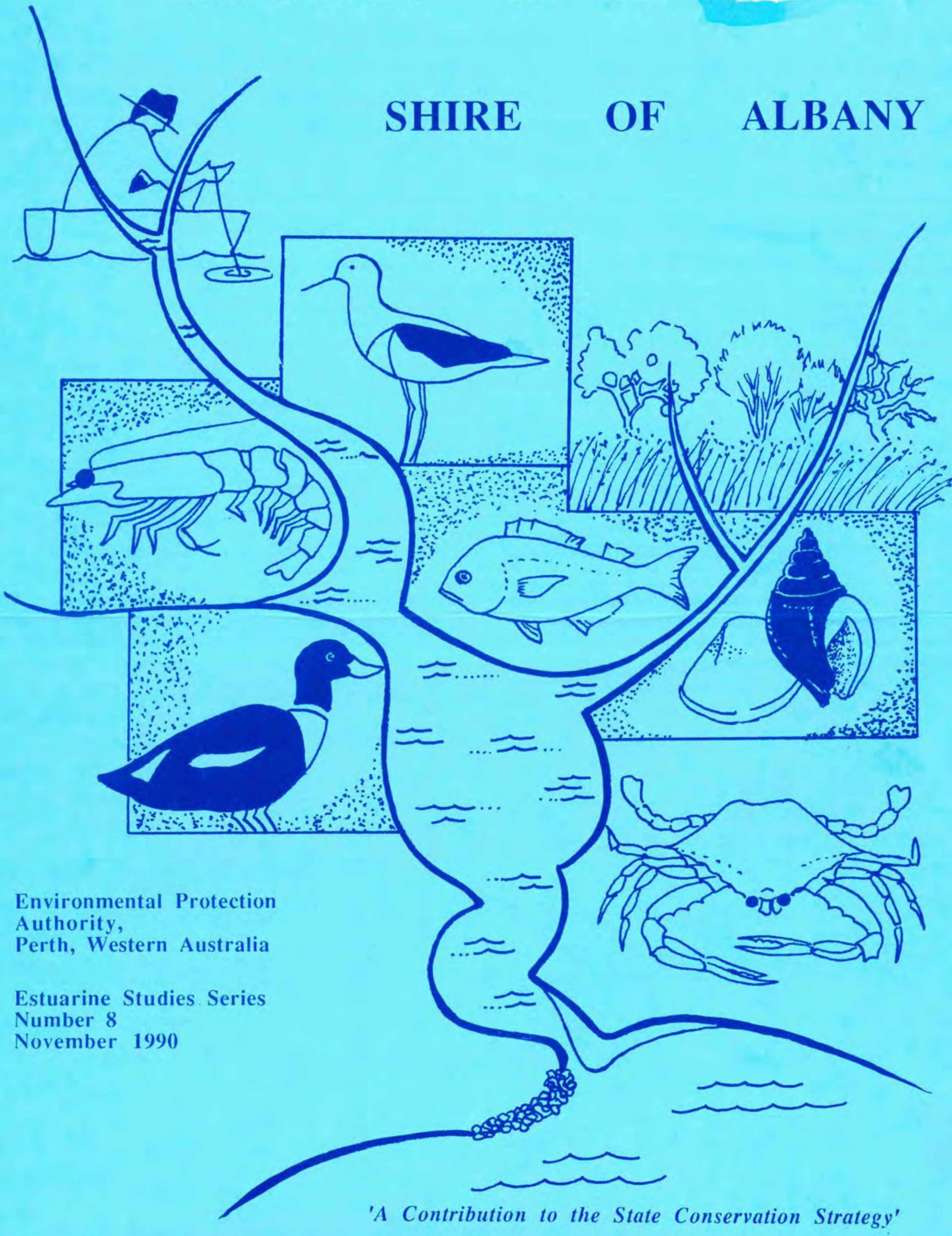
ESTUARIES AND COASTAL LAGOONS OF SOUTH WESTERN AUSTRALIA

ESTUARIES OF THE SHIRE OF ALBANY



Environmental Protection Authority,
Perth, Western Australia

Estuarine Studies Series
Number 8
November 1990

'A Contribution to the State Conservation Strategy'

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ERRATUM

Page 19:

The two photographs have been reversed.

An Inventory of Information on the
Estuaries and Coastal Lagoons of South Western Australia

ESTUARIES OF THE SHIRE OF ALBANY

By Ernest P. Hodgkin and Ruth Clark

Oyster Harbour, August 1990. Photo: Alan Murdoch

Torbay Inlet, March 1988 (Land Administration, WA)

Taylor Inlet, October 1978. Photo: Durant Hembree.

Environmental Protection Authority
Perth, Western Australia

Estuarine Studies Series No. 8
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COMMON ESTUARINE PLANTS AND ANIMALS

Approximate sizes in mm.

Plants
- A Rush - *Juncus kraussii*
- B Samphire - *Sarcocornia* spp.
- C Paperbark tree - *Melaleuca cuticularis*
- D Seagrass - *Ruppia megacarpa*
- E Diatoms 0.01

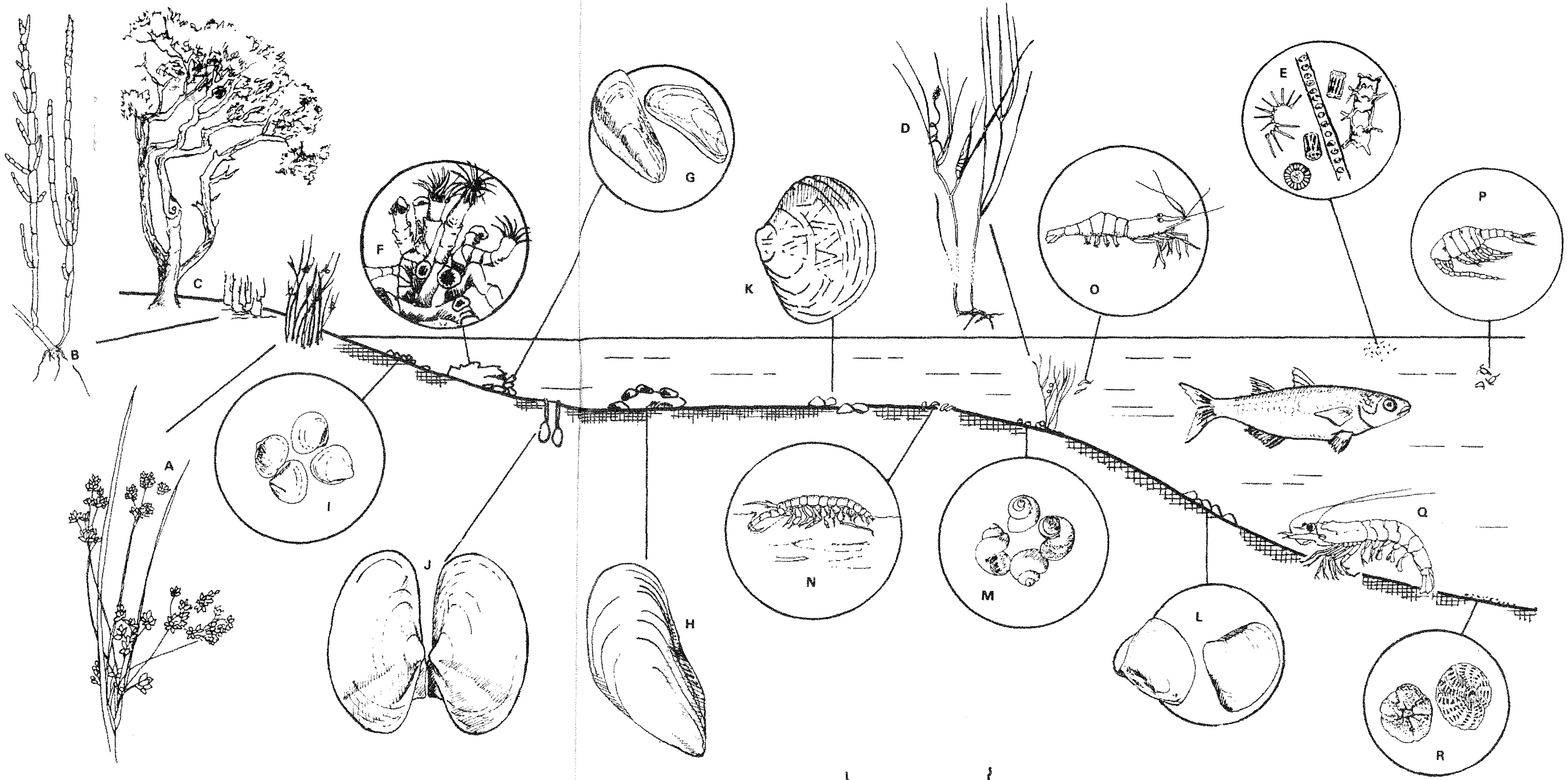
F Tubeworms - *Ficopomatos enigmaticus* 20

