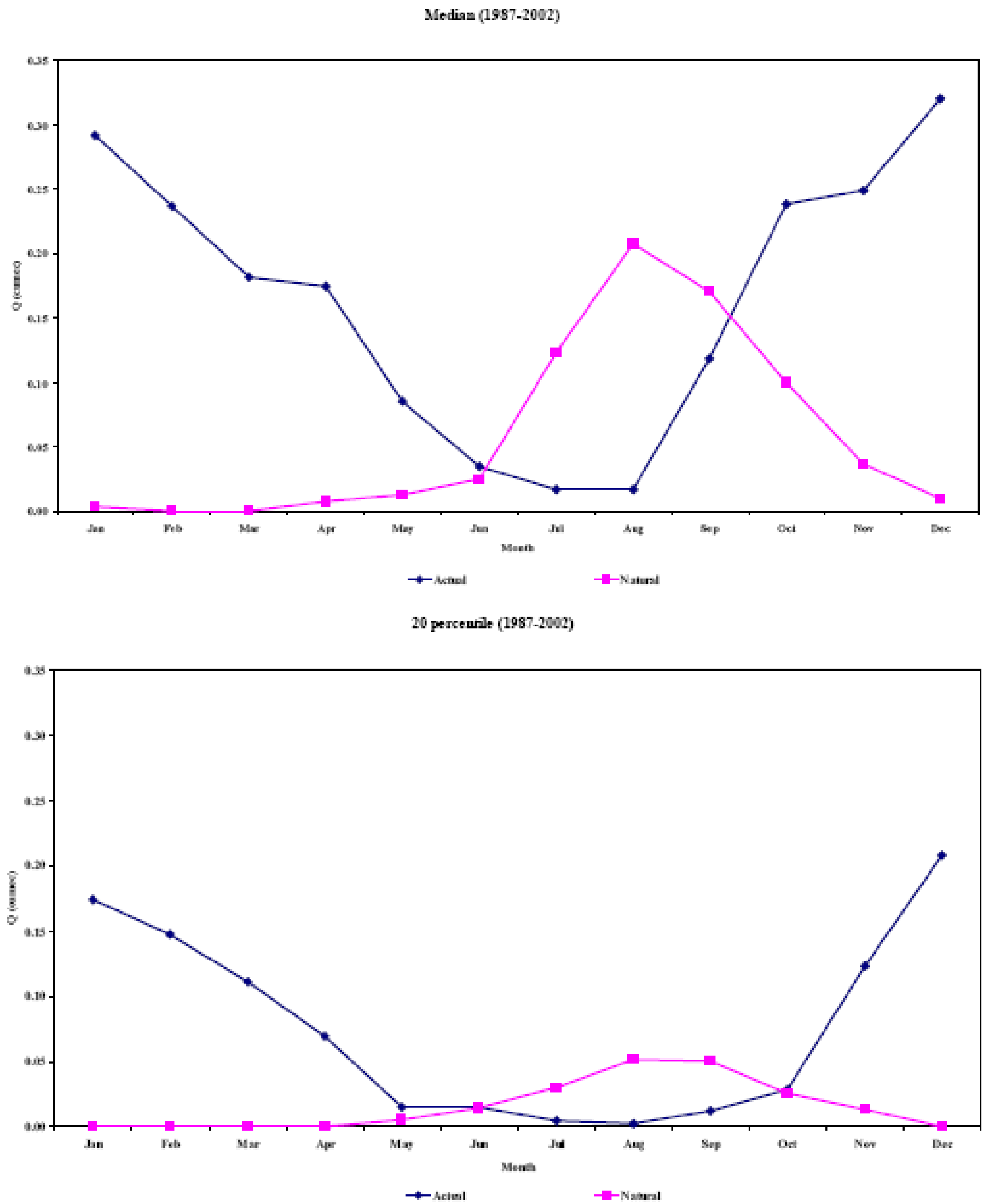


Figure 6.2: Seasonal patterns of mean daily flows in cumecs, by month, as median and 20 percentiles, Coal River at Mt Bains, downstream from the Craigbourne Dam based on actual and modelled natural flows 1987 – 2002. (Source; Davies *et al* 2002)

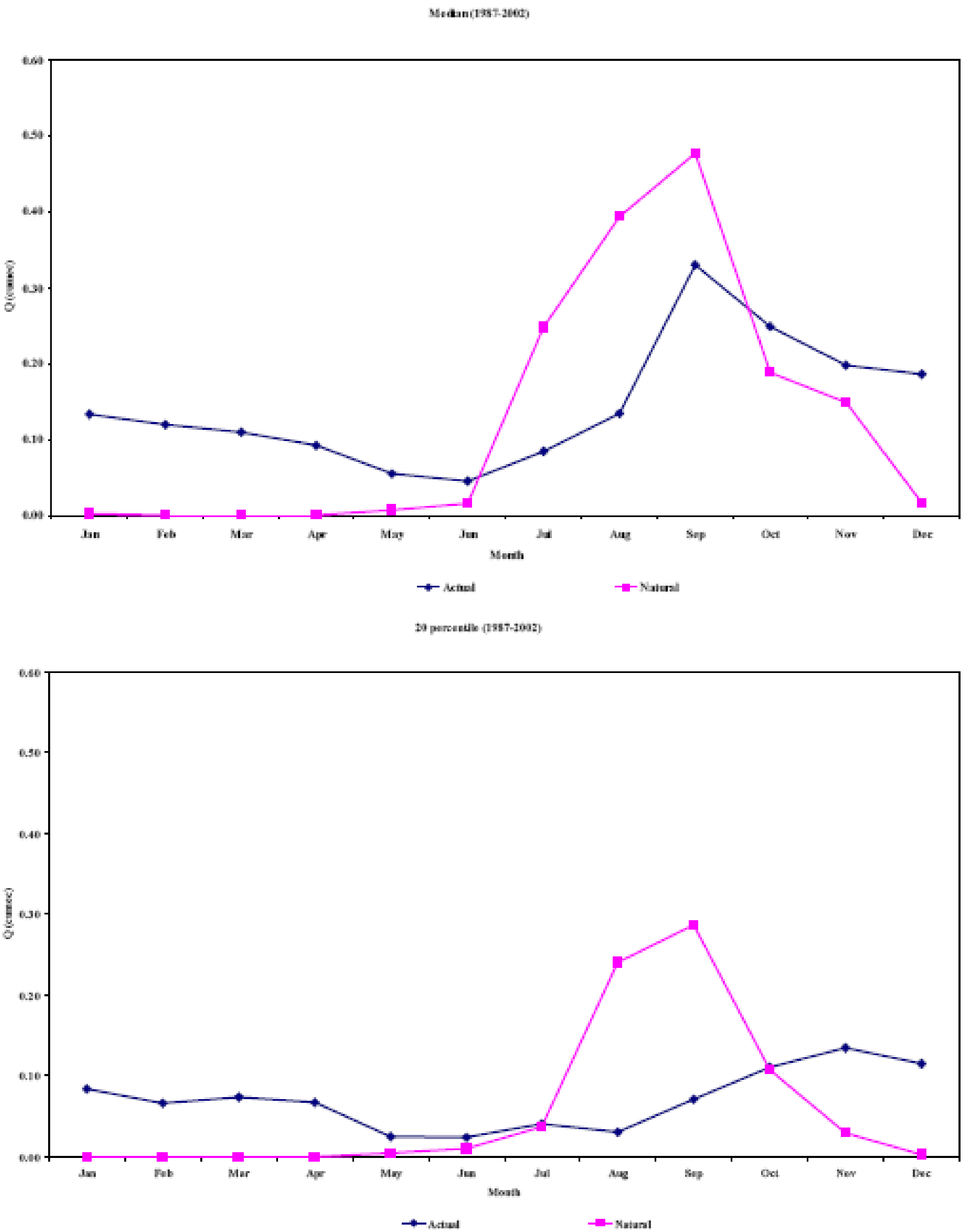


Figure 6.3: Seasonal patterns of mean daily flows in cumecs, by month, as median and 20 percentiles, Coal River at Richmond weir, based on actual and modelled natural flows 1987 – 2002. (Source; Davies *et al* 2002)

The ecological impacts of the regulated flow regime are not clear, although the generally lower flow contributes to drier conditions in the saltmarshes and possibly to increases in salinity. The tidal wedge is likely to penetrate further upstream and saline water now reaches the weir at Richmond. Such changes may affect the migration of anadromous fish known as whitebait which make a spring run up the river to spawn. The modified lower winter flows (when the water is stored for use in summer irrigation) remove a trigger for the spawning migrations to be initiated. Whitebait are an important food sources of larger fish predators, so any loss or reduction of this component can impact on the fish community of PWOL.

In the decade to 2009, low annual rainfall and drawdown on the dam exacerbated the changes to flows in the Coal River. The estuary is now predominantly saline and the occasional large flushes of fresh water following heavy rainfall no longer occur in most years. Previously, such flushes brought a wedge of freshwater downstream at least to Shark Point (R Morey pers.comm.). This had not happened for many years to 2008. The flood tide persists in the upper estuary and the lack of freshwater is thought to have contributed to the progressive decline of a stand of *Tectocornia arbuscula* at Saltbush Point (Prahalad pers.comm., Anna Crane pers.comm.). Loss of freshwater inputs into the fringing saltmarshes of the upper estuary may be a contributing factor to the increased salinity and altered vegetation community structures of the marshes. Larger areas of hypersaline bare ground are apparent in some of these marshes (Prahalad 2009).

The year 2009 was an exceptional year with rainfall reaching amongst the highest levels recorded for the Coal River catchment (Figure 6.4). Rainfall in June, August and September 2009 exceeded the mean values by a factor of three or more times. For the first time since it was first constructed the Craigbourne Dam filled and high downstream flows were experienced. So great were the flows at times recording failed, leaving gaps in the data. These conditions brought large amounts of freshwater into the Upper Coal Estuary and Orielton Lagoon for the first time in two decades.

Figure 6.1 shows that some mean monthly flow rates at Richmond in 2009 were the highest for the last fifteen years. Figure 6.5 illustrates the peak flows occurring during 2010, noting that data for July are missing. Comparing rainfall in the area (Figure 6.4) with the flows (Figure 6.5) suggests that as the ground became saturated, greater run-off reached the streams and rivers, yielding higher flow rates.

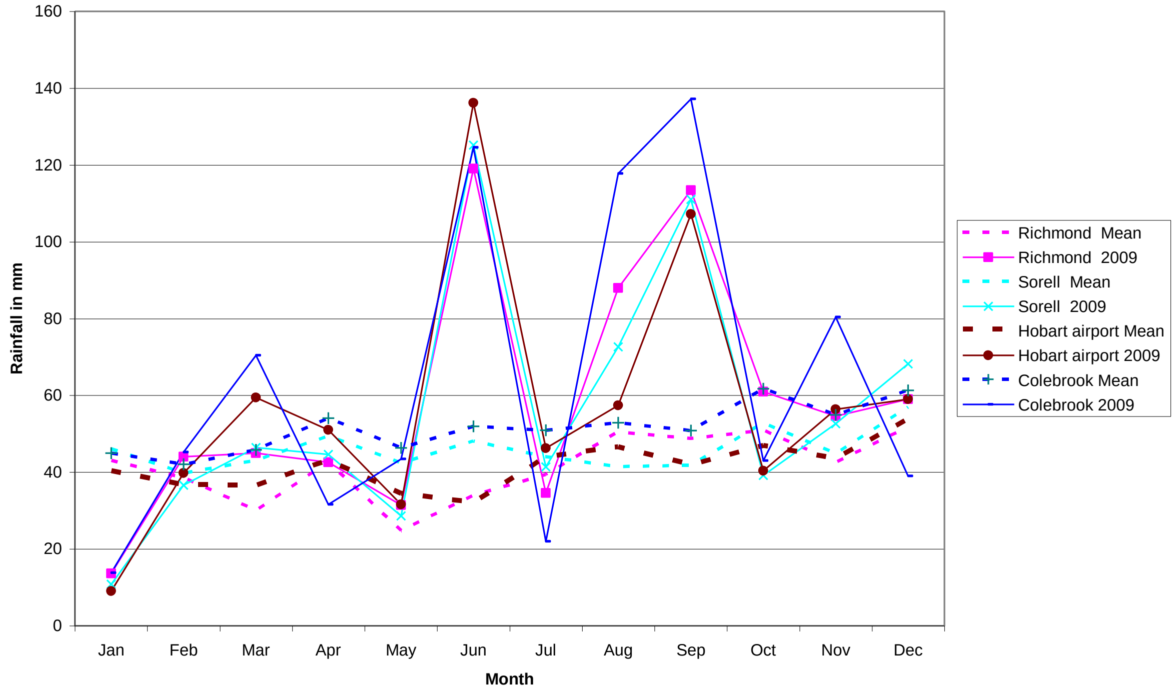


Figure 6.4: Monthly rainfall and mean monthly rainfall at four locations in the Coal River catchment and PWOL for 2009. (Source: BoM)

Note: Some data not quality controlled

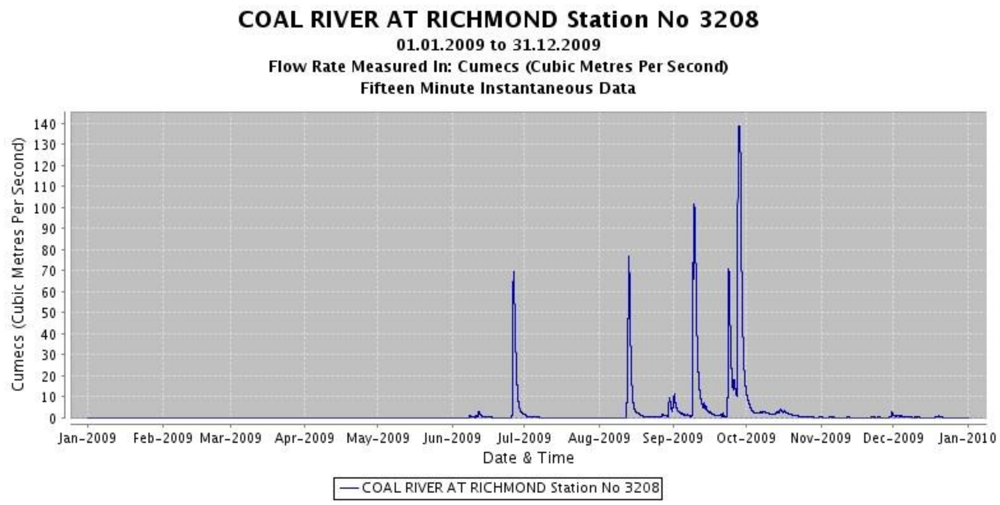


Figure 6.5: Flow rates for Richmond, continuous monitoring 2009. (Source: WIST). Note July data missing.

These recent events were the result of atypical weather patterns leading to unusually high rainfall. This does not overcome the ongoing issue of impedance to the flows in the Coal River and loss of annual peak winter flow events as noted by Davies *et al* (2002).

6.2.2. Increase tidal exchange and improvement in water quality in Orielton Lagoon

At the time of listing, Orielton Lagoon was a more or less enclosed water body with very limited tidal exchange. It had high levels of nutrients and was often covered by filamentous algae and occasionally was subject to blooms of noxious blue-green algae. Two important measures undertaken since listing have improved the water quality and tidal exchange.

Upgrade of the sewage treatment plant (STP) at Midway Point.

A new treatment plant was commissioned at Midway Point in 1991/92 including a de-nitrification stage. Nitrogen loads in the lagoon were reduced in comparison with earlier years (Kinhill 1993). Treated sewage outflow to Orielton Lagoon ceased completely in 2007. The secondarily treated water is now pumped to holding dams, further from the lagoon, along with partially treated sewage from the Sorell plant, and this grey water is sold to farmers and a golf course for irrigation purposes. This removes the direct input of sewage outflow into the lagoon, although drainage from its use in irrigation, particularly from the adjacent golf course, may continue to release nutrients into the lagoon.

The issue of sewage discharge has also been addressed in other areas of PWOL. Similar grey water management has been adopted for the sewage treatment plants in Upper Pitt Water with closure of the plant at Cambridge and Hobart Airport, replaced with a modern treatment facility also at Hobart Airport. The Richmond STP treats to secondary level and the grey water is stored for on-farm irrigation use.

Improvements in tidal exchange in Orielton Lagoon

Following investigations into the causes of noxious algal blooms (Brett 1992) and of strategies to resolve the problem (Kinhill 1993) new culverts were installed to facilitate tidal exchange. The sources of odour and noxious blooms were identified as the limited flushing and high levels of nutrients in Orielton Lagoon.