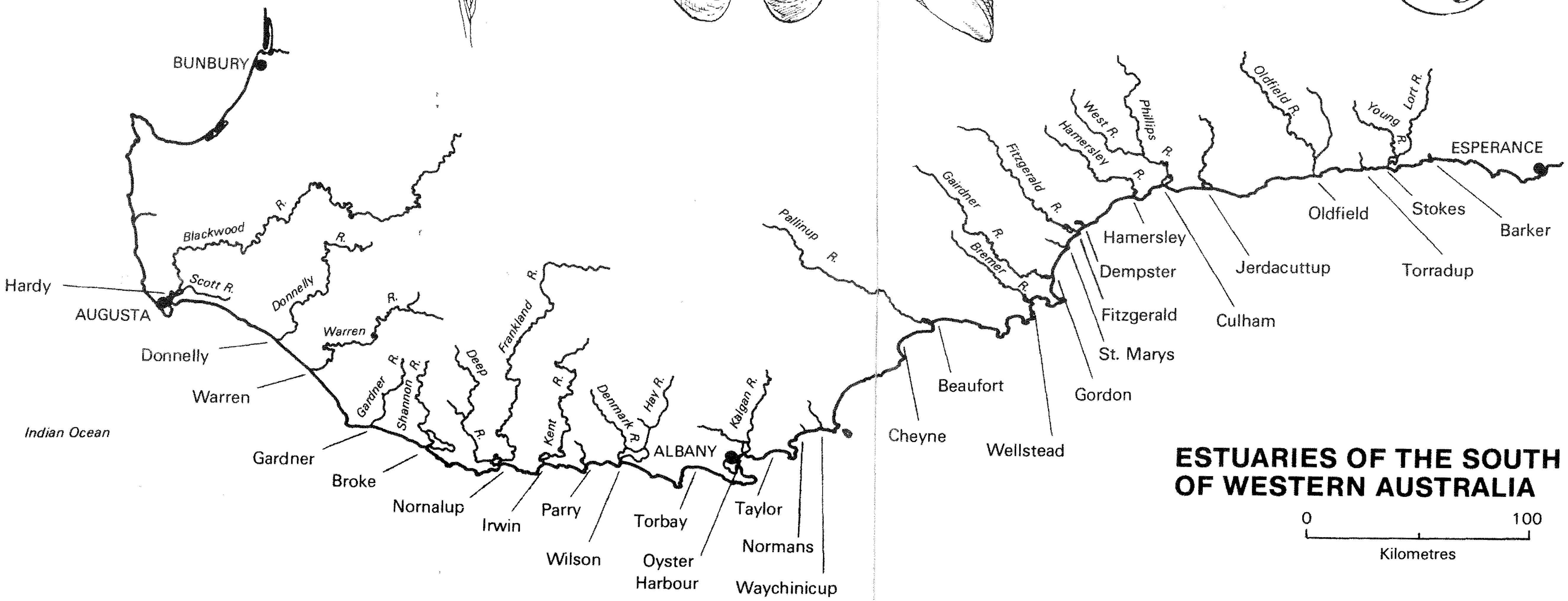
Bivalve molluscs
- G Estuarine mussel - *Xenostrobus securis* 30
- H Edible mussel - *Mytilus edulis* 100
- I *Arthritica semen* 3
- J *Sanguinolaria biradiata* 50
- K Cockle - *Katelysia* 3 spp. 40
- L *Spisula trigonella* 20

Gastropod molluscs
- M Snail - *Hydrococcus brazieri* 4

Crustacea
- N Amphipod - *Corophium minor* 15
- O Shrimp - *Palaemonetes australis* 40
- P Copepod - *Gladioferens imparipes* 2
- Q King Prawn - *Penaeus latisulcatus* 100

R Foraminifera 0.02





ESTUARIES OF THE SOUTH COAST OF WESTERN AUSTRALIA

B. A. Carbon
Chairman

FOREWORD

The Estuaries of the Shire of Albany is a study of the important, living waterways of the region. It is knowledgeable, informative and will be valuable to scholars and residents of the region.

This study completes the series of studies of estuaries and coastal lagoons of the south coast. Only one estuary has been omitted, Hardy Inlet the estuary of the Blackwood River, which was described at length in one of the first environmental studies conducted by EPA in 1974-75.

The Estuary studies are a part of the State Conservation Strategy which was announced by the Minister for the Environment in 1987. This committed Western Australia to the National Strategy's "objectives, principles and major goals set out for sustainable development and living resource conservation in Australia as a whole".

The estuaries are among WA's principal recreational resources and in recent years have come under increasing pressure. A number are now eutrophic and have unwelcome blooms of algae, mainly the result of the loss of fertilizers from leaching soils in their catchments. Oyster Harbour is the largest estuary in the Shire of Albany and the damage to the seagrass meadows by algal growth is well known following the recent EPA study on the Albany Harbours. A new plan to rescue the estuary is receiving strong community support.

The estuaries need to be managed if they are to survive as healthy ecosystems which can be used and enjoyed by future generations. These studies aim to summarise and interpret what is known about the estuaries to provide background information for the managers and for others concerned with their conservation or for the study of them.

Our estuaries are different in many respects from those in most other parts of the world and must be studied in the context of the local environment if they are to be understood and managed intelligently.

The study series has grown in scope and interpretation as the authors have gained a greater knowledge of the estuaries, however it is recognised that the information is still far from complete and it is to be hoped that as more data are obtained the studies will be updated. It is intended to prepare an 'Overview' of the estuaries of the south west, a comparative study which will endeavour to interpret the present day ecosystems in terms of their evolution.

The authors, Ernest Hodgkin and Ruth Clark have compiled an anthology of our estuarine wealth which will serve our society well. I acknowledge their gift to us. In turn, they have acknowledged their debt to local residents, but it is appropriate for me to acknowledge all the help given in preparation of these studies and on many other occasions to EPA and its staff. Thanks.

CONTENTS

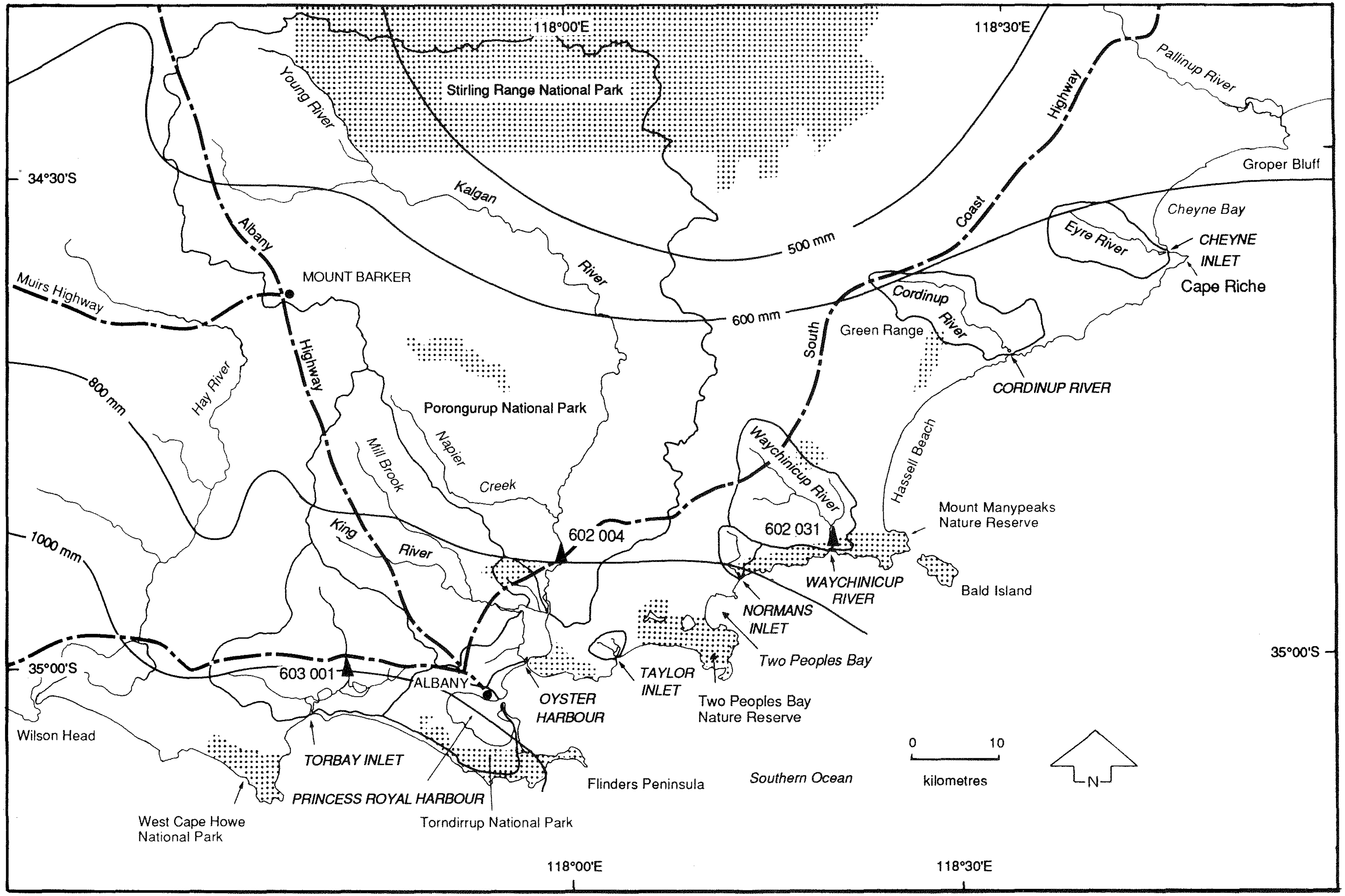


Figure 1 Catchments of the estuaries of the Shire of Albany. Shaded areas National Park or Nature Reserve. Mean annual rainfall isohyets.

1 INTRODUCTION

The Shire of Albany has one large estuary, Oyster Harbour with its two rivers, and a number of smaller estuaries: Torbay Inlet, Taylor Inlet, Normans Inlet, Cordinup River and Cheyne Inlet (Figure 1). Oyster Harbour opens into the sheltered waters of King George Sound through a deep channel which allows tidal exchange between the estuary and the sea all the year round. The water is only significantly diluted by river water following strong river flow, and then only briefly. This makes the harbour a very different environment from all the other estuaries of the south west where tidal exchange is obstructed by sand bars and the water changes seasonally from nearly fresh to marine or more salt than the sea.

The 280 km long coastline of the Shire from Wilson Inlet to the Pallinup River has hard rock (granitic) headlands which alternate with limestone cliffs and sandy beaches. The Flinders Peninsula shelters the mouth of Oyster Harbour from south westerly winds and swell, and other headlands shelter the mouths of the smaller estuaries. Where the eastern coastline turns northwards the long sandy beaches of Cheyne Bay, Hassell Beach and Two Peoples Bay face south east and east in the shelter of prominent headlands (Figure 1).

Oyster Harbour has a large catchment the headwaters of which are on the south flank of the Stirling Range and there is a large area of internal drainage east of the Kalgan River. The other estuaries only have small coastal catchments and between them there are areas of drainage to small creeks which seldom or never reach the coast. Two small rivers flow to lakes behind the beach at Two Peoples Bay. Along the 20 km of Hassell Beach there are a dozen small creeks, three of which end in lakes behind the dunes. Another ten creeks flow to Cheyne Bay, but their flow is absorbed by dune or beach sand and they only flow over the dunes or across the beach when in flood. The small Waychinicup River is unique in the south west; it flows to a narrow rocky gorge on an exposed granite coast where there is no sand to build a bar. These small rivers are described briefly in Chapter 9.

Rainfall averages about 1000 mm a year on the coast west of Albany but decreases inland to 500 mm near the Stirling Range and eastwards along the coast to 571 mm at Cape Riche (Figure 1). It is seasonal with most rain generally falling in winter. However river flow, especially from the large Kalgan River catchment, can be dominated by flood flow, in winter or summer. The small flow to the other estuaries allows sand bars to close their mouths and only be broken when there is strong flow; or when broken artificially as at Torbay Inlet.

Oyster Harbour was named by Vancouver when he explored the coast in 1791 and found abundant oysters. He also named King George Sound and Princess Royal Harbour and Breaksea, Michaelmas and Seal islands. In 1826 Lockyer chose a site on the northern shore of Princess Royal Harbour for the first European settlement in Western Australia, which he proclaimed in January 1827 more than two years before Captain Stirling established the Swan River Settlement at Perth (Garden, 1977).

From the 1830s to the 1850s whaling and sealing were active along the coast by American, British, French and other overseas whalers who often visited Albany. George Cheyne, a Scotsman who arrived in Albany in 1831, became involved in the industry and acquired land at Cape Riche where he established a whaling depot and trading base in the bay in 1839. He developed a pastoral property there and the farm buildings were built by convict labour from the local stone. Andrew Moir, also from Scotland, joined him in 1842 and later bought the land which is still owned by a descendant, Doug Moir. The wool from this and other farms was shipped from the bay until the 1930s. Another whaling depot was established at Two Peoples Bay about 1839 and whalers also used Torbay Inlet. An Englishman, Stuart, took up land around Taylor Inlet in the 1870s and built a large house overlooking the Inlet, but the land was not cleared until the 1960s. Geike, a possum skin collector, was the first settler at Manypeaks farm just north of Normans Inlet, later purchased by Gordon Norman.

1.1 THE ESTUARIES - LOCATION AND ACCESS

The location of the estuaries with their tributary rivers and catchments is shown in Figure 1. Oyster Harbour with its two estuarine rivers is close to the Town of Albany. Torbay Inlet is 26 km west of Albany with access from Lower Denmark Road. Taylor Inlet is 20 km east of Albany along Nanarup Road from the Lower Kalgan Bridge. Access to the other eastern estuaries is from South Coast Highway: Normans Inlet is 48 km east of Albany by road, Cordinup River 85 km, and Cheyne Inlet is 116 km. Grid references are to maps 2428 Mount Barker, 2427 Albany, 2528 Manypeaks and 2628 Cheyne on the 1: 100 000 topographic map series published by Natmap.

There are 24 motel/hotels, one hostel, 13 holiday cottages and 10 caravan parks at Albany accommodating about 3500 people; and four motel/hotels and one caravan park at Mount Barker for about 400 people (R.A.C., 1989). There is a small camping area at Normans Inlet and another at Cape Riche.

Oyster Harbour is 15.6 km^2 in area. It is shallow along the eastern shore but more than 5 m deep near the western shore and in the southern basin area. The narrow entrance channel to the sheltered waters of King George Sound is scoured to over 10 m deep between the sandy spit of Emu Point and the rock of the eastern shore. The King River is estuarine for 7 km through low lying land most of which is cleared almost to the water's edge. The Kalgan River winds for 9 km from a pool immediately below the Upper Kalgan Bridge through a narrow rocky valley with steep tree clad slopes.

The estuary is located between 117°54' and 118°00' East and 34°54' and 35°00' South. The mouth of Oyster Harbour at Emu Point is at grid reference: Mount Barker 865 265. There is access to the entrance at Emu Point and to the western shore at Lower King. Small boats can be launched to the King River at both upper and lower bridges, but it is very shallow above the lower bridge. Boats can be launched to the Kalgan River about 3 km from the Lower Kalgan Bridge, along a gravel road on the east bank.