The original two 1.7m diameter culverts at Orielton Lagoon had a floor height level near that of high water mark. In 1993 these were replaced (G. Nichols pers.comm. 2009) with a five box culvert system each culvert 3.6 x 1.8m with a sill set at mid-tide level of 0.35m (tidal range of Pitt Water estimated at -0.7 to +0.7m). A weir was placed on the northern (lagoon) side to maintain height at low tide. Baffles were used to control the initial opening of the lagoon. At the same time, a twin 1.5m diameter pipe culvert was installed under the causeway near Sorell to improve circulation within the lagoon (G.Nichols, pers.comm. 2009).

Opening of the new culverts and drains coincided with heavy rainfall and high lagoon levels. High flow rates brought silt and nutrients, scouring a channel in the intertidal flats on the southern side of the causeway near Sorell and leading to widespread filamentous algal colonising the flats (Figure 6.6).

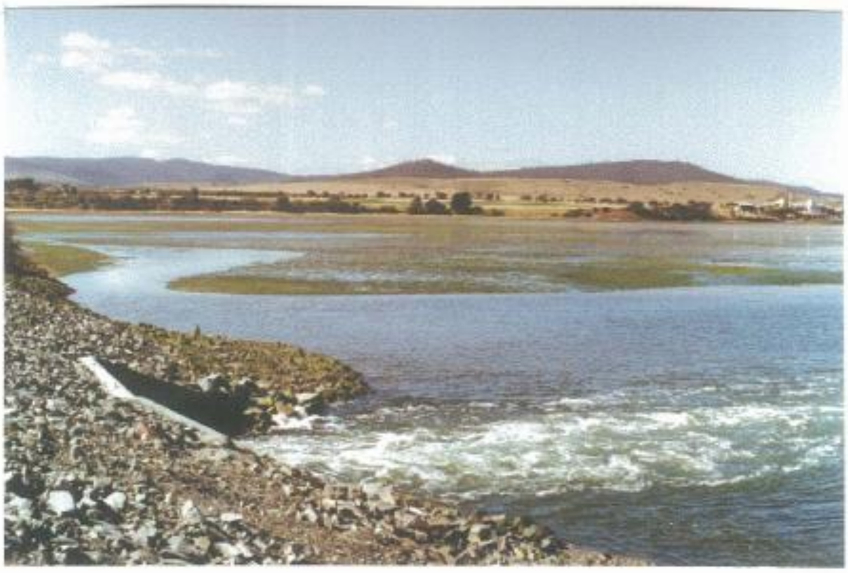


Figure 6.6: Algae on intertidal flats at Sorell, east of the pipe outlets 23/3/1994. (Source: Image by G. Prestedge, provided by Sorell Council)

The extent of intertidal exposure reportedly remains lower than in the days of the original bridge, though higher than at the time of listing. Thus, more area of intertidal flat would have occurred under natural conditions.

The current state of water quality in Orielton Lagoon

Water quality improved in Orielton Lagoon following these changes to the STP and the culverts. Circulation in Orielton Lagoon is thought to have improved (P Park pers.comm.).

Monitoring of key water quality parameters at five sites in the Pitt Water estuary system over a period of a year indicated that for most parameters Orielton Lagoon was comparable with other, more marine, sites (Temby and Crawford 2008). Dissolved oxygen was measured at around 100% for most of the year with occasional lower values (>90%). Nitrogen (nitrate plus nitrite) levels were low throughout the year and mostly below detection limits. Soluble reactive phosphorus levels were below 10 μg/L, in common with other sites, while silicate concentrations were below detection levels. Ammonia levels were generally low but peaked, along with sampling sites off Shark Point and at the 1st causeway bridge, at 91 μg/L in April 2007. There seems no ready explanation for this incident. Chlorophyll a remained relatively low and stable, peaking in the summer months. However, a smaller peak also occurred in August which is difficult to explain. In the same month, a high turbidity (14.7 NTU) event was recorded for Orielton Lagoon and is assumed to be related to rainfall in the catchment. In general turbidity was quite low (> 5 NTU), although somewhat higher for the two sites in the upper areas (Orielton Lagoon and Shark Point). Peaks in turbidity occurred in August, February and April suggesting that sediment disturbance rather than algal blooms was the cause. Importantly for Orielton Lagoon, the level of coliform bacteria was not elevated and comparable with other sites in PWOL.

In summary, the survey (Temby and Crawford 2008) indicated that the strategies to improve water quality and facilitate tidal exchange in Orielton Lagoon have been successful. However, the increased inflow of freshwater and run-off due to the exceptionally high rainfall of 2009 appear to have brought increased nutrients and lower salinities to the lagoon, at least on a temporary basis. Extensive areas of green algae were observed, particularly in the northern and western areas. Unpleasant odours were noted but testing revealed no toxic algae were present.

A survey of macroinvertebrates in Orielton Lagoon demonstrated that the changes were having an effect on the biota (Davies *et al* 2006). There were no data available for invertebrate communities in Orielton Lagoon either at the time of listing or before the construction of the additional culverts and lowering of the sills. Benthic invertebrate sampling at Orielton Lagoon and two reference areas (Upper Pitt Water and Carlton River estuary) in 1999 revealed that Orielton Lagoon benthic communities were dominated by amphipods, followed by annelids, This was in contrast to sites sampled in the Upper Pitt Water estuary which were dominated by polychaete worms (Davies *et al* 2006). When surveyed in 2005, all areas were dominated (>50%) by polychaete worms with amphipods comprising around 20–40 % of the remainder. Total abundance declined in Orielton Lagoon between 1999 and 2005 largely due to the reduction in abundance in several species of amphipod whose presence was considered indicative of the eutrophic status of the lagoon (Davies *et al* 2006). There was an increase in abundance of polychaetes and molluscs and increase in overall diversity of benthic macroinvertebrates. Although the invertebrate fauna of Orielton Lagoon still had a lower diversity compared to the other two estuaries, the shifts in community composition were considered indicative of a shift to a more typical estuarine community.

6.2.3 Changes in sediment deposition

Orielton Lagoon

There has been no detailed documentation of the sediment deposition or movement within, or from, Orielton Lagoon since the lowering of culvert sills and the addition of the culverts in 1993. There are well-established channels flowing from old and new culverts and the pipes (Figure 6.7) though the effects on sediment movement out of and in to the lagoon are not clear.

Figure 6.7: Aerial oblique image of 2nd causeway showing tidal channels draining from Orielton Lagoon through culverts and pipes. (Source: image I.Houshold May 2009)

An increase in outflow from Orielton Lagoon may have affected sand movement, channel development and intertidal exposure downstream of the Causeways. It has been reported that the intertidal flat south of the Second Causeway at Sorell is now less favoured feeding area for migratory waders (P.Park pers.comm.) although it is still used by other shorebirds, including pied oyster catchers.

There is some indication of increased sediment deposition in Orielton Lagoon with a saltmarsh fringe developing along the eastern shore of Orielton Lagoon. A saltmarsh has also established in the south-west corner of Orielton Lagoon (Figure 6.8). This is suggestive of predicted sediment movements in a wave-dominated barred estuary which is essentially the kind of system that Orielton Lagoon has become (I.Houshold pers.comm.).

Figure 6.8: Aerial image of recently established saltmarsh in the south west corner of Orielton Lagoon. (Source: Image by Prahalad May 2009)

Upper Pitt Water

Another consequence of the change to flow regime is an overall reduction of the ability of the river to transport sediment. Long-term residents report that the river is now shallower in the upper reaches of the estuary and has soft sandy shores (Anna Crane pers.comm, Cathy Way pers.comm.). Seagrass has disappeared from Upper Pitt Water upstream of Shark Point (see below) (P Morey pers comm.).

Sedimentation has been significant in Pitt Water as a consequence of land clearing, and agricultural and forestry activities in the catchment since early settlement. Sedimentation rates are likely to have been exacerbated by the effects of the Craigbourne Dam which has reduced gross water movements in Upper Pitt Water (Millin Environmental Services 2000).

Reservoir trapping reduces fluvial sediment supply. No data are available on sediment supply in the Coal River. Local residents report that sand has redistributed in Lower Pitt Water since construction of the dam.

6.2.4 Decline in abundance of birds, fish and invertebrates

Decline in numbers of waterbirds and waders

A decline in the number of waterfowl recorded in annual counts since 1985 (Figure 3.32) corresponds with a more widespread fall in numbers of waterfowl across South-East Australia. A similar decline was noted in Victoria where a statewide waterfowl survey in 2008 yielded the lowest number since counts began in 1987 (http://www.dse.vic.gov.au/DSE/nrenari.nsf). Fewer swan have been seen in Orielton Lagoon area in recent years and nesting no longer occurs on the lagoon (P. Park pers.comm.).

Migratory waders show annual variation in abundance but overall numbers appear to be declining (Figure 3.20). If the most numerous species, the red-necked stint, is removed from the graph, the decline in other species is more evident (Figure 6.9).

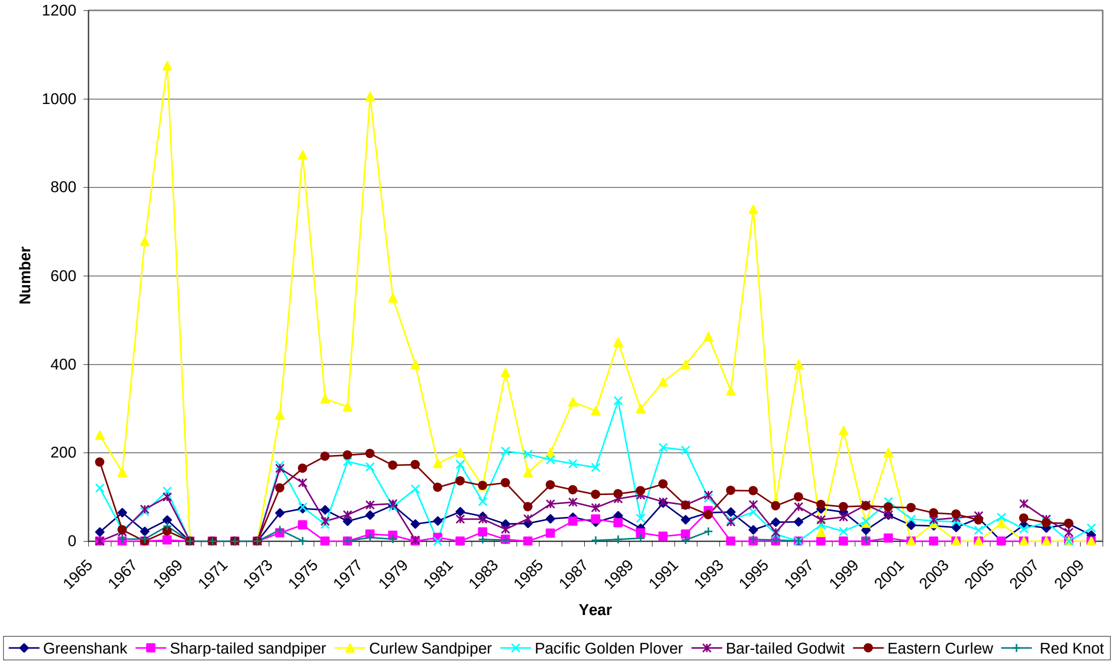


Figure 6.9: Numbers of seven species of migratory waders commonly occurring at PWOL 1965 – 2009. No records for 1969 – 1973. (Source: Birds Tasmania (2009) Unpublished survey data, Pitt Water Orielton Lagoon Ramsar site, 1964-2009).

In the years prior to listing of the Ramsar site, curlew sandpiper reached levels of abundance almost as high as the commonest species, the red-necked stint. In the succeeding two decades numbers declined and now they are infrequently recorded. The endangered Eastern curlew were reported to be in very large flocks in the 1920s (P. Park, pers.com., Read and Park 2002) but have declined to very low numbers.

Other species shown in Figure 6.9 have also declined. Some species have disappeared altogether from PWOL: the Short-tailed sandpiper, for example, has not been seen there for many years.

Numbers of the east-west migratory species, the double-banded plover, have also fallen since the time of listing with records suggesting that only about half the number visit during the Tasmanian winter as those in 1982 (Figure 3.35). In contrast, resident shorebird numbers appear to be sustained (Figure 3.30, 3. 31).

Amongst the gulls, unpublished data of Birds Tasmania (E.Woehler pers.comm.) indicate that silver gulls and Pacific gulls have declined slightly since the time of Ramsar listing. Numbers vary somewhat from year to year but overall silver gulls are now about 70% of 1983 datum and Pacific gulls 90 % of 1980 datum. By contrast, kelp gulls have increased in number over the same period of time by a factor of four times. Kelp gulls are also increasing in number elsewhere in Tasmania. These gulls are now occupying areas formerly used by waders, such as the tidal flats and saltmarsh at the mouth of Sorell Creek, and the north- eastern areas of Orielton Lagoon (P.Park pers.comm.). In addition, kelp gulls are now nesting around the head of Orielton Lagoon. It is not known what impact, if any, this is having on access to food supply and habitat for waders and resident shorebirds.

Loss of fish species diversity

Prestedge (1996) noted changes in the fish species diversity and abundance over the period of his observations between 1956 and 1995 (see Table 3.4). Significant decline in catches of perch, silver trevally, trumpeter and gurnard occurred, catches of ‘keepable’ size cod became scarce and flounder numbers were reduced (Prestedge 1996). Between 1975 and 1995 the only species that did not drop in numbers were flathead and salmon. In addition, Australian salmon *Arripis trutta* stayed only about four weeks in the estuary compared to the four months recorded in earlier years (Aquenal 2000). Prestedge (1996) attributed this to the fall in whitebait stocks. Shoals of whitebait and associated schools of salmon were observed in the 1990s but were less frequent and smaller in extent. Prestedge’s observations and estimates (Table 3.1) suggest a decline in abundance of varying degrees in every fish species.

Catch rate of sharks recorded in Pitt Water also declined (Aquenal 2000). A similar picture was evident in school shark pups. Upper Pitt Water has been a shark nursery area since the 1960s and in 1990 the entire area of Pitt Water was formally declared a shark nursery area. (Aquenal 2000). The decline in shark numbers has been attributed to a combination of overfishing, seagrass decline and other environmental changes in Pitt Water, although there may also be some changes in shark behaviour (Aquenal 2000).

Declines in abundance and distribution of invertebrates

Prestedge (1996) observed significant declines in abundance in a wide range of invertebrates between 1975 -1995. These declines were across all taxonomic and functional feeding groups, and all habitat types. These estimates used a qualitative scale (abundant >common>frequent>infrequent>uncommon>rare), the shifts observed generally a one step shift downwards. Several amphipod species fell from frequent to 'not seen'.

The distribution of the endemic seastar *Parvulastra vivipara* appears to have declined since first mapped in 1976 (Aquenal 2000). Its range in Upper Pitt Water is now restricted to the causeways, the sandstone bluffs at Pitt Water, Midway Point and Sorell, and outcrops of sandstone and section of rocky shorelines of Upper Pitt Water at Midway Point. Although previously recorded right along the shorelines of upper Pitt Water around to Shark Point, this area appears to no longer be suitable habitat with erosion of the cliffs resulting in dense fine silt coating the shores (H Dunn, observed May 2009). Prestedge (1998) found all known populations of the seastar had declined in abundance and had almost disappeared from the south-west corner of Upper Pitt Water. Potential factors influencing the decline of the seastar in Pitt Water include decrease in water quality associated with discharge from STPs and other wastes, stormwater run-off and seepage from septic tanks. In addition, increased sedimentation has filled spaces between rocks once occupied by seastars and Cunjuvi *Pyura stolonifera* have taken over the rocky shores (Prestedge 1998). Near drainage outlets stormwater run-off appears to trigger a necrotic disease in the seastars, killing some of its victims (Prestedge 1998).

Summary of declines in fauna

Loss in abundance and diversity appears to have affected all types of fauna in PWOL. The causes of these declines potentially include both within and adjacent to the site, as well as more wide-spread factors. Factors well beyond the site may affect numbers of shorebirds. The local causes attributed to declines are common across the various taxonomic groups: habitat loss including seagrass, rocky shorelines and healthy benthic sediments; localised problems affecting water quality, such as stormwater discharge, run-off from land practices and urbanization, direct or indirect discharge or drainage from secondarily treated sewage; displacement by species expansion or exotic species; overharvesting, and general increasing human use of the area creating disturbance to normal behaviour and habits.

Although no quantitative data are available for invertebrate and fish abundance and diversity, the extent of reported decline is a matter of concern (Table 3.4) (Aquanel 2000). The apparent decline is particularly disturbing given that the losses are across the board and not limited to particular habitats or taxon groups. Similar factors have been attributed to cause of these declines as those affecting seagrass and saltmarsh. Loss of both abundance and diversity, across different communities, habitat and taxon groups, may be considerable outside the natural variability for such an estuarine system.

6.2.5 Decline in seagrass beds

The decline in seagrass distribution was already evident at the time of listing (Figure 3.16). The area of seagrass in PWOL has further declined (Figure 6.10) with beds having disappeared completely from Orielton Lagoon and off Shark Point. In Upper Pitt Water they are confined to small patches near Lands End. While difficulties with image quality may have led to some error in accurate mapping, the trends are clear and consistent with the observations of Prestedge (1996).

A recent survey of estuaries in Southern Tasmania (Mount *et al* 2005) found that while Pitt Water had the second highest absolute amount of seagrass of all the estuaries surveyed, this was not high in comparison to the total area of the estuary. The highest density occurred in the end of the main entrance channel, outside the Ramsar boundary. Small patches of seagrass were also identified in the mouth of the Coal River and near Railway Point, but not in areas south of the 2nd causeway as described by Prestedge (1996).

The most recent and accurate map of seagrass distribution was generated in 2005 (Mount *et al* 2005) using aerial imagery interpretation and ground-truthing (Figure 3.3). Further mapping of Orielton Lagoon (Lucieer pers.comm.) confirmed no seagrass at all within the lagoon, whereas earlier anecdotal reports had indicated some seagrass at the time of listing.

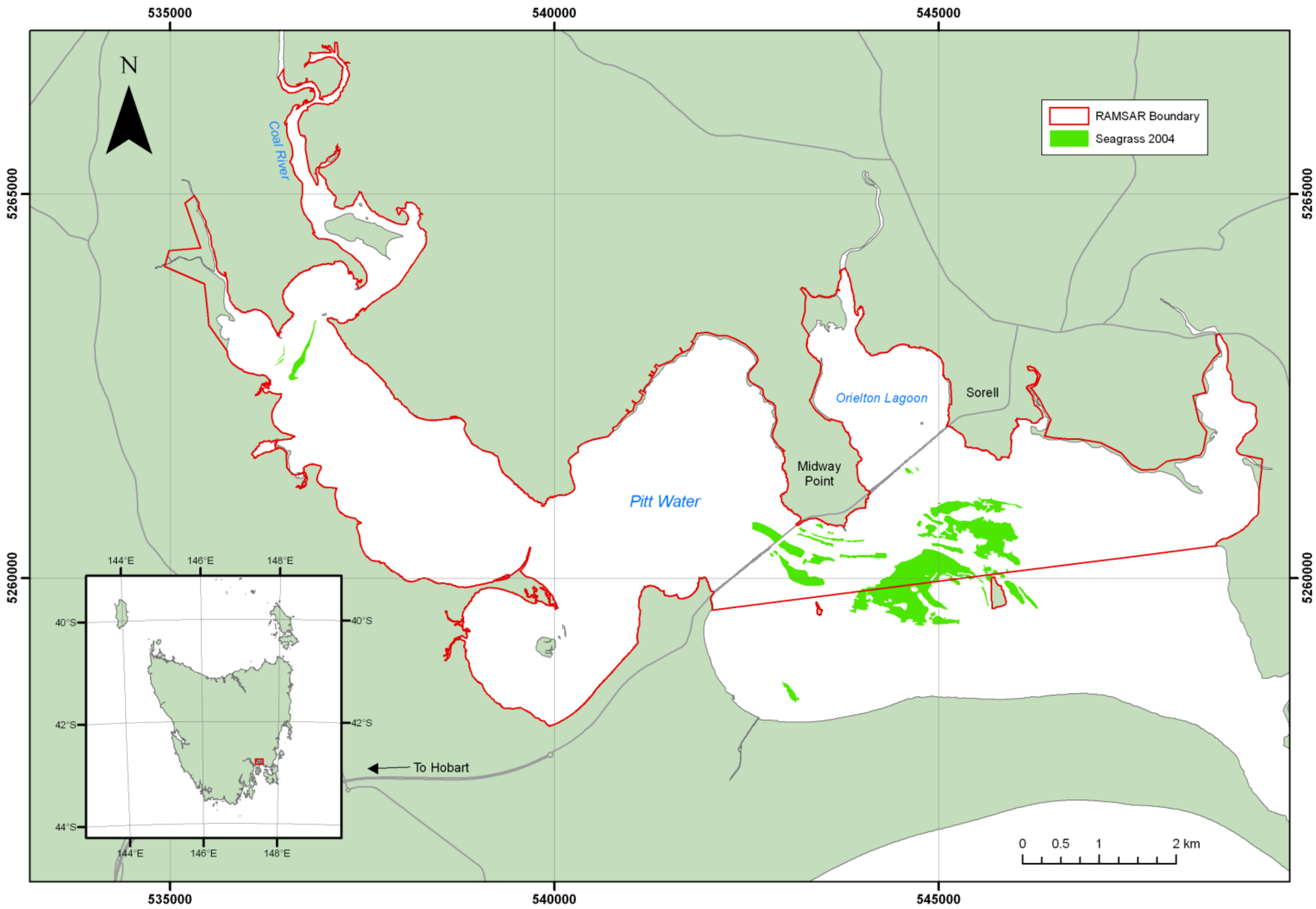


Figure 6.10: Distribution of seagrass in PWOL in 2004. (Source: M.Morffew, Centre for Spatial Information Sciences, School of Geography and Environmental Studies, University of Tasmania 2009. (Based on data in LIST, DPIW Tasmania).

The green alga *Codium* was observed in the 1960s and early 1970s colonising the edges of the shorelines and tidal flats that were flushed with sea water (Prestedge 1996). As water quality declined *Codium* disappeared and epiphytic growth on seagrasses was reported (Prestedge 1996). Loss of seagrass beds also occurred and dense growth of species of filamentous algae proliferated (Aquenal 2000).

The lowering of the culvert sills in 1993 released nutrient loaded water into Pitt Water and led to proliferation of the filamentous green alga *Endospira* sp (Aquenal 2000) in Lower Pitt Water. Prestedge (unpub, cited in Aquenal 2000) observed prolific growth of a range of species of green algae in Pitt Water over a period in the mid 1990s. This growth was attributed to increased nutrient levels but the sources were not identified.

Different conditions within Orielton Lagoon created different patterns of replacement of seagrass during the period the lagoon was closed off from tidal influence between 1953 and 1993. Filamentous green algae occurred in large areas and sometimes dried out causing unpleasant smells (Kinhill 1993). Several species of blue-green algae caused major blooms over the years, including *Aphanizomenon* in February 1986, *Oscillatoria* sp in 1992 and N*odularia spumigenam* in 1992 (Aquenal 2000). No macrophytes were evident by 1993 (Kinhill 1993). The algal blooms triggered intervention to improve the tidal exchange and reduce nutrient levels in the lagoon.

The loss of seagrass and patterns of algal growth demonstrate responses of marine plant life to changes in environmental conditions and are indicative of the history of changing hydrology and water quality within PWOL (Aquenal 2000). Loss of seagrass means loss of habitat and food for a range of fish and birds. The significant decline in seagrass beds appears to have caused similar declines in invertebrate and fish numbers and species (Millin Environmental Management Services 2000).

Seagrass is considered to be a good indicator of ecosystem health. A number of factors affecting the health of seagrass beds (Rees 1993) are know to occur in PWOL (Aquenal 2000). These include an increase in sediment deposition and localised poor water quality. While the water quality, especially turbidity and nutrient levels, of Orielton Lagoon have improved in the last decade, there appears to be no regrowth of areas previously vegetated with seagrass.

Comparison of Figures 3.16 and 6.10 demonstrates the ongoing loss of seagrass in PWOL. This appears outside natural variation but the seagrass does not appear to have lost further ground between 2004 and 2008, although different mapping techniques may have blurred the picture.

6.2.6 Changes in saltmarsh floristics, extent and condition

Comparison of saltmarsh communities mapped in 1975 with mapping undertaken in 2009 (Prahalad 2009) shows that since listing several significant changes to the saltmarsh communities and habitat have occurred. The changes have two principal dimensions: change in area and change in vegetation communities.

Saltmarshes lie at the interface of land and sea and are a naturally dynamic ecosystem. A number of factors influence saltmarsh topography including sediment deposition and erosion, tidal patterns, drainage, adjacent land use practices, and inputs of freshwater. Change in the extent of saltmarshes has been widely reported around the world (Prahalad 2009). The loss in area of saltmarsh shoreline at PWOL as it retreated landward between 1975 and 2009 exceeds gain in area of saltmarsh by a factor of four. An equal amount of saltmarsh has been lost on the landward side as a result of reclamation and drainage. There has been greater erosion of saltmarshes on the seaward side in the open estuary and exposed parts of the lagoon, and less severe erosion in inner estuary or more sheltered locations within the lagoon.

Prahalad (2009) also noted considerable changes in the vegetation community composition across many of the areas of saltmarsh in PWOL. There was an overall expansion of *Sarcocornia quinqueflora* and loss of the saltbush *Tecticornia arbuscula* and sedgey-rushy saltmarsh species such as *Austrostipa stipoides*, *Juncus krausii* and *Gahnia filum*. More areas of bare ground occurred in previously vegetated sites within the saltmarshes. The increase in bare ground occurred predominantly at the expense of *S . quinqueflora* and *T. arbuscula* dominated vegetation communities. A change from *T. arbuscula* to *S. quinqueflora* dominance was the biggest shift in terms of area and numbers of occurrences.

Changes at particular saltmarsh sites within PWOL are:

- in the Coal River area there was a loss of dominance by *T. arbuscula* and an increase in the area of bare ground;
- in the Duckhole area there was an increase in area of *S. quinqueflora* and of bare ground (Figure 6.11);

- in the Barilla Bay area a stand of *A. stipoides* and *T. arbuscula* has been lost, either to non-saltmarsh communities, bare ground or other saltmarsh species. Die-back of *T. arbuscula* at the back of the north eastern part of the Barilla Bay saltmarsh area resulted in about 14, 138m^2 of bare ground. In the areas of the saltmarsh in Barilla Bay which were exposed to regular tidal inundation the change from *T. arbuscula* dominated community to *S. quinqueflora* dominated community was extensive;
- in Orielton Lagoon, bare ground has been colonised by a range of saltmarsh species, the patterns of colonization following elevation within the marsh and tidal inundation;
- in Iron Creek there has been an increase in *S. quinqueflora* and bare ground with *Wilsonia humilis* colonising the slightly elevated ridges. At the seaward face, there has been a conspicuous loss of *A. stipoides* due to erosion (Figure 6.12); and
- At Orielton Lagoon the saltmarsh is recolonising areas which were once extensive bare ground as a result of freshwater inundation, fire and hypersaline conditions. The regrowth is patchy but both shrubby saltbush species *T. arbuscula,* and *Sarcocornia* spp are recovering (Figure 6.13).

Figure 6.11: Saltmarsh at Duckhole Rivulet showing extensive areas previously vegetated now bare ground, some coated with dead filamentous algae. (Source H Dunn May 2009).

Figure 6.12: Leading exposed edge of saltmarsh at Iron Creek spit retreating with loss of *Austrostipa stipoides.* (Source: H Dunn May 2009).

Figure 6.13 Recovery of saltmarsh at Orielton Lagoon with recolonization of bare ground by *T. arbuscula* and *Sarcocornia* spp. (Source: H.Dunn May 2009).

Several factors are likely to have contributed to these changes in the saltmarsh vegetation. These include length of inundation, salinity, freshwater supply, local topography and sediment processes. A feature of the hydrology of Upper Pitt Water is the increased tidal penetration since the time of listing and in particular within the last ten years or so. This would allow for increased tidal inundation of the marshes of the upper reaches of the estuary, affecting the high marsh species and favouring low marsh species. The effects of wave exposure are a significant factor in loss of saltmarsh in some areas of PWOL. These effects are shown in Figure 6.14 although some contribution to these changes may be attributed to the groyne effects resulting from an old railway line (Bradbury J, pers.comm. 2010).

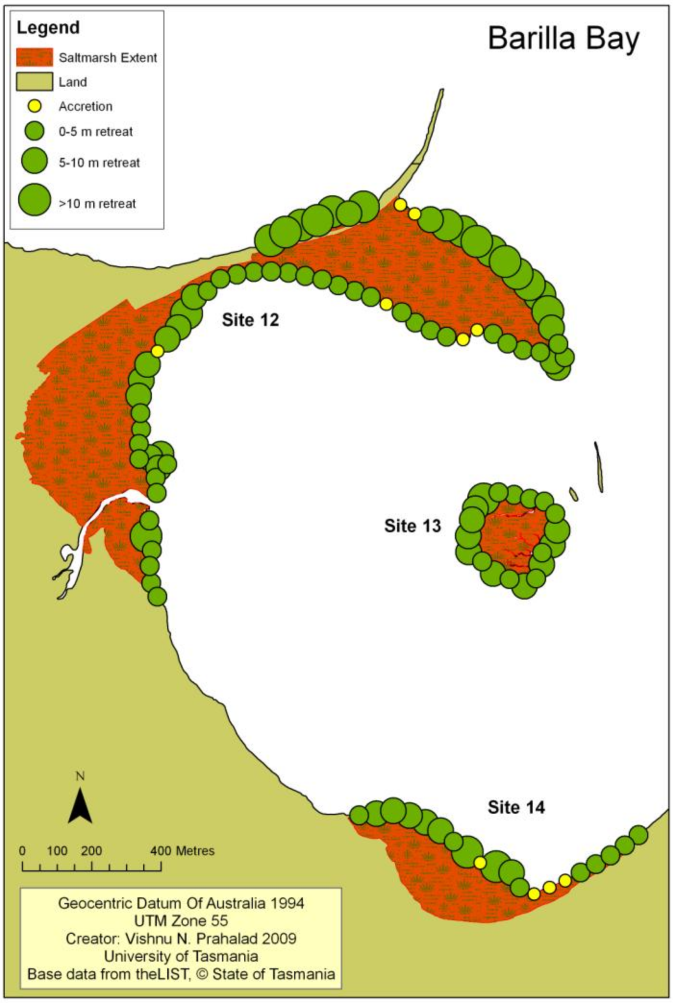


Figure 6.14 Accretion and erosion (retreat) of saltmarsh area in Barilla Bay between 1965 and 2005. (Source: Prahalad 2009).

There was no evidence to suggest a decline in saltmarsh-dependant flora or fauna listed under the Tasmanian *Threatened Species Protection Act 1995*. In fact, there is evidence that areas colonised by *Wilsonia humilis* may have increased (Prahalad 2009).

Changes in saltmarsh community composition and exposure of additional areas of bare ground and ponding have effects on invertebrate communities and available sites for roosting, feeding and nesting by shorebirds. Drying out of the upper reaches of the saltmarshes has facilitated invasion of exotic weed species in the saltmarshes. The introduced shrub African boxthorn *Lycium ferocissimum* is now widespread at the landward limits of the marshes.

The work of Prahalad (2009) has demonstrated widespread decline in saltmarsh extent and change in vegetation communities. The identified causes for these losses suggest that the extent of loss and limited replacement exceed natural variability. Landward limits of saltmarshes are constrained by some landowners, preventing natural shifts in such coastal communities and habitats. Some areas of saltmarsh have been drained or filled. On seaward edges, excessive loss has been occurring in exposed sites. In Upper Pitt Water saltmarshes are suffering under recent changes in river flow and tidal regimes which affect hydrology, sediment transport and sediment deposition. The observed changes are contrary to the expected expansion of saltmarshes in such a system under unmodified conditions.

6.3 Summary of changes in ecological character since listing

Three key changes in ecological character can be summarised from the observed changes. These are:

1. A change in the hydrology and associated processes in Upper Pitt Water
2. A change in the tidal regimes in Orielton Lagoon
3. A decline in biodiversity and abundance of communities throughout the site.

6.3.1 Change in the hydrology and associated processes in Upper Pitt Water

The causes of the change hydrology in Upper Pitt Water have been outlined: lower annual flows of freshwater are discharging from the Coal River and peak flow periods have been reversed (summer in place of winter). Some recent years have had no peak flows, although 2009 was exceptional. The changes have been caused by construction of an in-stream dam and increased use of irrigation in summer. The consequences have been exacerbated by a series of very dry years, a trend predicted to continue under climate change scenarios.