Torbay Inlet is now only a small part, (about 1 km^2), of what was formerly a larger estuarine system that included Lake Manarup which is now a compensating basin alongside the drain from Marbelup Brook and Lake Powell. Floodgates prevent estuary water entering the two lakes or backing up into cultivated land in swamps to the east.

The Inlet lies between 117°40' and 117°41 East and 35°02' and 35°03' South. The mouth is at grid reference: Albany 615 218. Access to the Inlet is from the Lower Denmark Road, along a gravel and sand track from the Elleker Grasmere Road to the east bank of the inlet channel, or to the west bank by a gravel track from Perkins Road.

Taylor Inlet, also known as Nanarup Inlet, is less than 1 km^2 in area. It is surrounded by low hills with a dense, but narrow, belt of woodland between the water and cleared land on three sides. The mouth opens through a short channel onto a low sandy beach in the shelter of a rocky island.

The Inlet lies between 118°03' and 118°04' East and 34°59' and 35°00' South. The mouth is at grid reference: Manypeaks 965 265. Access is east along Nanarup Road from Lower Kalgan Bridge.

Normans Inlet is less than 0.5 km^2 in area and is very shallow. It lies in a narrow valley in the Mount Manypeaks range of granite hills and is largely surrounded by bush in reserves. The mouth opens through a narrow channel onto the 3.5 km long Normans Beach, sheltered from the south west by the rocky headland of North Point and Boulder Hill. **King Creek** flows in a parallel valley before winding behind a high foredune to the south end of the beach and across rocks to the sea.

Normans Inlet is located at 118°13' East and 34°55' South. The mouth is at grid reference: Manypeaks 110 347. It is accessible via Homestead Road (bitumen and then gravel) south off South Coast Highway then east along Normans Beach Road (gravel and sand). King Creek is located at 118°12'30" East and 34°56' South. The mouth is at grid reference 103 339. It can be reached on foot from Normans Inlet, 1 km south along the beach.

Cordinup River nestles in a valley at the eastern end of Green Range through which the river winds to a small lagoon with samphire and tea tree swamps. A narrow channel cuts through the dunes and across a blowout to the beach in a small bay between rocky headlands.

The lagoon is located at 118°34' East and 34°42' South, and the mouth is at grid reference: Cheyne 425 585. Access is from South Coast Highway; from the west along Warriup Road, then through private property with three gates which may be locked; from the east along Mettlers Lake Road (gravel), south down Venns Road, thence through private property to the estuary. Permission is needed for entry to Cordinup.

Cheyne Inlet, the estuary of the Eyre River, is at the south end of Cheyne Bay in the shelter of Cape Riche. It is estuarine for about 4 km in a narrow valley, with a lagoon of less than 0.5 km^2. The mouth opens onto the beach against the rocks of the Cape. Farm land borders the south shore of the river and lagoon and the north shore is still bush.

The Inlet is located between 118°45' and 118°46' East and 34°36'30" South. The mouth is at grid reference: Cheyne 608 694. Access is from South Coast Highway south east along Sandalwood Road to the mouth. Access to the farm and south bank of the river is via Cape Riche Road (gravel) from Lake Mettlers Road.

1.2 GEOLOGICAL HISTORY OF THE ESTUARIES

Today's estuaries are of very recent origin, they are only about 6000 years old. Nevertheless the history of the south coast estuaries is a part of the long geological story of the coastal belt where rivers drain to the southern ocean. The basement rocks, the hard Precambrian granitic rocks, were eroded into hills and valleys long before Australia separated from Antarctica some 60 million years ago. Then in the late Eocene (40 million years ago) the sea inundated the coast as far inland as the Stirling Range and covered the drowned landscape with marine sediment. This sediment is now the Plantagenet Group which includes the spongolite rock (Pallinup Siltstone) of the 100 km wide plain at about 200 m above sea level. Later, when the Darling Plateau rose the coastal belt - the Ravensthorpe Ramp of Cope (1975) - tilted from the Jarrahwood Axis, sloping gently to the coast and beyond to the edge of the continental shelf (Figure 1.2). Rivers carved valleys through the spongolite to the coast where the Precambrian granitic peaks survive as coastal hills and headlands, such as the Albany Mounts and Cape Riche.

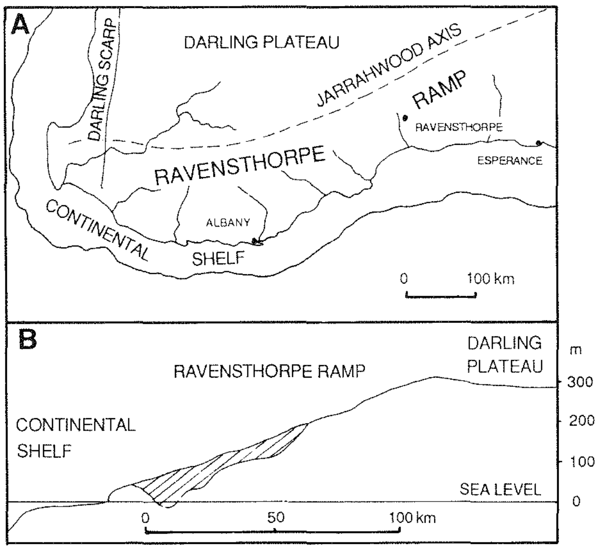


Figure 1.2 Generalised diagrams. A to show the location of the Jarrahwood Axis and Ravensthorpe Ramp; B a profile perpendicular to the coast, hatched area Pallinup Siltstone. Adapted from Cope (1975).

Some of these peaks remained as islands, but during interglacial periods of the Pleistocene (the last 2 million years) when sea level was about the same as at present they were linked by coastal dunes which enclosed bays such as the Albany Harbours and Wilson Inlet. The dune sand became cemented to limestone, Tamala Limestone, the cliffs of which now form much of the southern coastline. In the last ice age sea level was more than 100 m lower than it is now, the coastline was 30-40 km further south near the edge of the continental shelf, and there were valleys and perhaps lakes where the estuaries are now. When the polar ice began to melt 20 000 years ago sea level rose rapidly and by about 6000 years ago had reached its present level; sea water flooded the valleys and they became the estuaries and coastal lagoons of today.

At first the estuaries were always open to the sea and sea water mixed freely with fresh water from the rivers, but subsequently there have been great changes. The ocean beaches formed again from sand washed up from the sea bed and eroded from the dunes. Sand was added to the old dunes and built new dunes and spits, like the Middleton Beach - Emu Point peninsula, which narrowed the mouths of most estuaries. Beach sand built flood tide deltas into the estuaries and sand bars that have blocked the mouths of many. Now exchange with the sea is restricted to periods when the bars are open, they are poorly flushed and the salinity regime is totally different from that of 6000 years ago. Some such as Lake Gardner near Albany and the Jerdacuttup Lakes (in the Ravensthorpe Shire) are now coastal lakes.

When first flooded the estuaries were deeper than they are now, some probably with valleys to hard rock. For a time sea level may have been up to 2 m higher than it is now. Sediment eroded from the catchments and sand from the sea beaches has progressively filled the Pleistocene valleys, some now almost to sea level. Coarse sediment brought by floods has built river deltas and spits. Waves have smoothed sandy shorelines and built beach ridges which the vegetation has stabilised. Samphire and other salt tolerant plants have trapped sediment and formed salt marshes that have encroached on the open water. These same processes continually reshape the estuaries today and reduce their volume.

2 CATCHMENT CHARACTERISTICS

The large catchment of the Kalgan River, the principal tributary to Oyster Harbour, extends north of the Porongurup Range into an area of relatively low rainfall (Figure 1). The river water is saline whereas its southern tributaries are fresh, as is Marbelup Brook to Torbay Inlet. Rainfall decreases from west to east and east of the Kalgan River, the rivers only drain small coastal catchments and their waters are progressively more saline. The large Pallinup River on the eastern border of the Shire drains from north of the Stirling Range.

The greater, southern part of the Oyster Harbour catchment is in the Shire of Albany, but the Kalgan River catchment extends north into the Shires of Plantagenet and Cranbrook. Mill Brook, a main tributary of the King River, extends into the Shire of Plantagenet. The catchments of the other estuaries are within the Shire of Albany.