Data on the particular effects of these hydrological changes on the ecology of the estuary are limited. Anecdotal information suggests that the saline tidal wedge penetrates further up stream, as far as the Richmond weir. Saltmarshes in Upper Pitt Water have responded to this inundation with a decline in shrubby *T. arbuscula* to be replaced by *S. quinqueflora* and bare ground. The absence of flushing flows has caused changes in sediment transport and deposition contributing to the changes in saltmarsh distribution and community structure. Local residents report increases in sediment depths in some locations of up to 0.5m.

Freshwater outflows and flushes are required to trigger native fish spawning behaviours and play a role in attracting juveniles of marine species such as flounder and shark (Davies *et al* 2002). Local residents report no whitebait runs in recent years.

Davies *et al* (2002) provided recommendations for environmental flows in the Coal River to maintain estuarine health. These recommendations are based on modelled natural flows for the system together with analysis of two levels of risk (minimal and moderate) for environmental flow thresholds. The recommended patterns were based on established procedures for determining appropriate environmental flows and take into account the natural occurrence of drought years (Table 6.1).

Table 6.1: Recommended initial pattern of high/flood flows for the Coal River, based on historical median and annual floods, and adjusted trigger and fresh events. (Source: Davies *et al* 2002).

	Normal years			Drought years		
	Peak ht (cumec)	Duration (days)	Timing	Peak ht (cumec)	Duration (days)	Timing
At Dam						
Median	10.0	1	1 per 2 years			
Annual	5.0	1	1 per year			
Trigger	3.0	1	2 per year, spring and autumn	2.0	1	1 per year in autumn
Freshes	0.5	0.5	1 per month, May to November	0.5	0.5	3 per year, May to November
At Richmond						
Median	20.0	1	1 per 2 years			
Annual	10.0	1	1 per year			
Trigger	5.0	1	2 per year, spring and autumn	2.0	1	1 per year in autumn
Freshes	0.5	0.5	1 per month, May to November	0.5	0.5	3 per year, May to November

The extremely low base flows, reversal of season of any peak flow and loss of flushing flows exceeds the Limits of Acceptable Change for freshwater flows in the Coal River.

6.3.2 Change in the tidal regime in Orielton Lagoon

At the time of listing, the minimal tidal exchange allowed between the body of the lagoon and the main Pitt Water system led to poor water quality and toxic algal blooms. The creation of several new culverts and two drainage channels was designed to improve water quality while retaining the intertidal habitats. The culvert sills are set at mid-tide level, hence still limiting full exposure of the flats. A very wet year in 2009 led again to (non-toxic) algal blooms suggesting the lagoon remains responsive to nutrient loads. Proposed Limits of Acceptable Change reflect the aims of the tidal management regime.

The intervention to increase tidal flows and water circulation within Orielton Lagoon in 1993 is a positive change in the ecological character of PWOL. It is likely that after only 17 years of changed regime Orielton Lagoon is yet to reach a new stable state.

6.3.3 A decline in biodiversity and abundance of communities throughout the Site

At the time of listing, PWOL was assessed as meeting Criterion 3: ‘A wetland should be considered internationally important if it is a particularly good example of a specific type of wetland characteristic of its region’ (1980 criteria, see Appendix 1). This referred to both physical form and biota. In 2009 the condition of the site is assessed as ‘extensively modified’ (http://www.ozcoasts.org.au/search_data/detail_result.jsp). In addition, the Criterion for representativeness, Criterion1 in the 2005 set, (see Appendix 1) now requires a representative wetland to be in ‘natural or near-natural condition’. Thus the site no longer meets this criterion.

It is difficult to set limits of acceptable change for most of the biotic components of the ecological character of PWOL due to limitations on data sets and lack of knowledge of natural variation. There is quantifiable evidence of declines in two communities and contraction in habitat area occupied by one species:

- a significant loss in the area of seagrass continuing a progressive decline noted prior to listing
- a decline in saltmarsh with conversion to areas of bare ground and replacement of saltbush *Tecticornia* with *Sarcocornia* and consequent loss of associated flora and fauna

- the distribution and abundance of the endemic seastar *Parvulastra (=Patiriella) vivipara* has declined .

There is corroborating evidence of a loss of species diversity and abundance across other taxon groups (Aquenal 2008) and different habitat types, including: fish, benthic invertebrates, shorebirds and waterbirds.

The likely causes of these declines are common to estuaries across Australia (http://www.ozcoasts.org.au). Factors clearly evident in PWOL include: changes to freshwater flows, nutrients, urban developments, overfishing, introduced species, human disturbance, sediment loads and climate change. Factors external to the site may also be implicated.

Overall, the evidence points to a change in ecological character with a demonstrable shift to an estuary with less diverse and abundant communities at risk of further decline.

6.4 Conceptual models for current components and processes

The observed changes at PWOL are summarised in the following models. Conceptual models for two areas of the site at the time of listing are shown in Section 4. These are updated for the present time (2009) and 'section' models are added to provide comparison between 1982 and 2009.

6.4.1 Upper Pitt Water

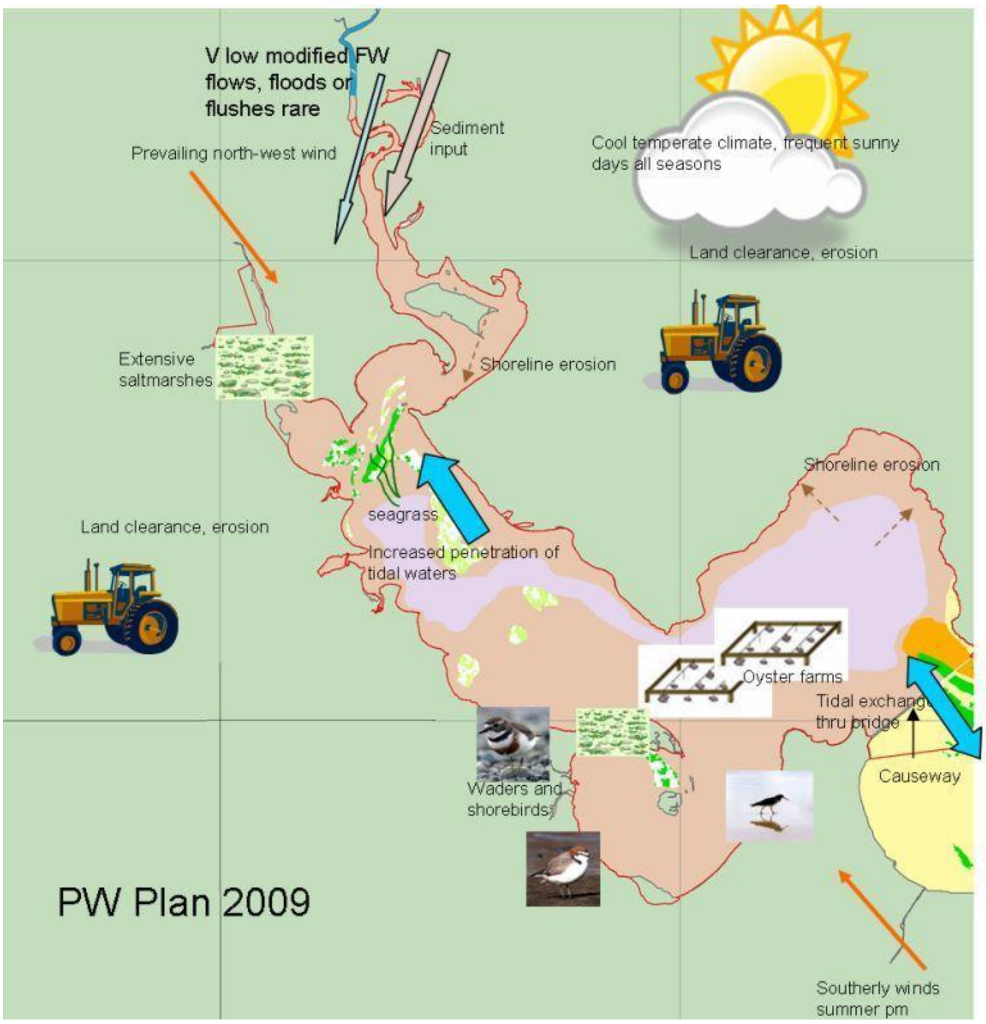
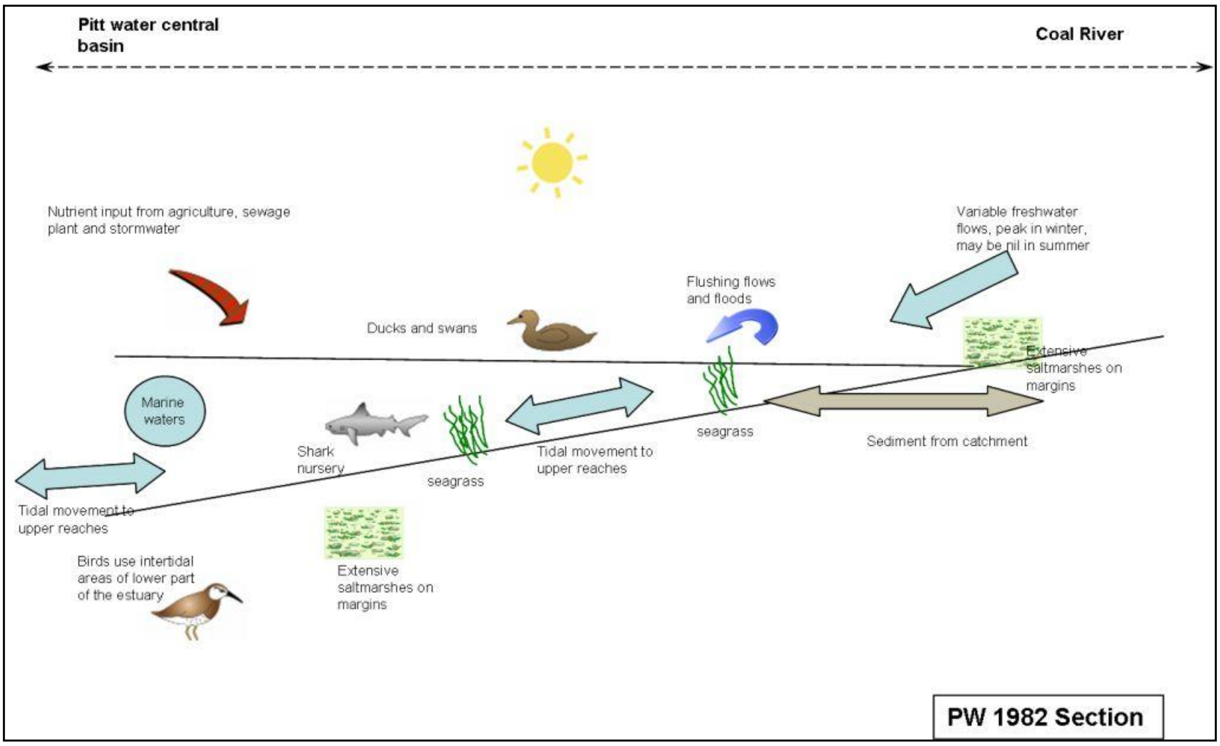


Figure 6.15: Conceptual model of Upper Pitt Water in 2009- plan view.

Differences between 2009 and 1982 (see Figures 4.4 and 6.15) are: lower and modified river flows without floods as a consequence of the Craigbourne Dam and increasing abstraction; lower sediment input; increased upstream penetration of tidal waters; increased shoreline erosion; introduction of marine farming at Barilla Bay; loss of much of the seagrass; loss of area and condition of saltmarshes: possible reduction in shark breeding; limitation of movement of anadromous fish species, and lower numbers of migratory waders. These changes are summarised in section view (Figure 6.16).



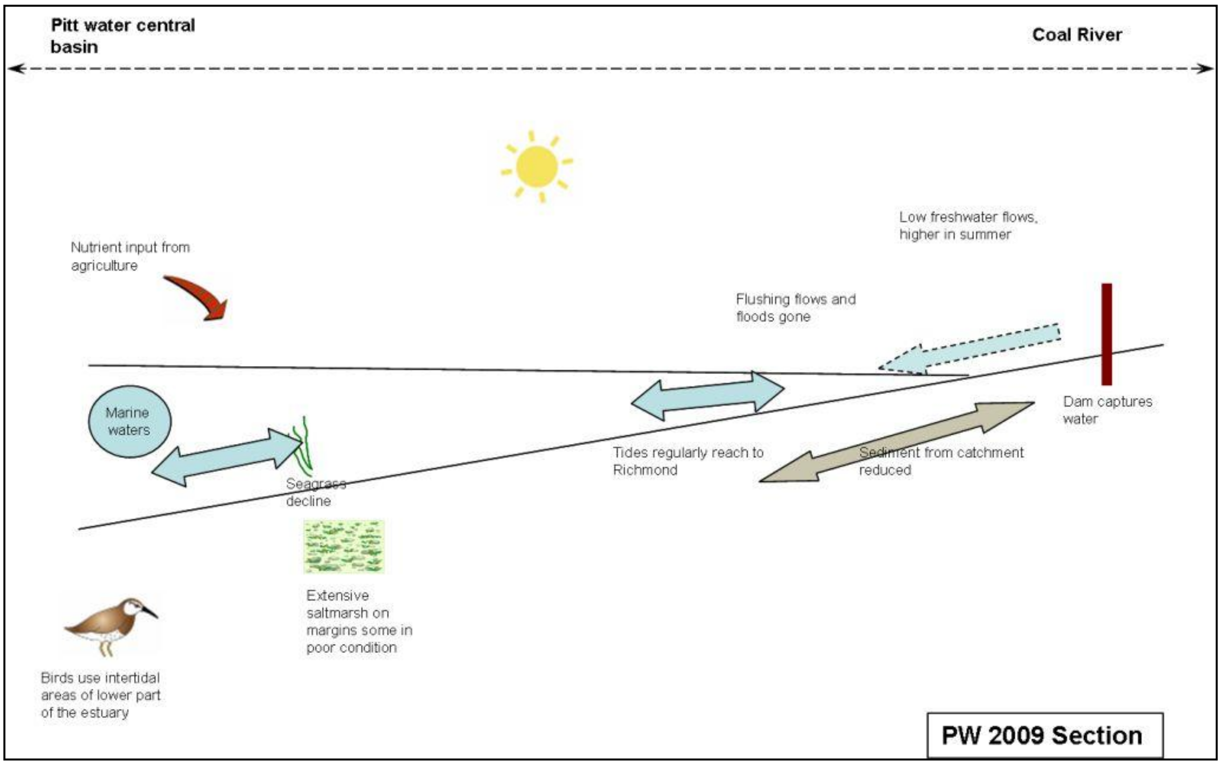
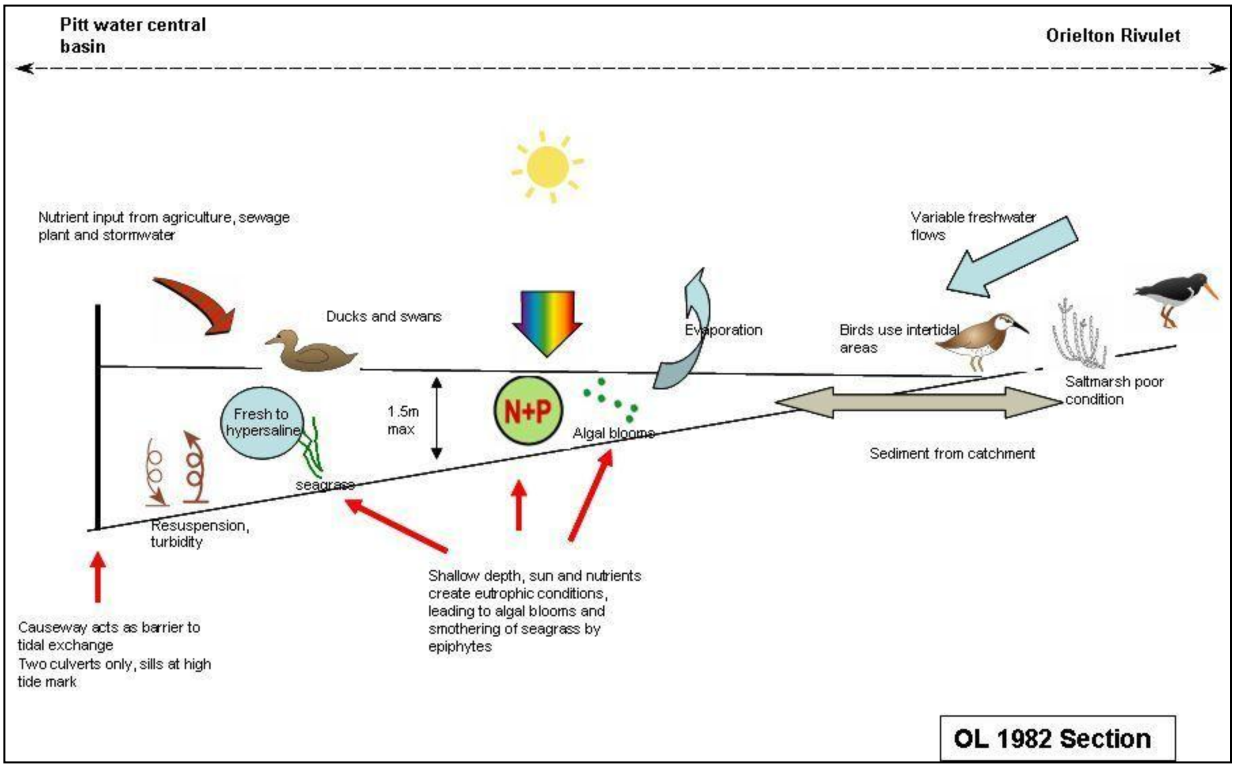


Figure 6.16: Conceptual model of Upper Pitt Water: section view comparing 1982 and 2009

6.4.2 Orielton Lagoon

Figure 6.17: Conceptual model of Orielton Lagoon in 2009- plan view.

Differences between 2009 and 1982 (see Figures 4.5 and 6.17 and section views in 6.18) are: increased tidal exchange and closure of STP resulting in better water quality (now marine), improvement in saltmarsh condition by recolonisation; absence of algal blooms, loss of seagrass, as yet no re-colonisation; increased shoreline erosion and stormwater inputs; increased sediment deposition and establishment of saltmarshes on eastern shoreline and SW corner; increased urban development; lower numbers of migratory waders.



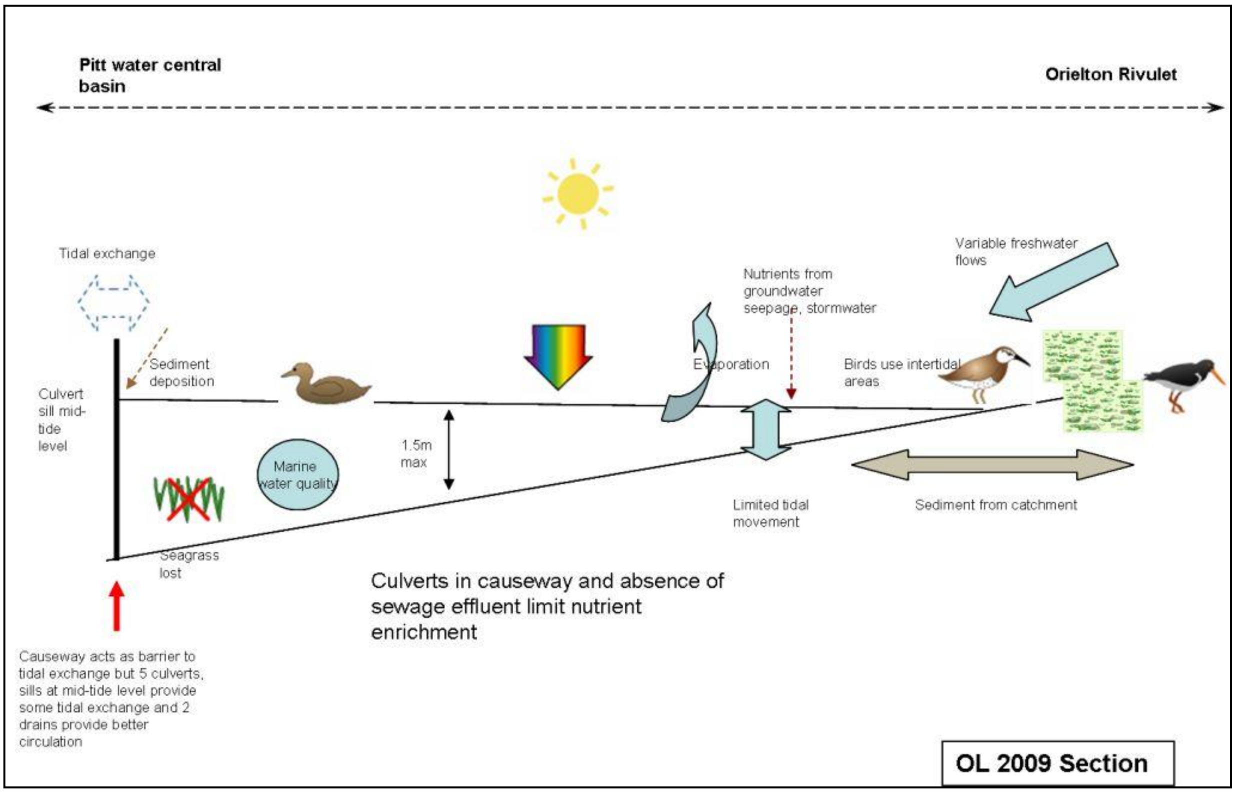


Figure 6.18: Conceptual model of Orielton Lagoon: section view comparing 1982 and 2009.

Section 7 Threats to PWOL

7.1 Introduction

Coastal environments that are recently developed in geological terms are in an ongoing state of evolution and change as a consequence of natural processes. The nature of threats must be seen in the context of the natural evolution of the estuary. In the case of PWOL, the natural processes of the estuary are considerably modified by the construction of barriers (the causeways) across the main waterway. In addition, land clearance and agricultural practices going back decades have left legacies of changes to sediments and water quality, as well as river regulation and abstraction. The outcomes have been particularly dramatic in Orielton Lagoon. Since listing in 1982, positive changes had been made to the functioning of this system with a return to more normal estuarine processes of tidal exchange and nutrient cycles. The threats listed below (Table 7.1) emerge from observed trends in components and processes, and in developments in the surrounding lands and catchment areas.

Some types of threats interact, raising the likelihood of impacts on the system. For example, loss of flows, especially flushing floods, in the rivers exacerbates the effects of erosion as the additional sediments entering the waterway do not get flushed through the system. Another example is increasing natural salinity in the catchment which, if coupled with drier and warmer climatic conditions, leads to compaction, salt scour and change in species composition in saltmarshes.

Key threats to PWOL are:

- Loss of freshwater inputs to system
- Changes in sediment transport
- Agricultural activities adjacent to PWOL
- Waste products
- Urban and rural development
- Invasive species
- Climate change.

Table 7.1: Threats to PWOL, potential impact on ecological character, likelihood of occurrence and timing.

Actual or likely threat or threatening activities	**Potential impact(s) to wetland components, processes and/or services**	**Likelihood**	**Timing of threat**
Significant change to freshwater input into estuary system • Absence of environmental flow regime for Coal River • Increased abstraction for water for irrigation in all catchments • Increase in demand for groundwater use	• Further alteration of hydrological regimes in upper Coal River • Loss of flushes • Increase in salinity of upper Pitt Water/loss of some estuarine characteristics of Coal River below Richmond • Change to some saltmarsh communities through loss of some saltmarsh species requiring lower salinities, leading to loss of saltmarsh biodiversity and potential loss of rare species • Loss of anadromous fish species • Loss of trigger for reproduction or migration of some fish species	Certain	Immediate

Table 7.1: Threats to PWOL, potential impact on ecological character, likelihood of occurrence and timing (continued)

Actual or likely threat or threatening activities	**Potential impact(s) to wetland components, processes and/or services**	**Likelihood**	**Timing of threat**
Changes in sediment transport • Loss of mobility and renewal • Smothering of seagrass • Change in sediment quality in key feeding areas • Bank erosion • Change in nature and distribution of landform units	• Excessive erosion or deposition changes habitat and alters flow patterns • Loss of habitat, feeding areas for waders • Affects health of seagrass • Affects composition of sediments (size fractions and organic matter) so less suitable for wader prey species	High	Immediate/Medium
Agricultural activities adjacent to PWOL • unrestricted stock access • overgrazing and land clearing resulting in erosion • nutrient overload, including irrigation with recycled water • increase in salinity in water table • potential disturbance of ASS soil • disturbance of dispersive soils	• Trampling of saltmarsh vegetation causing compaction and ponding, alters hydrology within marshes • Sediments wash into river from eroding banks • Increase in nutrient disrupts carbon cycle and can lead to algal blooms and death of seagrass • Increasing salinity in catchment	High	Immediate/Medium

Table 7.1: Threats to PWOL, potential impact on ecological character, likelihood of occurrence and timing (continued)

Actual or likely threat or threatening activities	**Potential impact(s) to wetland components, processes and/or services**	**Likelihood**	**Timing of threat**
Waste products • stormwater discharge • excess sewage outfall • food processing • quarrying • industrial development and construction sites • leakage or discharge from golf course irrigation and drainage	• Increase nutrient load especially in enclosed waters of OL • Risk of noxious chemicals and pathogens • Local effects of increased nutrient load at Sorell Point outfall	Medium/certain *Note: risk high during high rainfall events*.	Immediate
Urban and rural development • additional subdivisions affecting run-off • disturbance from human activities including cycles, trail bikes, pets, horses, light pollution, • potential disturbance of ASS soils • disturbance of dispersive soils	• Change in water quality and quantity in OL • Disturbance to flora and fauna, especially birdlife • Infrastructure on shorelines to provide for recreational use	Certain	Immediate

Table 7.1: Threats to PWOL, potential impact on ecological character, likelihood of occurrence and timing (continued)

Actual or likely threat or threatening activities	**Potential impact(s) to wetland components, processes and/or services**	**Likelihood**	**Timing of threat**
Invasive species • saltmarsh flora • marine pests • birds • extension of range of aggressive native species	• Reduce habitat eg boxthorn in saltmarshes and on rocky shoreline • Compete with native flora species • Displacement of species • Changed geomorphic processes of sediment trapping and binding	Certain	Immediate
Climate change • sea level rise • increase in temperatures • decrease in rainfall • increase in windiness	• Altered hydrological regimes including loss of flows, higher tides, increase in fetch • Reduction in water depth in OL and parts of Upper Coal River • Impacts on flora and fauna eg increase spread of species including introduced species • Retreat of some shoreline, loss of key habitat	Medium	Medium/Long

7.2 Discussion - the key threats to PWOL

7.2.1 Loss of freshwater inputs to PWOL

PWOL is an estuarine system, albeit with a negative hydrology as a consequence of a naturally low flow from the main river systems. Section 3 details the relative volumes and flow patterns resulting from dry climate and small catchments. Rainfall has, since the earliest records of some 60 years ago, been variable from year to year but before 2009 there had been a series of low rainfall years.

Increasing numbers of dams and use of water for irrigation, notably the construction of the Craigbourne Dam in the Coal River, has further reduced the volume of flow and a loss of the former occasional flushing flows. An assessment of environmental flow requirements for the estuary (Davies *et al* 2002) has not been implemented. An unusual high rainfall year in 2009 does not reduce the need to address the issue of environmental flows in the Coal River on a long-term basis.

7.2.2 Changes in sediment transport

Anecdotal information and observation suggest that the processes of sediment transport continue to be disrupted as a consequence of long-term human intervention in tidal movements at Orielton Lagoon and as a consequence of the limited flows in the Coal River. These are noted in Section 6: Changes since listing. Data are not available on the nature and extent of this trend.

7.2.3 Agricultural activities adjacent to PWOL

Improvements have occurred in agricultural practices by many landowners. However, some poor practices continue, such as allowing stock access to the water’s edge, refuse disposal and dumping near or at the waters edge and poorly managed irrigation (Figure .7.1).

The legacy of past overgrazing and clearing of vegetation in the riparian zone allows continued sheet, rill and tunnel erosion (Figure 7.2). Fine sediment is then transported into the waterway where it may form a layer of unconsolidated sediment over the stream bed, shoreline and intertidal areas.

Excavation for land drainage and installation of services and assets such as water pipelines and underground cables are the main potential threats to the disturbance of acid sulfate soils in the agricultural areas. ASS are often overlain by colluvial, windblown or beach sediments that are often utilised for production.

(a) Irrigation spray and wash-outs

(b) Stock trampling – sheep and cattle hoofprints in saltmarsh

Figure 7.1: Affects of poor agricultural practices on the Coal River estuary ecosystem. (Photos: (a) I Houshold (b) H Dunn 2009).

Figure 7.2: Bare ground and erosion in the Upper Pitt Water/Coal River. (Photos: B.Hardwick March 2009)

7.2.4 Waste products and nutrients

Orielton Lagoon is a semi-enclosed waterway particularly vulnerable to inputs from stormwater. It has 11 such outlets, only 2 of which have gross sediment traps (G. Robertson pers.comm.). On the Sorell shoreline of the lagoon there are five discharges: none of the pipes has any stormwater treatment. On the Midway Point shore there are six outfalls, two have sediment traps but are reported to be difficult to access for maintenance.

In addition, a number of drains carry surface water from the causeway into the lagoon. There is a moderate and ongoing risk of noxious substances flowing into the lagoon from these sources. Additional subdivisions in the Sorell area and industrial developments adjacent to Barilla Bay will add to the problem.

Considerable improvements have been made to sewage treatment processes and outfalls in the area. Three smaller plants with low levels of treatment (at Cambridge and Hobart Airport) have been decommissioned and construction of a larger and higher treatment operation at Hobart Airport now discharges treated waste into the larger volume of Lower Pitt Water (Gallagher pers.comm.). The small plant at Richmond has secondary treatment and is stored for re-use in irrigation. The Midway Point plant was upgraded in the late 1990s to reduce nutrient release and by 2007 was de-commissioned. Currently effluent is treated and pumped to holding ponds further up the catchment at Penna from where it is sold for irrigation. Some output from the Sorell plant is pumped to the Penna holding ponds but the excess waste, which is only secondarily treated, is released into the lower reaches of the Sorell Rivulet. While this can prove an effective waste management strategy, it appears that the extended period of heavy rain in 2009 led to leaching of nutrients from such grey water use into parts of the site, particularly Orielton Lagoon.

Output from the Sorell plant to the mouth of the Sorell Rivulet has potential to affect the water quality and biota in the small estuary and nearby flats.

7.2.5 Urban development

Sorell is one of the fastest growing municipalities in Tasmania. Comparison of air photos over the decades, and particularly since the time of listing of the Ramsar site, show that the area surrounding Orielton Lagoon in particular has had huge growth in urban developments, largely residential subdivisions. More people are using the area for exercise and recreation, including dog walking, cycling and trail bike riding. The disturbance caused by these activities is affecting the values of the site with damage to vegetation and reduction of available sites for feeding and roosting for shorebirds and waders. The construction of a cycle way at the causeway in the southwest corner of OL displaced Pied oyster catchers and Bar-tailed godwit from roosting. Oyster catchers also nested in that area. Increasing awareness has led to the construction of fencing and signage to deter access directly onto the shoreline at critical points near Sorell. Excavations for urban infrastructure and housing close to the waters edge as well as unauthorized recreational vehicle disturbance from trail bikes and 4 wheel driving in the supra and extratidal areas are the main threat to the disturbance of ASS in the urban areas. Increased numbers of housing developments and associated problems will continue to be a threat to PWOL.

7.2.6 Invasive species

Invasive species are a constant issue for sites close to human activity such as PWOL. An extensive list of introduced plant species has been recorded within the site, including species such as African boxthorn *Lycium ferocissimum* and *Plantago coronopus*, which can invade the saltmarsh fringe, and numerous marine pests occur within the wider Derwent Estuary area (Aquenal 2008a).

There are at least 80 introduced species in Tasmanian waters (Alastair Morton pers.comm.). Introduced marine species can disperse readily and those which pose risk in Australian waters are designated under the Consultative Committee for Introduced Marine Pest Emergencies (CCIMPE). National Control Plans have been developed and agreed for six of the most serious marine pasts in Australia, all of which occur in Tasmania. These are: *Asterias amurensis (*Northern Pacific seastar), *Undaria pinnatifida (*Wakame, Japanese seaweed*)*, *Varicorbula gibba (*European clam), *Carcinus maenas (*European green crab) *Musculista senhousia* (Asian date mussel), *Sabella spallanzanii* (fan worm). The first four of these species are established on the south east coastline of Tasmania, including the Derwent estuary.