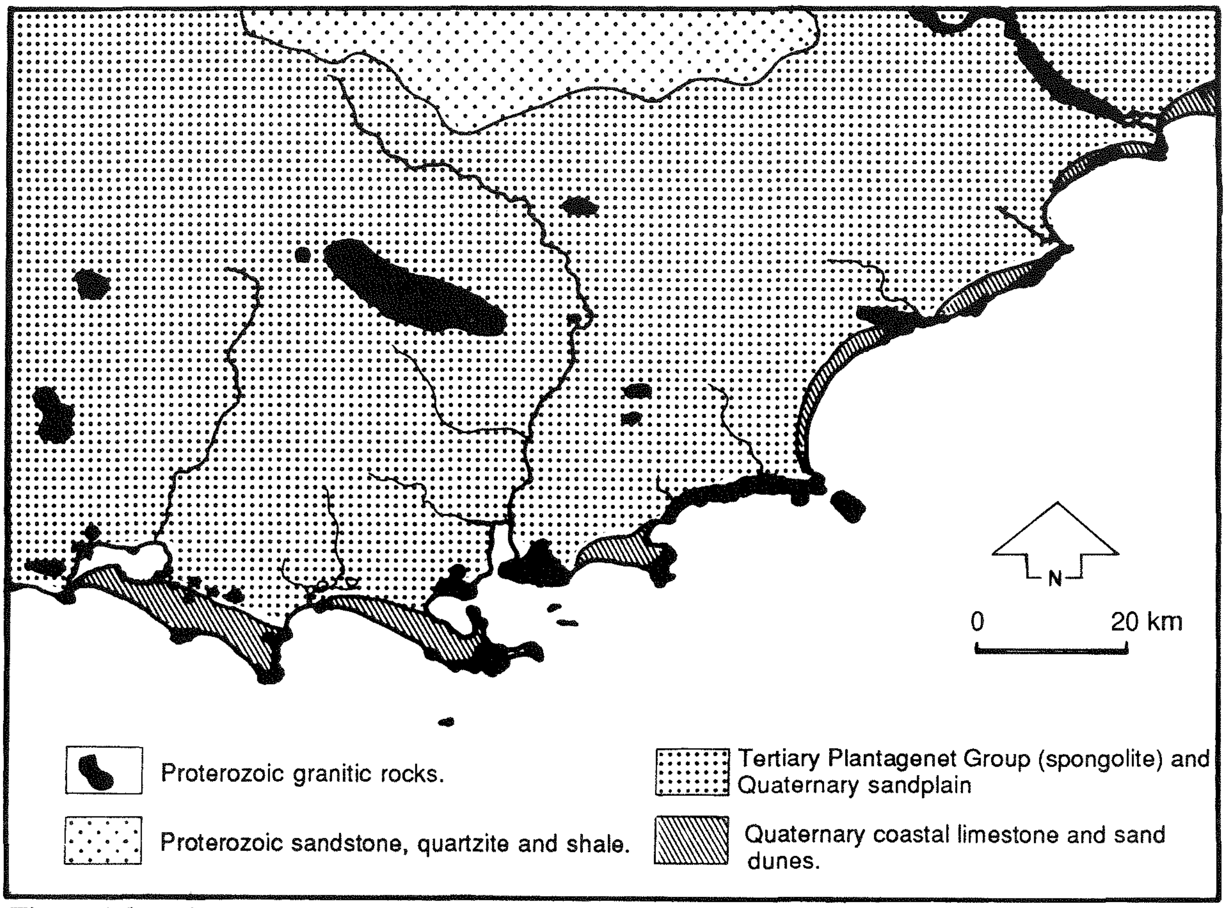


Figure 2.1 Basic geology of the river catchments.

2.1 LANDFORMS, GEOLOGY AND SOILS

The main features of the landscape of the Shire and its river catchments are dictated by the wide, gently undulating plain 100 to 200 m above sea level between the Stirling Range and the narrow chain of rocky headlands that alternate with limestone cliffs and sandy beaches along the coast (Figure 2.1). Sandplain and laterite form the weathered surface of the plain over the spongolite rock which outcrops in river valleys and near the coast. Spongolite is a relatively soft, horizontally bedded sedimentary rock that is easily eroded and the rivers and creeks have carved narrow valleys 20 to 40 m deep into the sandplain and spongolite with wide areas of low relief between them.

East of the Kalgan River a large area of sandplain has no external drainage and many of the small lakes and swamps are saline. Near the coast several small rivers flow to closed lakes behind the coastal dunes, as in Two Peoples Bay, while other creeks have cut narrow valleys through the spongolite to end among the dunes and cliffs along Hassell Beach and Cheyne Bay. These are described and figured in Chapter 9.

The lower reaches of the King and Kalgan rivers have short, steep, irregular slopes with much spongolite and occasional granite outcrops. There are sandy and gravelly yellow duplex soils on slopes and deep loamy sands and some yellow duplex soils on the terraces. The narrow valley floors are filled with river sediments. Upstream the broad valleys have short, gentle flanking slopes, but escarpments and bluffs form local irregularities and in places the upper Kalgan River has cut through the spongolite to the granitic rock beneath. Yellow duplex soils are dominant. The surface horizons are grey brown fine sand, and lateritic gravels are frequently present. The fine sand and clay content is subject to erosion by both wind and water.

A narrow belt of low lying land and swamps extends from Torbay Inlet to Princess Royal Harbour between coastal dunes to the south and sandplain to the north. There are fine textured estuarine deposits with organic loams and diatomaceous earths and some low dunes with yellow duplex soils. The broad concave valleys of Marbelup Brook, Seven and Five Mile Creeks have flat swampy floors in sedimentary rocks with sands and iron podzols on smooth slopes and podzols and yellow duplex soils on swampy floors.

Taylor Inlet lies between the hard gneiss rock of Mount Taylor and the coastal dunes of Nanarup Beach. The northern part of its small catchment is on sandplain and spongolite. Normans Inlet and King Creek are sandwiched in gaps in the granitic rocks, between the Mount Manypeaks range and Boulder Hill. Their catchments drain from gently undulating spongolite and sandplain terrain inland with some poorly drained areas and swamps. The larger Waychinicup River catchment is similarly situated, its tributaries rise on the sandplain and the valleys cut into the spongolite before entering the gorge through the hard coastal rock. Outcrops of Nanarup Limestone (Eocene) in the catchments of Taylor Inlet and Normans Inlet are quarried and the rock ground for application to acid soils.

The Cordinup River drains to the estuary both from the Precambrian rocks of Green Range and from the spongolite plain. The estuary lies in a valley between granite on the east and limestone on the west. The Eyre River drains an area of sandplain and its valley winds through the spongolite before discharging into an alluvial valley from which Cheyne Inlet opens to the sea through a gap in the gneiss rock of the Cape Riche headland.

The geology of the area is described and mapped by Thom and Chin (1984) and Muhling and Brakel (1985). The landforms and soils of the area are described and figured by Churchward et al. (1988).

2.2 COASTAL FEATURES

The character of the coast is determined by the different rock types and by the orientation of the coastline to the prevailing south westerly winds and swell and the summer south easterlies (Figure 2.1). The hard Precambrian rocks form the headlands and rugged, cliffed coasts, though the various granitic rocks (granite, gneiss etc.) show different erosional features. The two large bays, Cheyne Bay and Hassell Beach, are carved in the softer spongolite rock. This is eroding along much of Cheyne Bay, but is covered by dune sand or limestone along the Hassell Beach shore. Both bays face south east between headlands. The Two Peoples Bay and Torbay shorelines appear to have advanced into the bays since they were flooded by the rising sea level enclosing the lakes and swamps.

Beach and dune sand generally has a large broken shell content, the calcium carbonate from which cements the dune sand to limestone. This coastal limestone may be soft and easily eroded or hard and resistant to marine erosion. The long lines of high cliffs west of Albany which face the south westerly swell are hard Pleistocene limestone, but often capped by unconsolidated dune sand. Onshore and nearshore reefs below some of the cliffs and along the curve of some bays are also hard limestone, though this is often cemented beach sand.

These coastal features are discussed in more detail in Chapter 9 in relation to the many small rivers that flow to the coast.