A study of the Port of Hobart from the Tasman Bridge to the Royal Yacht Club at Sandy Bay identified about 70 introduced and cryptogenic species (Aquenal 2008a). The Pacific seastar is considered to be a particular threat because of its fecundity, dispersive capacity and foraging behaviour (Aquenal 2008a). Gut contents indicate that it has ‘the potential for considerable impacts on assemblage of native benthic species' (Aquenal 2008a, p 78). The preferred prey species of the Pacific seastar include species such as bivalves which are also prey items for shorebirds.

Evidence from the study for the Port of Hobart undertaken in 2002 led to the conclusion that the range of pest species was likely to be impacting on the benthic ecology and environmental health of the estuary (Aquenal 2008a). The authors further suggest that contaminants can exacerbate the impact by increasing the susceptibility of the region to invasions by marine pests. PWOL was not included within the survey area although its waters are contiguous with those of the Derwent estuary (Figure 1.2).

The Pacific oyster *Crassostrea gigas* was introduced into Pitt Water for shellfish farming in the 1920s and 1930s. These early trials were commercially unsuccessful but are thought to have been the source of early invasion of this introduced species. Feral populations of oysters have established in natural habitats of PWOL.

Pitt Water area is considered to be currently relatively free of introduced species with the exception of the Pacific oysters (Alastair Morton pers.comm. 2009). Oyster farmers in the area indicate that they find very few introduced species and baseline surveys for each new marine farming lease established in Pitt Water have so far found no introduced species. Under licensing conditions, marine farmers are required to report any marine pests detected on their lease area (Alastair Morton pers.comm. 2009).

Figure 7.3: Northern Pacific Seastar, an introduced marine pest widespread around Tasmanian's south-east coasts. (Source: Identification guide for northern pacific seastar, DPIW)

Changes and pressure on habitat availability in the wider Derwent Estuary area can bring greater numbers of a native species into PWOL area, causing displacement of other species. Kelp gulls (*Larus dominicanus*) are increasing in number in Southern Tasmania and are now feeding, roosting and nesting in areas of Orielton Lagoon used by migratory waders (P Park, pers.comm.). The consequences of this are not clear.

Invasive species may also be native species that flourish under conditions where the system is out of balance or under stress. Some, such as certain algae, can cause serious short-term problems as a consequence of eutrophication. Under such conditions, epiphytic algae can smother seagrass, blue – green algae can create toxic blooms and some algae are potentially a concern for marine farm operations.

Feral cats are present within the site and potentially prey upon some bird species at roosting sites.

7.2.7 Climate change

Evidence is building for changes in mean temperatures, rainfall, and sea level rise. Edgar *et al* (1999) note that climate change can have three key effects on estuarine systems: increasing water temperatures, modified rainfall patterns and sea level rise. A fourth change is increased storminess, hence storm surge height and frequency (J. Bradbury, pers.comm. 2010). These predictions suggest change to the system hydrodynamics. Changes in climatic conditions are likely to have different consequences for different species. Higher mean temperatures and lower rainfall can affect seasonal patterns of abundance, reproductive cycles, migration patterns and biodiversity. The most visible indicator of possible climate change is sea level rise and erosion of shorelines.

At PWOL, several shorelines exhibit steady erosion, though it is unclear whether the rate of erosion has increased in recent years (Figures 7.3, 7.4). It is possible that loss of some former habitat for the seastar *Parvulastra vivipara* at Penna may be due to increasing erosion of the siltstone backshore, coating the rocky shoreline with fine silt. Some saltmarshes appear to be eroding and new marine channels developing as a result of increasing penetration of tidal waters. Erosion may be due to several interacting factors, for example increased tidal penetration due to loss of river flows, increasing tidal surges, rising sea levels, vegetation clearance and increase in windiness.

Mapping of the vulnerability of coastlines in Tasmania shows that many sectors of PWOL are highly vulnerable to change (Figure 7.5). Some of the sandstone shores (rocky, some a bit cliffed) that have been included in the "High Vulnerability" shoreline class are the rocky sandstone shores around Midway Point and PittWater Bluff. These may be more correctly classed as "Minimal Vulnerability" class, at least in terms of their vulnerability to coastal erosion. The remaining high vulnerability shores on the map are soft saltmarsh shores and clayey Tertiary sediment shores, both of which are highly erodible (C.Sharples, pers.comm 2009).

(a) Eroding beach ridge saltmarsh, Iron Creek spit

(b) Eroding succulent saltmarsh and tidal channel, Duckhole Rivulet

Figure 7.4: Erosion on leading edges of saltmarshes possibly due to effects of sea level rise or climate change. (Images H. Dunn April 2009).

(a) Erosion at Sorell Point (H Dunn May 2009)

(b) Erosion at Shark Point Road, Penna (H Dunn May 2009)

Figure 7.5: Erosion on the shorelines of PWOL, May 2009.

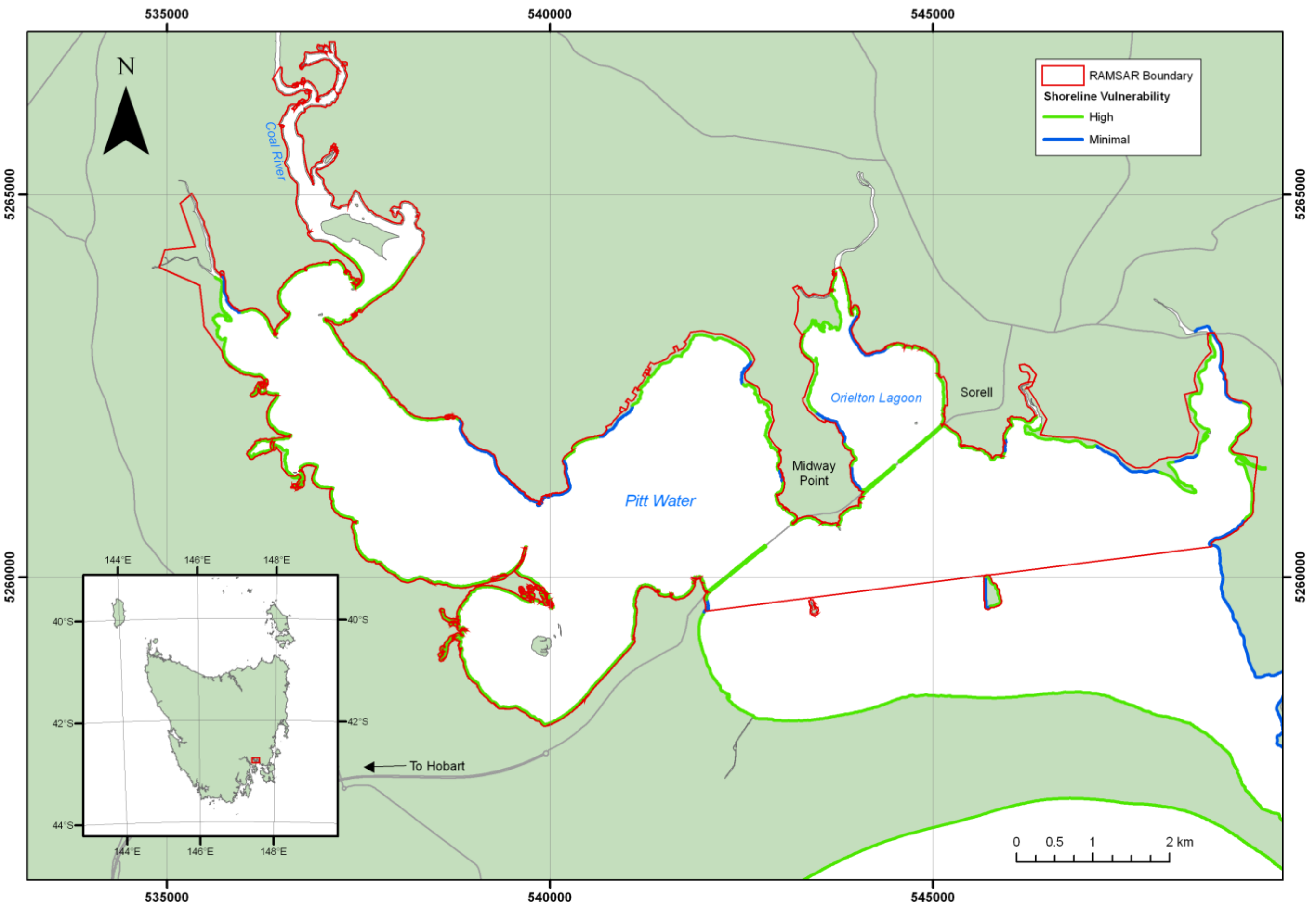


Figure 7.6: Vulnerability to climate change of shorelines at PWOL. (Source: M.Morffew, Centre for Spatial Information Sciences, School of Geography and Environmental Studies, University of Tasmania 2009, based on data from Sharples 2006).

Section 8 Knowledge gaps

The compilation of the ECD relied on information that was patchy, limited spatially and temporally and often targeted for a particular development or activity rather than to gain information or understanding about the ecological character, the components and processes of the site. There are very little time series data, this being limited to climate data. Flow data were limited by changes in use of various stations and missing records. Observations and recording of bird sightings were sporadic in earlier years and methodology not standardised until 1984. Only one comparable data set is available for biological components of PWOL applying at the time of listing and in the present. This is the survey of saltmarsh vegetation conducted in 1975 (Glasby 1976) and repeated in 2009 (Prahalad 2009).

Identified knowledge gaps and suggestions for monitoring or other action to address the gap are shown in Table 8.1

Table 8.1: Identified knowledge gaps for PWOL with suggested monitoring or other action to address the gap.

Component	Specific component or process	Identified knowledge gaps	Suggested monitoring or other action to address the gap
Freshwater flows	Flows downstream from Richmond	Patterns of freshwater flows	Maintain continuous monitoring at Richmond and upstream sites
	Flows in Orielton Rivulet (station close 1996)	Patterns of freshwater flows ,	Reinstate and maintain continuous monitoring at Brinktop Road
Geomorphology	Sediment transport in upper Coal River	Contribution of shoreline erosion to sediment budget Rate of deposition and mapping of depositional features	Sediment budget Assess depositional features from air photos as baseline Sediment pin monitoring at key sites
	Intertidal flats used as feeding area	Intertidal exposure at OL under different tide levels	Map and model exposure
	Sediment transport within OL	Rate and areas of deposition and erosion Sediment sources	Map and model sediment deposition and erosion Measure sediment input from rivers and shoreline
	Sediment movement, channel development and geomorphic condition of flats south of causeway at Sorell	Depth and nature of sediments at tidal flats near Sorell Sediment sources and channel characteristics	Investigate depth, characteristics and sediment transport of tidal flats below 2nd causeway.

Table 8.1: Identified knowledge gaps for PWOL with suggested monitoring or other action to address the gap (continued).

Component	Specific component or process	Identified knowledge gaps	Suggested monitoring or other action to address the gap
Tidal movements	Tidal penetration to Richmond	Height and residence times for saline waters to the head of the estuary at Richmond	Monitoring of salinity and salinity profiles from 1st causeway to Richmond
	Tidal exchange and tidal processes in OL	Extent of exchange of tidal waters in and circulation patterns in Orielton Lagoon	Monitor tidal exchange and circulation under different tidal regimes
	SLR and impacts on saltmarsh and shorelines	Extent of SLR impacts compared with natural change in evolving system	Expand shoreline vulnerability studies to key areas of high sensitivity/significance
Water quality in Orielton Lagoon	Water quality characteristics across extent of Orielton Lagoon	Single site only near causeway, need validation for representation of entire lagoon.	Comprehensive survey of water quality in Orielton Lagoon, including near stormwater outlets
Fish community	Fish nursery areas	Status of fish nursery areas, available habitat for different species	Mapping of types of sediments and seagrass in relation to tidal movement, exposure
Invertebrate communities	Prey species for waders at all favoured locations	Compare with 2 areas sampled and full range of prey species	Surveys of invertebrate communities
	Saltmarsh invertebrates	Species at all saltmarsh sites and habitat types	Surveys of invertebrate communities
	Pelagic invertebrates Benthic invertebrates of open marine waters	Presence and abundance Presence and abundance	Surveys of invertebrate communities

Section 9 Site monitoring needs

Significant information gaps have been identified in Section 8. Baseline information is required for several key components and processes. Therefore, an important component of monitoring is the setting up of sound and replicable baseline data to address these gaps.

Monitoring must be cost-effective, using remote or automated systems where possible, building on monitoring requirements for other needs or users. In addition, it may be important to consider some data and trends within a wider context of similar ecosystems in Southern Tasmania. Thus, surveys such as the Southern Estuaries program (Temby and Crawford 2008, 2008a) and integrated surveys undertaken by NRM South will provide not only data for PWOL but also enable comparison with other estuaries. Routine surveys of water quality for monitoring effluents, discharge and potential operational effects of users of the waterway, such as marine farms and wastewater treatment, can provide evidence important to monitoring the status of PWOL.

Surveys will be the most costly of these monitoring actions, so these must be designed with the most appropriate sampling strategies to maximise effort and to ensure that, as far as possible, the surveys will allow for comparison with similar ecosystems elsewhere. The use of surrogates, keystone or indicator taxa and targeted surveys should also be considered.

Davies *et al* (2002) identified monitoring needs in the context of environmental flow requirements for the Pitt Water estuary. These are based on the assumption of allocation of water to the Coal River to address the problems resulting from low flow and loss of natural peaks in flow patterns. Some of these monitoring needs are just as appropriate for monitoring the changes in ecological character of PWOL. Further monitoring needs address the situation of Orielton Lagoon and its particular Ramsar values.

The objective of monitoring is classified in the following categories in accordance with the ECD framework (DEWHA 2008):

- establish baseline
- detection of change
- establish limits of acceptable change

- ongoing condition.

‘Frequency’ is the suggested time frame for monitoring activities, either in establishing baseline information or to detect change. In the absence of detailed knowledge of all ecosystem processes and the influence of external factors, these are estimates only. Some indicators may be considered sensitive indicators of change at a system level. Monitoring may be a higher priority at more frequent intervals for that reason. Seagrass is generally considered to be one such indicator.

Priority is assessed against value as indicator of change in critical components, processes or services, availability of baseline data and practicality for monitoring. Some important Ramsar values, such as counts of migratory waders and other birds, are currently monitored on a systematic basis. Reference to such monitoring is included in the table for completeness. However, such data is variable and subject to external factors beyond the site boundaries and may therefore be unsuitable for assessing short-medium term trends. The results can be improved by including local resident birds in the surveys. The current status of some important Ramsar values has been documented within recent years but not as part of a Ramsar monitoring framework. These include detailed mapping of the area and communities of saltmarsh and distribution and abundance of the seastar *Parvulastra vivipara.* These studies provide good baseline information on which to build.

Some water quality parameters documented in previous studies provide valid but patchy information, therefore infill of these data is required for particular areas to provide a complete picture of the site.

Monitoring proposals are set in the context of Limits of Acceptable Change, Table 5.3, values for which the site is listed and supporting services to maintain the site’s ecological character.

Table 9.1: Monitoring actions for PWOL.

Component, process or ecosystem service	Specific component, process, or service	Objective of monitoring	Indicator or measure	Frequency	Priority
Freshwater input	Flows in Coal River at Richmond	Ongoing condition	Flow above Richmond weir (continuous monitoring)	Review data annually	High
	Flows in Orielton Rivulet entering Lagoon	Ongoing condition	Flow at Brinktop Road (Continuous monitoring)	Review data annually	High
	Flows in Sorell Rivulet	Establish baseline	Flow above STP	Review data annually	High
	Flows in Iron Creek	Establish baseline	Flow above Iron Creek Bridge	Review data annually	High
	Volume of stormwater for high rainfall events	Establish baseline	Volume at all stormwater outlets in PWOL	Review after event	High
Tidal exchange	Tidal movements in upper Pitt water	Detection of change	Establish baseline, then monitor	Every 10 years	High
	Tidal movement in OL	Detection of change	Establish baseline, then monitor	Every 10 years	High

Table 9.1: Monitoring actions for PWOL (cont.).