2.3 RIVERS

Table 2.31 shows the areas of the river catchments, the areas cleared, estimated runoff, and the mean annual discharge to the estuaries. There are Water Authority gauging stations on the Kalgan River, Marbelup Brook, Torbay Main Drain, King Creek, Angove River and Waychinicup River. Runoff in the other rivers is estimated on the basis of data from these gauging stations, from rainfall, and the proportion of cleared land in the catchments.

Table 2.31 Catchments of estuaries and rivers in the Shire of Albany. Total and cleared catchment areas. Estimated mean annual discharge and runoff to the estuaries and rivers.

	Catchment area (km^2)	Cleared area (km^2)	Percentage cleared	Mean annual discharge to estuary ($X10^6m^3$)	Runoff (mm)
Oyster Harbour*	3013	2064	68	-	-
Kalgan River*	2562	1701	66	54	21
King River*	402	336	83	40	140
Johnston Creek*	18	7	38	-	-
Yakamia Creek*	31	20	64	-	-
Torbay Inlet *	278	197	71	37	135
Taylor Inlet	10	7	70	1.4	140
King Creek	19	12	63	2	118
Normans Inlet	18	8	46	1.8	100
Waychinicup River	145	59	41	8.4	58
Cordinup River	104	40	38	5.4	52
Cheyne Inlet	77	47	61	6.8	88

*Cleared catchment area to March 1988. All other catchments to February 1987.

The **Kalgan River** is the largest river system in the area. Its northern tributary, the Young River, rises near Cranbrook 30 km from the coast and drains the southern face of the Stirling Range where rainfall averages about 500 mm a year (Figure 1). It winds across the sandplain for about 110 km in a valley that becomes progressively narrower to Oyster Harbour, where rainfall is over 900 mm. Napier Creek, 36 km long, joins the river from the west 5 km north of Upper Kalgan Bridge. There are many pools along the Kalgan River, the largest just upstream from the bridge is 1 km long and 5 m deep. The **King River** drains a smaller, high rainfall area north west of Oyster Harbour. It is about 27 km long and is joined by Mill Brook 2 km west of Upper King Bridge.

Drainage to **Torbay Inlet** is from two very different sources: from Marbelup Brook (18 km long) and Five and Seven Mile Creeks on hills to the north; from flat swampy land east and west of the Inlet where the flow is now mainly in a managed system of drains with flood gates.

Taylor Inlet has only two small streams each no more than 2 km long flowing to it.

Normans Inlet has one small river which flows for about 6 km from Waychinicup Road to the estuary. The nearby **King Creek** has a 17 km^2 gauged catchment.

Cordinup River flows for about 21 km to the sea around the north and east of Green Range. Mullocullop Creek drains the south west side of the range for about 13 km to the landlocked Mirrambeen Lake (Section 9.4).

The **Eyre River** flows for 13 km from the sandplain and spongolite hills to Cheyne Inlet, north of Cape Riche.

RUNOFF AND RIVER FLOW The low runoff figure (21 mm) for the Kalgan River catchment reflects the large part of the catchment that lies in the low rainfall area away from the coast. This contrasts with the high runoff (135 mm) to Torbay Inlet from the Marbelup Brook catchment.

Figure 2.31 shows yearly flow at three WA Water Authority gauging stations and emphasises the great variability in flow to the estuaries. Most flow is generally during the five months June to October (Figure 2.32), but such mean flows are distorted by unseasonal floods such as that of January 1982 which produced 75% of that year's total flow in the Kalgan River in a few days (Figure 2.33). The maximum instantaneous flow was estimated to be 468 m^3/second (WA Water Resources Branch, PWD, 1984). A flood in January 1939 destroyed the Upper

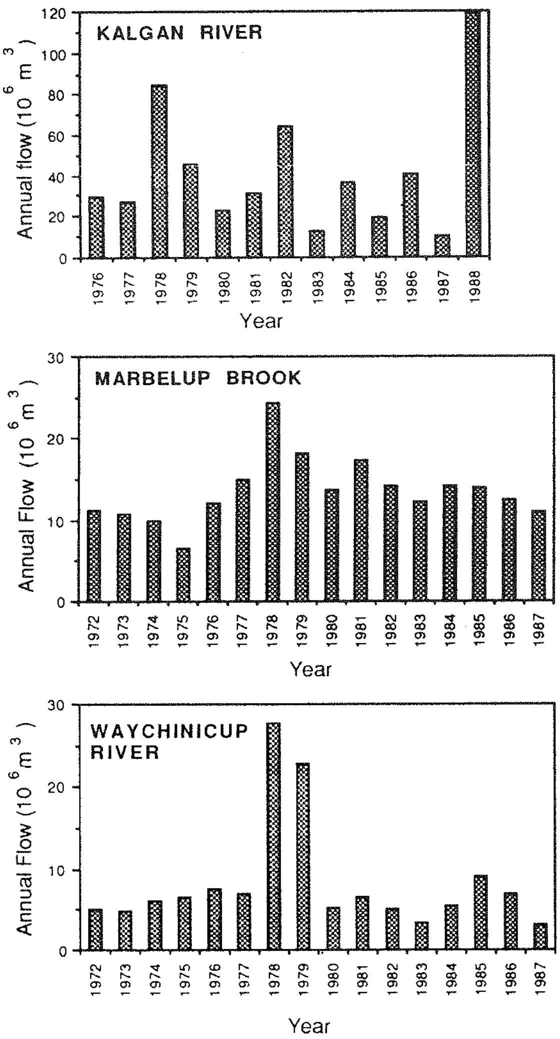


Figure 2.31 Total yearly flows at gauging stations, Kalgan River, 602 004, Marbelup Brook, 603 001 and Waychinicup River, 602 031 (WA Water Authority).

Kalgan Bridge and washed the wreckage down to the lower bridge (Johnson, 1982). Such high flow rates carry heavy loads of sediment to the estuaries, also high loads of plant nutrients from cleared catchments (Section 3.5).

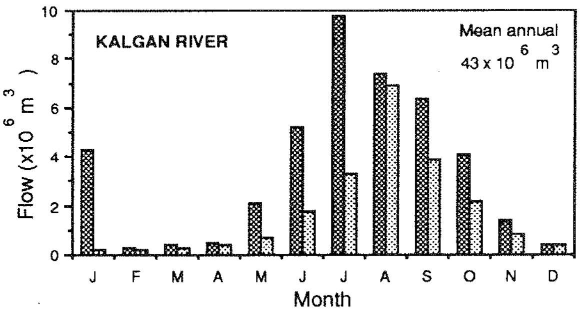


Figure 2.32 Mean ▪ and median ▫ monthly flows at Kalgan River gauging station 602 004, (1976-1987) (WA Water Authority)

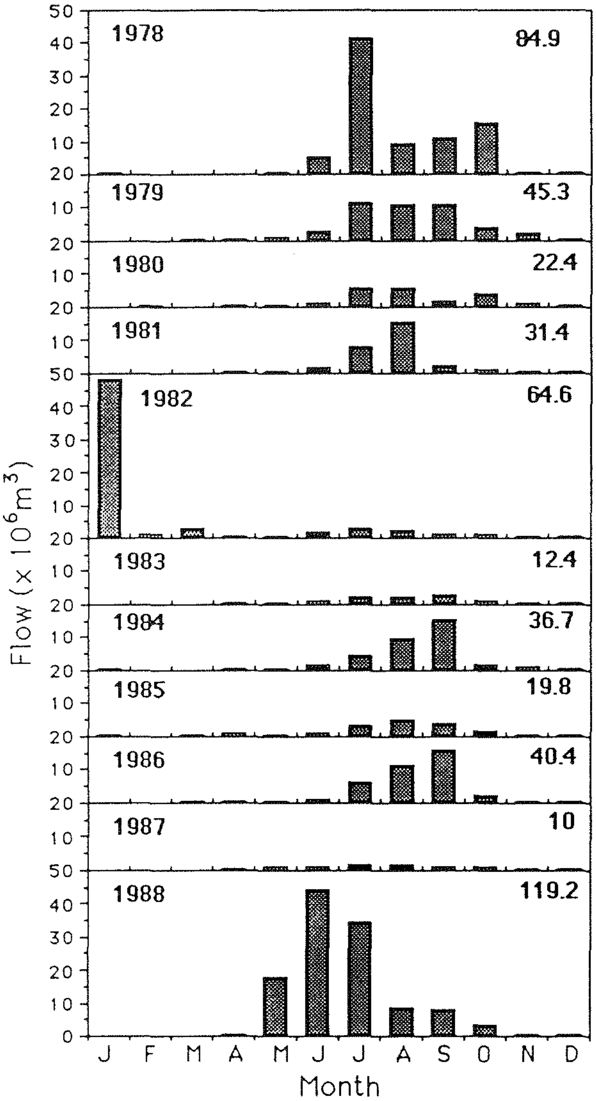


Figure 2.33 Monthly flows in the Kalgan River at gauging station 602 004 from 1978-1988. Yearly totals on right. (WA Water Authority)