Component, process or ecosystem service	**Specific component, process, or service**	**Objective of monitoring**	**Indicator or measure**	**Frequency**	**Priority**
Water quality	Upper Pitt Water surface waters	Detection of change	N, P, DO, salinity, pH, turbidity, Chl A, coliforms, monthly sampling	3 yearly	High
	Orielton Lagoon surface waters	Detection of change	N, P, DO, salinity, pH, turbidity, Chl A, coliforms monthly sampling	3 yearly	High
Water quality at high rainfall events	Orielton Lagoon surface waters	Ongoing condition	N, P, DO, salinity, pH, turbidity, Chl A, coliforms	At event and later to assess recovery rates	High
Geomorphology	Sediment supply and distribution	Establish baseline	Source of sediment and distribution	10 yearly	High
	Bank erosion	Detection of change	Rate of erosion at key locations eg Sorell Point, Shark Point Road & upper Coal River,	5 yearly	High
	Extent of geomorphic units	Detection of change	Aerial mapping	10 yearly	Mod

Table 9.1: Monitoring actions for PWOL (cont.).

Component, process or ecosystem service	Specific component, process, or service	Objective of monitoring	Indicator or measure	Frequency	Priority
Fauna communities and species	Seastar *Parvulastra vivipara*	Detection of change	Abundance and distribution	5 yearly	Mod
	Intertidal flats Benthic fauna of flats	Detection of change Establish baseline	Area of flats used by waders/shorebirds Species richness, abundance and distribution in high priority areas for waders	5-yearly Immediate/5 yearly	High
	Fish community Shark breeding	Detection of change Detection of change	Species present Breeding – incidence, rate of pupping	Immediate/5 yearly Immediate/5 yearly	Mod
	Migratory waders	Detection of change	Species richness and abundance	Bi-annual	High
Flora communities and species	Saltmarsh vegetation extent and floristics	Establish limits of acceptable change Detection of change	Aerial mapping of area and locations of loss or gain of saltmarsh components Vegetation communities	5 yearly 10 yearly	Mod Mod
	Seagrass	Detection of change	Area and distribution of seagrass	5 yearly	High

Section 10: Communication, education and public awareness (CEPA) messages.

10.1 Audiences, messages and purposes for communication

There is a range of audiences for communication messages concerning PWOL. These include:

- Residents of nearby settlements including Sorell, Midway Point, Richmond, Penna, Cambridge and their outskirts
- Landowners with property bordering the Ramsar site, with somewhat different needs for those with rural properties and those on the urban fringes
- Visitors to the area for recreation, including fishing, water-based activities, walking etc
- Aldermen and officers of local governments at Sorell and Clarence
- Commercial and industrial operations adjacent or nearby to the Ramsar site
- The wider Tasmanian community
- Agencies with legislated responsibilities for land and water management, resources and infrastructure.

The principal messages emerge from

- the values of the site
- the social and environmental benefits of the site
- activities and impacts that threaten the site.

The purposes of communication lie in

- ensuring the best possible management of the site through public collaboration with the managing agency
- providing the basis for planning and environmental management within jurisdiction outside the formal site boundary
- facilitating community based groups to support on-ground action
- advising landowners about how their operations can best be managed to protect values

- educating the community about ways to enjoy and appreciate the site without causing impacts on the values.

10.2 The values of the site

Important messages about the values of the site arise primarily from Ramsar criteria for which the site was listed and for the other benefits for the community.

10.2.1 Important at an international level for migratory birds.

While many residents will be aware of birdlife at PWOL, they may have limited knowledge of the significance of the site on the EAAF.

Figure 10.1: Orielton Lagoon: a southern site on the EAAF. (Sources: Images H.Dunn, A Fletcher. Map: http://www.eaaflyway.net/.)

10.2.2 Biodiversity values of the site

PWOL is important for biodiversity of Tasmanian estuary systems for a number of reasons, including:

- a good example of a wave-dominated estuary with examples of typical landforms, features and processes
- a diversity of fish species and a nursery area for shark as well as flathead, flounder and other estuarine species
- a diverse range of marine invertebrates of intertidal flats, open water and shorelines, including a rare endemic seastar
- a suite of saltmarshes exhibiting different flora communities
- a wide variety of birdlife including shorebirds, marine birds, waterfowl, waders and many others
- a habitat for rare and threatened species including five saltmarsh or wetland plants, an endemic seastar for which PWOL is the stronghold, birds such as the Great crested grebe and a number of other threatened fauna which have been recorded in the wetland.

Figure 10.2: Little pied cormorant, a top predator in the food chain at PWOL. (Source: Alan Fletcher)

10.3 Social and environmental benefits

10.3.1. Social and commercial benefits

The site provides many and varied services and benefits to the local community including:

- Marine farming areas for cultivation of oysters
- Recreational assets including fishing, water-based activities, walking and bird-watching
- A pleasant and scenic environment for local residents
- A dynamic environment capable of diluting and modifying some organic (treated) wastes
- A landscape context that defines the nature of place for the lower Coal River and Sorell area
- An attractive setting for travellers and tourists
- Cultural and Aboriginal heritage values.

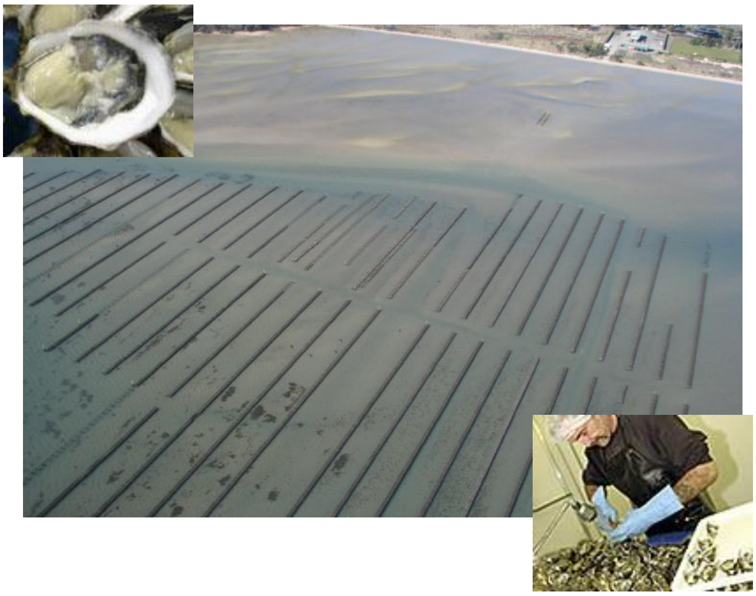


Figure 10.3: Oyster farming, an important ecosystem service in PWOL. (Source: Oyster beds image Prahalad, Barilla Bay Oysters website)

10.3.2 Environmental benefits

- PWOL sustains a complex estuarine ecosystem
- Sediments and nutrients are processed within the site from marine, riverine and terrestrial sources
- Supports a range of habitats including sub- and intertidal habitats, habitats of rocky and sandy shores and saltmarshes, and their associated flora and fauna communities.

10.4 Activities and impacts that threaten the site

PWOL has been physically modified and its processes altered for the last 150 years. The activities and management practices have resulted in threats to the site's values which include:

- land clearance causing increase in sediment and nutrient loads
- abstraction of water from rivers for irrigation, including the construction of a major dam on the Coal river, resulting in lower flows and changes in the flow regime
- construction of causeways restricting the natural tidal movements and exchange, especially at Orielton Lagoon
- draining and in-filling of saltmarshes
- allowing access to saltmarshes by stock and vehicles, altering their hydrology and compacting soils
- developing marine farms within the site, thereby creating the potential for changes to sediment dynamics, flows, nutrient levels and waste products
- discharging waste from sewage treatment plants into enclosed embayments
- discharging untreated waste from stormwater outflows
- using foreshores important for birdlife for companion animals, horse-riding and recreational vehicles leading to disturbance and possible interruption to breeding
- introduction and lack of control of weeds, including garden escapes

- introduction and lack of control of feral animals, especially marine pests
- damage or deliberate manipulation of shorelines, including vegetation clearance, filling, or artificial retention.

The effects of these activities can be cumulative. Education and information should address the need to reduce these impacts in order to retain the benefits and services for the community, and to protect the values of the site.

Figure 10:4: Gross alteration to a creek supplying freshwater and sediment to PWOL. (Source: Prahalad 2009).

Figure 10.5: Invasive species recognition (Northern Pacific seastar). (Source: http://www.dpi.nsw.gov.au/fisheries)

10.5 Managing PWOL

A Management Plan for the entire Pitt Water and Orielton Lagoon site, when prepared, should address matters that lie within the jurisdiction of the land manager, the Parks and Wildlife Service. However, activities and decisions of a range of other agencies and users are critical to the amelioration of threats and protection of the Ramsar site's values. These include the Tasmanian and Australian Governments, water managers, land managers, those responsible for roads and transport, farmers and other landowners, the local communities down to community groups, local people and visitors.

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Glossary

Acceptable change	The variation that is considered 'acceptable' in a particular measure or feature of the ecological character of a wetland. Acceptable variation is that variation that will sustain the component or process to which it refers. See "Limits of Acceptable Change".
Abundance	Total number of individuals present
Alluvial	Pertaining to alluvium, or material transported by flowing water
Barred estuary	Estuary with a sand-bar at the mouth, which may or may not close off the exchange of water
Baseline	Evidence at a starting point.
Benthic	Bottom dwelling
Bio region	A scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc IBRA, IMCRA
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.
Catchment	The total area draining into a river, reservoir, or other body of water
Change in ecological character	The human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005a, Resolution IX.1 Annex A).
Community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000a).
Conceptual model	A summary, often diagrammatic, to express ideas about components and processes and their interrelationships
Cryptogenic	Species whose origin is unknown, that is they may or may not be native to the area
Diversity	Number of species present in a particular environment or community
Dominance value	
Ecological character	The combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.
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 2005b).
Ecosystem Components	The separate physical, chemical and biological parts of a wetland ecosystem
Ecosystem	The changes, reactions and interactions which occur naturally

Processes	within ecosystems
Ecosystem services	The benefits that people receive or obtain, directly or indirectly, from an ecosystem
Endemic species	A species that originates and occurs naturally in a particular limited area.
Floristic community	Clearly definable assemblage of plant species derived from quantitative analysis of plot data
Geomorphology	The landforms and processes
Groundwater	Water occupying cracks, pores and other spaces below the surface
Groundwater	All free water found below the watertable
Holocene	Most recent geological epoch up to the present
Introduced (non-native) species	A species that does not originate or occur naturally in a particular area.
Inundation	The condition of water occurring above the surface, (Brinson, 1993)
Limits of Acceptable Change	The variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland without indicating change in ecological character which may lead to a reduction or loss of the values for which the site was Ramsar listed.
Littoral	Of the shoreline
Monitoring	The systematic collection of information over time intervals to provide evidence of any change.
Negative hydrology	Hydrology of an estuary where freshwater input varies temporally (depending on local catchment and climate conditions) and is typically relatively low.
NTU	Measure of turbidity (Formazin Turbidity Unit FTU) by an instrument called a nephelometer hence NTU
Permian	Geological period from about 280 – 240 Million years BP
Planktonic species	Very small plants and animals that dwell in the water column
Pleistocene	Geological epoch preceding the Holocene
Polychaete	Marine bristle worm
Pore-water	Water held in spaces between particles
Quaternary	Youngest geological period comprising the Holocene and Pleistocene epochs, form about 2 million years ago to present.
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 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	The form upon which Contracting Parties record relevant data on

Information Sheet (RIS)	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 Site	A wetland 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].
Richness	Number of species present in a particular environment or community
Riverine	Of the river
Terrigenous	Originating on land
Tertiary	Geological period from about 65 Million years BP
Threatened species	A species that is scheduled under legislation according to established criteria of status or risk
Triassic	Geological period from about 240 -195 Million years BP
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).

Appendix 1. Ramsar criteria at the time of listing of Pitt Water – Orielton Lagoon in 1982

The criteria adopted by the First Conference of the Contracting Parties, Cagliari (24-29 November, 1980)

1. Quantitative criteria for identifying wetlands of importance to waterfowl

A wetland should be considered internationally important if it:

(a) regularly supports either 10,000 ducks, geese and swans; or 10000 coots; or 20,000 waders,

or (b) regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl,

or (c) regularly supports 1% of the breeding pairs in a population of one species or subspecies of waterfowl.

2. General criteria for identifying wetlands of importance to plants or animals

A wetland should be considered internationally important if it:

(a) supports an appreciable number of a rare, vulnerable or endangered species or subspecies of plant or animal,

or (b) is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna,

or (c) is of special value as the habitat of plants or animals at a critical stage of their biological cycles

or (d) is of special value for its endemic animal or plant species or communities.

3. Criteria for assessing the value of representative or unique wetlands

A wetland should be considered internationally important if it is a particularly good example of a specific type of wetland characteristic of its region.

Appendix 2. Ramsar criteria applicable in 2009

Criteria adopted by the 7th (1999) and 9th (2005) Meetings of the Conference of the Contracting Parties, superseding earlier Criteria adopted by the 4th and 6th Meetings of the COP (1990 and 1996), to guide implementation of Article 2.1 on designation of Ramsar sites.

Group A of the Criteria. 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 of the Criteria. Sites of international importance for conserving biological diversity

Criteria based on species and ecological communities

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

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.

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.

Specific criteria based on waterbirds

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

Criterion 6: 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.

Specific criteria based on fish

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.

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.

Specific criteria based on other taxa

Criterion 9: 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.

Appendix 3. Birds of the Pitt Water – Orielton Lagoon Ramsar Site (2009)

Family	Common name	Scientific name	Status TSPA	Status EPBC Act
Phasianidae	brown quail	*Coturnix ypsilophora*		
Anatidae	blue-billed duck	*Oxyura australis*		
Anatidae	musk duck	*Biziura lobata*		
Anatidae	black swan	*Cygnus atratus*		
Anatidae	Cape Barren goose	*Cereopsis novaehollandiae*		
Anatidae	Australian shelduck	*Tadorna tadornoides*		
Anatidae	Pacific black duck	*Anas superciliosa*		
Anatidae	Australasian shoveler	*Anas rhynchotis*		
Anatidae	grey teal	*Anas gracilis*		
Anatidae	chestnut teal	*Anas castanea*		
Anatidae	hardhead	*Aythya australis*		
Podicipedidae	hoary-headed grebe	*Poliocephalus poliocephalus*		
Podicipedidae	great crested grebe	*Podiceps cristatus*	v	
Procellarideae	fairy prion	*Pachyptila turtur subantarctica*	e	VU
Phalacrocoracidae	little pied cormorant	*Phalacrocorax melanoleucos*		
Phalacrocoracidae	black-faced cormorant	*Phalacrocorax fuscescens*		
Phalacrocoracidae	pied cormorant	*Phalacrocorax varius*		
Phalacrocoracidae	little black cormorant	*Phalacrocorax sulcirostris*		
Phalacrocoracidae	great cormorant	*Phalacrocorax carbo*		
Pelecanidae	Australian pelican	*Pelecanus conspicillatus*		
Ardeidae	white-faced heron	*Egretta novaehollandiae*		
Ardeidae	little egret	*Egretta garzetta*		
Ardeidae	great egret	*Ardea alba #+*		
Ardeidae	cattle egret	*Ardea ibis #+*		
Threskiornithidae	Australian white ibis	*Threskiornis molucca*		
Threskiornithidae	royal spoonbill	*Platelea regia*		
Accipitridae	white-bellied sea eagle	*Haliaeetus leucogaster +*	v	
Accipitridae	swamp harrier	*Circus approximans*		
Accipitridae	brown goshawk	*Accipiter fasciatus*		
Accipitridae	collared sparrow hawk	*Accipiter cirrhocephalus*		
Accipitridae	wedge-tailed eagle	*Aquila audax*	e	EN
Falconidae	brown falcon	*Falco berigora*		
Falconidae	Australian hobby	*Falco longipennis*		
Falconidae	peregrine falcon	*Falco peregrinus*		
Falconidae	nankeen kestrel	*Falco cenchroides*		
Rallidae	Tasmanian native-hen	*Gallinula mortierii*		
Rallidae	Eurasian coot	*Fulica atra*		
Scolopacidae	Latham's snipe	*Gallinago hardwickii #*		
Scolopacidae	black-tailed godwit	*Limosa limosa #+*		
Scolopacidae	Hudsonian godwit	*Limosa haemastica*		
Scolopacidae	bar-tailed godwit	*Limosa lapponica #+*		
Scolopacidae	whimbrel	*Numenius phaeopus #+*		
Scolopacidae	eastern curlew	*Numenius madagascariensis #+*	e	