WATER CHEMISTRY The salinity of river water increases as rainfall decreases, both inland and eastwards along the coast. **Kalgan River** water is saline with an average TSS of 3100 mg/L, but less than 500 mg/L during extremely high flows, and is highly coloured (WA Water Resources Branch, PWD, 1984). **King River** water was from 1000 to 2000 mg/L when sampled in 1988. **Marbelup Brook** water is fresh, averaging 360 mg/L and is highly coloured. **King Creek** water averages 600 mg/L and the water is highly coloured. **Waychinicup River** water is moderately coloured and averages 720 mg/L (WA Water Resources Branch, PWD, 1984). There are no data for the **Eyre River.**

NUTRIENTS Nutrient concentrations in river water vary greatly with river flow (Table 2.32). The high figures (3300 µg/L in the Kalgan and 2600 µg/L in the King) occurred in May 1988 when a storm caused flood flow in both rivers (Simpson & Masini,1990). The limited data for other rivers are noted in the relevant chapters.

Table 2.32 Nutrient concentrations in the King and Kalgan river water 1987-1988,µg/L.

	King R.	Kalgan R.
Total P		
average	180	40
range	0-2600	20-3300
Total N	3900	4150
nitrate	100	1300
ammonia	820	950

2.4 RAINFALL

The Albany region is transitional between the high rainfall area of the Manjimup and Denmark shires and the more arid area of the Jerramungup and other shires to the east. The mean annual rainfall is 800-1000 mm near the coast west of Albany, it decreases inland to about 500 mm near Cranbrook, and eastward along the coast to 571 mm at Cape Riche (Figures 1 and 2.4). The annual extreme ranges are much greater (Table 2.4). Most rainfall is generally in winter but occasional summer cyclonic storms may precipitate 200 mm or more in a few days. All stations recorded such falls in January 1939 (261 mm at Kalgan River), February 1955 (243 mm at Cape Riche) and January 1982 (241 mm at Cape Riche). These storms caused high flows in the rivers and extensive flooding.

2.5 LAND OWNERSHIP AND USE

The greater part of the catchments of Oyster Harbour and Torbay Inlet are alienated land and about 70% has been cleared for agriculture, for sheep and cattle grazing, some cereal production and dairy farming, and for vegetable growing near Torbay Inlet. Along the coast there are still extensive areas where native vegetation remains undisturbed in a number of National Parks and other reserves (Figure 1). About half the catchments of the small estuaries have been cleared, mostly where the rivers rise on higher land.

Land around Albany and along the fertile coastal strip east towards Wilson Inlet was cleared and developed in the last century, but most of the northern part of

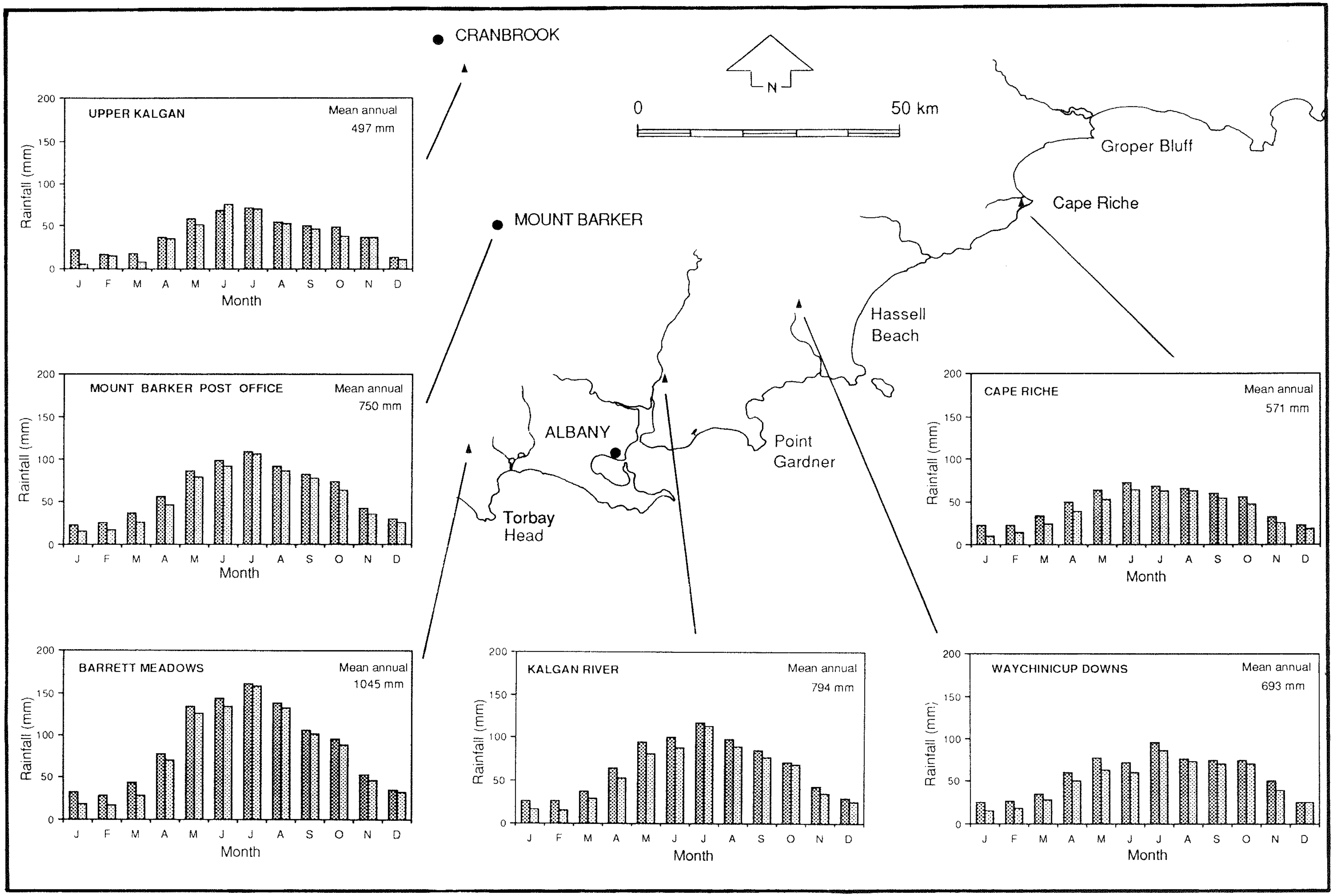


Figure 2.4 Mean and median monthly rainfall at inland stations: Upper Kalgan, 009 768, (1967-1984) and Mount Barker Post Office, 009 581, (1886-1984) and coastal stations Barrett Meadows, 009 599, (1914-1985), Kalgan River, 009 559, (1911-1984), Waychinicup Downs, 009 799, (1960-1986) and Cape Riche, 009 520, (1897-1985) (Commonwealth Bureau of Meteorology). Mean ▩ , median ▨ .