Scolopacidae	marsh sandpiper	*Tringa stagnatilis #+*		
Scolopacidae	common greenshank	*Tringa nebularia #+*		
Scolopacidae	common sandpiper	*Actitis hypoleucos #+*		
Scolopacidae	grey-tailed tattler	*Heteroscelus brevipes #+*		
Scolopacidae	ruddy turnstone	*Arenaria interpres #+*		
Scolopacidae	great knot	*Calidris tenuirostris #+*		
Scolopacidae	red knot	*Calidris canutus #+*		
Scolopacidae	little stint	*Calidris minuta #+*		
Scolopacidae	red-necked stint	*Calidris ruficollis #+*		
Scolopacidae	pectoral sandpiper	*Calidris melanotos #*		
Scolopacidae	sharp-tailed sandpiper	*Calidris acuminata #+*		
Scolopacidae	curlew sandpiper	*Calidris ferruginea #+*		
Scolopacidae	buff-breasted sandpiper	*Tryngites subruficollis #*		
Scolopacidae	ruff	*Philomachus pugnax #+*		
Haematopodidae	pied oystercatcher	*Haematopus longirostris*		
Haematopodidae	sooty oystercatcher	*Haematopus fuliginosus*		
Recurvirostridae	black-winged stilt	*Himantopus himantopus*		
Recurvirostridae	banded stilt	*Cladorhynchus leucophalus*		
Charadriidae	Pacific golden plover	*Pluvialis fulva # +*		
Charadriidae	grey plover	*Pluvialis squatarola #+*		
Charadriidae	red-capped plover	*Charadrius ruficapillus*		
Charadriidae	double-banded plover	*Charadrius bicinctus*		
Charadriidae	lesser sand plover	*Charadrius Mongols #+*		
Charadriidae	greater sand plover	*Charadrius leschenaultii #+*		
Charadriidae	Oriental plover	*Charadrius veredus #*		
Charadriidae	black-fronted dotterel	*Elseyornis melanops*		
Charadriidae	banded lapwing	*Vanellus tricolor*		
Charadriidae	masked lapwing	*Vanellus miles*		
Laridae	Pacific gull	*Larus pacificus*		
Laridae	kelp gull	*Larus dominicanus*		
Laridae	silver gull	*Larus novaehollandiae*		
Laridae	Caspian tern	*Sterna caspia #+*		
Laridae	crested tern	*Sterna bergii*		
Laridae	little tern	*Sterna albifrons #+*	e	
Laridae	fairy tern	*Sterna nereis*	v	
Laridae	white-winged black tern	*Chlidonias leucopterus*		
Columbiformes	common bronzewing	*Phaps chalcoptera*		
Cacatuidae	yellow-tailed black-cockatoo	*Calyptorhynchus funereus*		
Cacatuidae	galah	*Cacatua roseicapilla*		
Cacatuidae	sulphur-crested cockatoo	*Cacatua galerita*		
Psittacidae	musk lorikeet	*Glossopsitta concinna*		
Psittacidae	green rosella	*Platycercus caledonicus*		
Psittacidae	eastern rosella	*Platycercus eximius*		
Psittacidae	swift parrot	*Lathamus discolor*	e	EN
Psittacidae	blue-winged parrot	*Neophema chrysostoma*		
Cuculidae	pallid cuckoo	*Cuculus pallidus*		
Cuculidae	fan-tailed cuckoo	*Cacomantis flabelliformis*		
Cucuilidae	Horsfield's bronze cuckoo	*Chrysococcyx basalis*		
Strigidae	southern boobook	*Ninox novaeseelandiae*		

Tytonidae	masked owl	*Tyto novaehollandiae*	e
Podargidae	tawny frogmouth	*Podargus strigoides*	
Apodidae	white-throated needletail	*Hirundapus caudacutus #+*	
Halcyonidae	laughing kookaburra	*Dacelo novaeguineae*	
Maluridae	superb fairy-wren	*Malurus cyaneus*	
Pardalotidae	spotted pardolate	*Pardolotus punctatus*	
Pardalotidae	striated pardolate	*Pardolotus striatus*	
Pardalotidae	striated fieldwren	*Calamanthus fuliginosus*	
Pardalotidae	brown thornbill	*Acanthiza pusilla*	
Pardalotidae	yellow-rumped thornbill	*Acanthiza chrysorrhoa*	
Meliphagidae	yellow wattlebird	*Anthocaera paradoxa*	
Meliphagidae	little wattlebird	*Anthocaera chrysoptera*	
Meliphagidae	noisy miner	*Manorina melanocephala*	
Meliphagidae	yellow-throated honeyeater	*Lichenostomus flavicollis*	
Meliphagidae	crescent honeyeater	*Phylidonyris pyrrhoptera*	
Meliphagidae	New Holland honeyeater	*Phylidonyris novaehollandiae*	
Meliphagidae	black-headed honeyeater	*Melithreptus affinis*	
Meliphagidae	eastern spinebill	*Acanthorhynchus tenuirostris*	
Meliphagidae	white-fronted chat	*Ephthianura albifrons*	
Petroicidae	scarlet robin	*Petroica multicolor*	
Petroicidae	flame robin	*Petroica phoenicea*	
Petroicidae	dusky robin	*Melanodryas vittata*	
Pachycephalidae	grey shrike-thrush	*Colluricincla harmonica*	
Dicruridae	grey fantail	*Rhipidura fuliginosa*	
Campephagidae	black-faced cuckoo-shrike	*Coracina novaehollandiae*	
Artamidae	dusky woodswallow	*Artamus cyanopterus*	
Artamidae	grey butcherbird	*Cracticus torquatus*	
Artamidae	Australian magpie	*Gymnorhina tibicen*	
Artamidae	grey currawong	*Strepera versicolor*	
Corvidae	forest raven	*Corvus tasmanicus*	
Alaudidae	skylark	*Alauda arvensis*	
Motacillidae	Richard's pipit	*Anthus novaeseelandiae*	
Passeridae	house sparrow	*Passer domesticus*	
Fringillidae	European greenfinch	*Carduelis chloris*	
Fringillidae	European goldfinch	*Carduelis carduelis*	
Hirundinidae	welcome swallow	*Hirundo neoxena*	
Hirundinidae	tree martin	*Hirundo nigricans*	
Sylviidae	little grassbird	*Megalurus gramineus*	
Zosteropidae	silvereye	*Zosterops lateralis*	
Muscicapidae	common blackbird	*Turdus merula*	
Sturnidae	common starling	*Sturnus vulgaris*	

TSPA = *Threatened Species Protection Act (1995) (r) rare, (v) vulnerable, (e) endangered*
EPBC Act = *Environment Protection and Biodiversity Conservation Act (1999)(V) Vulnerable, (EN) Endangered*(#) JAMBA, (+) CAMBA,

Source: Parks and Wildlife Service, Tasmania 2009

Appendix 4. Extracts from a survey of saltmarshes in Tasmania (Kirkpatrick and Glasby 1981)

The survey of Tasmanian saltmarshes provides data about the vegetation, area and condition of saltmarshes in the PWOL region.

In addition to a Tasmanian wide mapping of the occurrences of saltmarshes, an intensive study was undertaken in the Derwent estuary region. Sites in this area were mapped by floristic communities. The sites included most of the large areas of saltmarsh in the Pitt Water Estuary area.

Locations of the sites sampled in the Derwent Estuary area are shown in Figure A4.1.

The full list and key for floristic communities is shown in Figure A4.2.

Reference:

Kirkpatrick J. B. and Glasby .J (1983) *Saltmarshes in Tasmania: Distribution Community composition and Conservation.* Occasional papers 8. Department of Geography, University of Tasmania, Hobart.

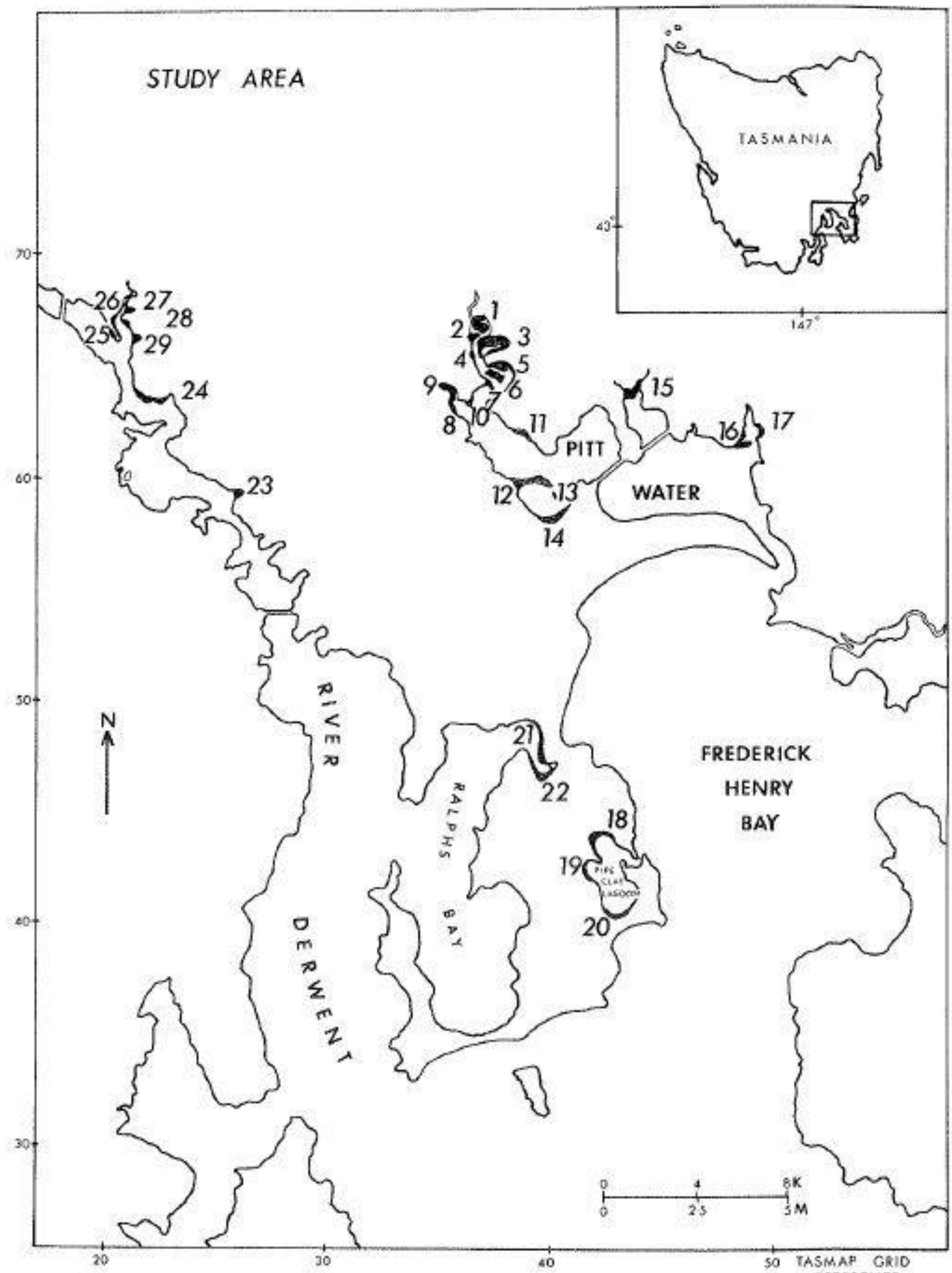

Figure A4.1: Study sites of saltmarshes in the Derwent Estuary area (Kirkpatrick and Glasby 1981).

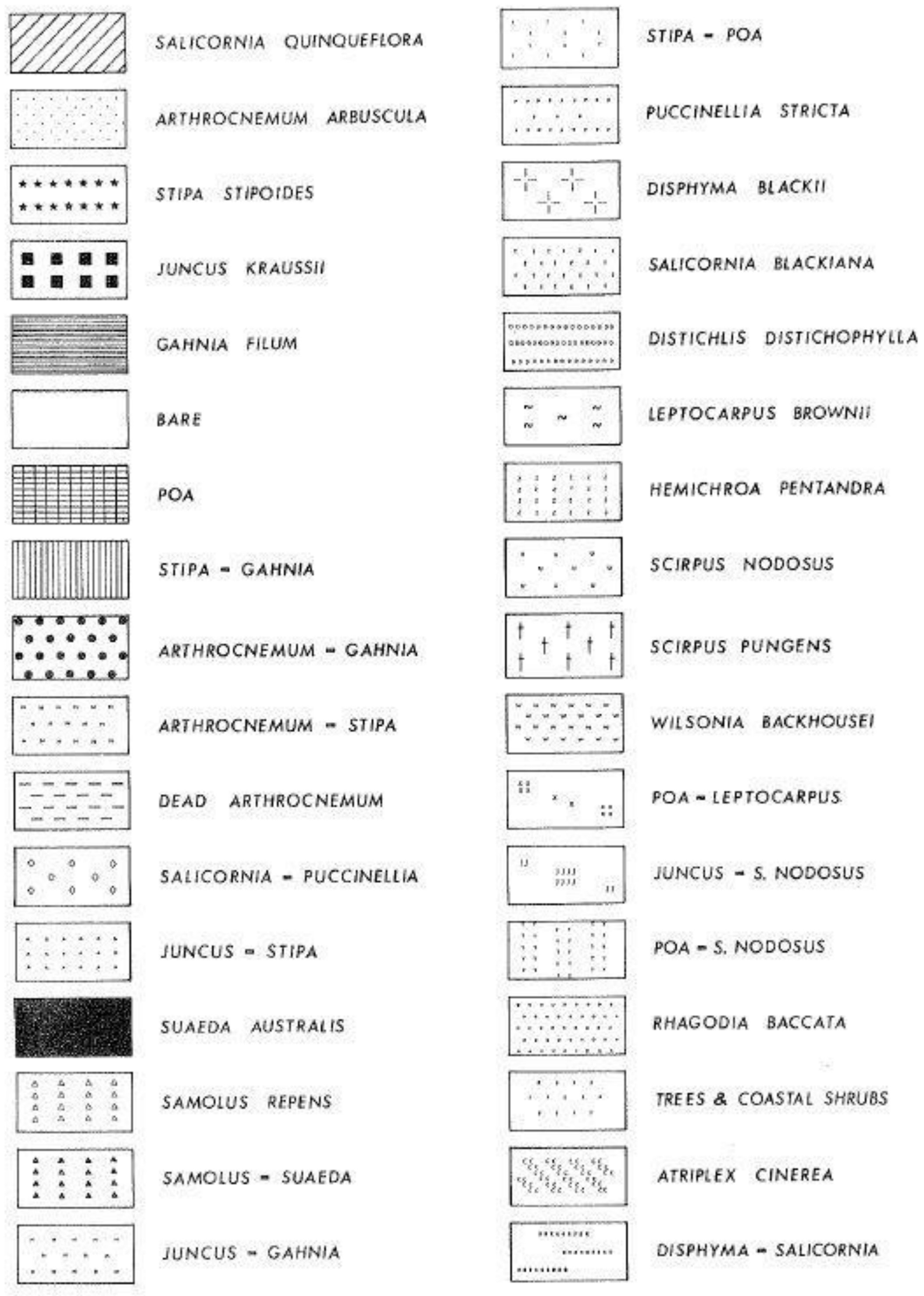

Figure A4.2: Key to floristic communities in saltmarshes (Kirkpatrick and Glasby 1981).

Compiler of the ECD

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Helen Dunn has worked in the fields of conservation assessment and conservation management for the last twenty years. Her particular fields of interest have been in freshwater and marine ecosystems, and in the identification, protection and management of high value ecosystems.

Previous work includes:

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- Consultancies on identification of high conservation value aquatic ecosystems for Land and Water Australia, and the Aquatic Ecosystems Task Group (AETG) and DEWHA
- Member of the core scientific group developing the Tasmanian Conservation of Freshwater Ecosystem Values (CFEV) project
- Preparing technical reports on criteria and thresholds for ‘special values’ assessment for the CFEV project
- Analysis of the implications of land tenure and protection options for aquatic ecosystems of high conservation value for the CFEV project
- Preparation of ECDS for three Ramsar sites in Tasmania (Interlaken Lakeside Reserve, East Coast Cape Barren Island wetlands and Moulting Lagoon).
- Consultancies and reports on evaluating management effectiveness for protected areas.

Helen Dunn has PhDs in Education and in Geography and Environmental Studies. She holds the position of Land and Water Scientist on the Consultative Committee for the Tasmanian Wilderness World Heritage Area.