Table 2.4 Mean annual highest and lowest, monthly and annual rainfall at six rainfall stations. (Commonwealth Bureau of Meteorology)

	UPPER KALGAN 1967-1984 009768	MOUNT BARKER 1886-1984 009581	BARRETT MEADOWS 1914-1985 009599
Average annual	497 mm	751 mm	1045 mm
Lowest annual	317 mm (1972)	466 mm (1891)	748 mm (1969)
Highest annual	577 mm (1976)	1102 mm (1917)	1554 mm (1917)
Highest monthly	190 mm (Jan 1982)	261 mm (Jly 1912)	314 mm (Jan 1939
Highest two mthly	205 mm (J/Fb 1982)	352mm (My/Jn 1917)	521 mm (My/Jn 1923)
	KALGAN RIVER 1911-1984 009559	WAYCHINICUP DOWNS 1960-1986 009799	CAPE RICHE 1897-1985 009520
Average annual	794 mm	693 mm	571 mm
Lowest annual	477 mm (1940)	524 mm (1962)	273 mm (1936)
Highest annual	1139 mm (1917)	919 mm (1978)	957 mm (1917)
Highest monthly	283 mm (Jly 1912, My 1963)	275 mm (My 1963)	326 mm (Ap 1913)
Highest two mthly	405 mm (J/J 1978)	408 mm (J/J 1978)	397 mm (J/J 1978)

the Shire and the Kalgan River catchment has only been developed since the 1950s. On the eastern coast, Cape Riche was first settled by George Cheyne in 1839 for grazing and as a staging post for whalers. The small farms near Normans Inlet, Mulloculllop Creek and the Cordinup River and were developed in the 1920s and 1930s. The land around Taylor Inlet was not cleared until the 1960s.

2.6 VEGETATION

The vegetation of the eastern part of the Shire is described and mapped in relation to landforms and soils by Churchward et al. (1988) on a scale of 1 : 100 000.

Although some 70% of the catchments of Oyster Harbour and Torbay Inlet have been cleared there are still patches of forest in reserves and uncleared areas of alienated land where Jarrah (*E. marginata*) and Marri (*E. calophylla*) forests are present throughout. *Banksia* woodland is also common, especially on higher ground. Wandoo (*E. wandoo*) grows in the low rainfall area of the upper Kalgan River catchment, with *Melaleuca* scrub, Swamp Yate (*E. occidentalis*) and salt tolerant plants (halophytes) in the valleys. There is a small area of Karri (*E. diversicolor*) forest on the Porongurup Range and Yate (*E. cornuta*) grows along the slopes of the range. The upper catchment of the King River has Swamp Yate and Blackbutt (*E. patens*) in the valleys. There is also patchy Albany Blackbutt (*E. staeri)* forest on higher ground in the lower catchments of the King and Kalgan rivers and of Marbelup Brook.

There are dense Peppermint (*Agonis juniperina*) and *Oxylobium lanceolatum* thickets immediately around Torbay Inlet and east to Lake Powell, with *Lepidosperma* spp. on more poorly drained areas. The northern slopes of the coastal dunes are well vegetated dunes with Banksia, Yate and Bullich (*E. megacarpa*). There are woodlands with *Banksia* spp. and *Allocasuarina fraseriana* on the lunettes east of Seven Mile Swamp. *Gahnia decomposita* and *Scirpus* spp. are common along the Torbay Main Drain sedgelands and there are scattered thickets of *Melaleuca cuticularis*.

The greater part of the Taylor Inlet catchment is cleared but there is mallee-heath on the granite hills and woodland and dense scrub on the dunes. The well drained catchment has woodlands of depauperate Jarrah with *Banksia attenuata* and *Xylomelum occidentale* with a dense shrub layer. Norman Inlet and King Creek are sandwiched between steep granite hills with mallee-heath; the catchments are largely cleared farm land on spongolite, but there is low forest and sedges on the floors of the deep valleys. The similar, but larger, catchment of the Waychinicup River still retains a considerable area of poor mallee-heath and jarrah-sheoak woodland with scattered swampy areas on sandplain in the reserve.

King River. Sediment fan from a farm drain.

The vegetation of the area east of 118° 30' was mapped by Newbey (1979) from field surveys and from aerial photography flown in 1969 before much of the relevant area had been cleared. In the hilly catchment of the Cordinup River the vegetation was principally a low woodland with a Marri (*Eucalyptus calophylla*) plant association on the plain and Flat-topped Yate (*E. occidentalis*) along the valleys. Coastal limestone west of the estuary carried a closed-heath and on the east open-scrub. Much of the lower catchment has recently been planted with Tasmanian bluegums (*E. globulus*) and other forest trees. The catchment of the nearby Wilyunup Creek had a Jarrah (*E. marginata*) tall open-shrubland but is now largely cleared grazing land.

The lower catchments of Cheyne Inlet and creeks draining to Cheyne Bay have a complex and variable vegetation on the spongolite with patches of Tallerack mallee (*E. tetragona*). The granite of the Cape Riche range has an open-heath.

Channel blasted through the rock bar in the Kalgan River.

3 OYSTER HARBOUR - PHYSICAL FEATURES

Oyster Harbour is a large, deep lagoon; it is one of the few estuaries of the south west that are permanently open to the sea, to the sheltered ocean water of King George Sound (Figure 3.11). It is the only south coast estuary which has a deep entrance, without a sand bar. Tidal exchange is little damped and there is mixing between harbour water and marine water in King George Sound. In consequence the water is close to sea water salinity most of the time, except near the river mouths and briefly following flood flow when surface salinity drops precipitately. This provides a favourable environment for the diverse marine fauna, a very different environment from that of any other estuary of the south coast. Hardy Inlet and Nornalup Inlet, the other two permanently open lagoon systems of the south coast, both have shallow bars and large rivers flowing into them, long periods of low salinity in winter, and a less diverse fauna with few marine species (Hodgkin, 1978; Hodgkin and Clark, 1988a).

The King River and Kalgan River are part of the estuarine system and are tidal for 7 and 9 km respectively. Exchange with the harbour is restricted and the water becomes fresher upstream, and it is often sharply stratified with fresh river water flowing over high salinity harbour water that has intruded below it.

Oyster Harbour is largely surrounded by private property, with residential developments along much of the western shore north of Yakamia Creek and only a narrow fringe of native vegetation to the water's edge. Emu Point is residential and has an Albany Town Flora Reserve in a swampy area on its north side. A large marina has been excavated in the harbour shore here. National Park and other still forested reserves border the south eastern quarter of the shore. The estuarine reaches of the rivers wind through cultivated land but the steep banks of the Kalgan are still tree clad. The catchment extends from a low rainfall area along the southern face of the Stirling Range to the wet coastal area where the estuary is situated; 70% is cleared farm land (Table 2.31).

3.1 LANDFORMS

RIVERS The Kalgan River is tidal for 9 km from its mouth at the north eastern corner of Oyster Harbour to the Upper Kalgan Bridge. A 1 km long river pool above the old bridge is separated from the pool at the head of the estuary by a steep rock fall under the bridge. The tidal river traverses a deep valley along which granitic rocks (gneiss) are exposed both onshore and in places in the river. About 1 km downstream from the bridge there is a rock bar which is exposed at low tide separating the upper part from the rest of the estuary. Upstream of this bar the river is only 20-30 m wide, but downstream it widens progressively to 100 m about 3 km from the mouth. The valley then opens out and the river widens to 250 m at the Lower Kalgan Bridge, with swamps and sandy shallows for a short distance upstream from the bridge and at the mouth of the river. The river channel extends for about 2 km through the shallows of Oyster Harbour where it is well defined and 50-75 m wide (Figure 3.12).

There are three islands in the River: Elbow Island, high and 100 m across, lies in a bend of the river at about 4 km; the small White Island just south of the lower bridge; and a small island in the rock bar. A channel was blasted through the rock bar, probably first in the 1890s and again in the 1920s, to give passage for boats carrying fruit and wool from farms on the Kalgan River to Oyster Harbour.

The King River is estuarine for 7 km from its mouth at the Lower King Bridge to where it is joined by Mill Brook. From Mill Brook to the Upper King Bridge the river has a narrow winding channel between 1-2 m high sandy banks. There are granite outcrops in the river near the Upper King Bridge and about 1.5 km downstream from it. It then flows through low lying pastoral land with a fringe of sedges (*Juncus kraussii*) and paperbark trees (*Melaleuca cuticularis*). For 2 km above the Lower King Bridge there is a wide deltaic area of salt marsh and intertidal sand flats through which a shallow, narrow channel winds. The river narrows and deepens again at the 70 m long bridge. The deltaic sediments include shell beds that continue for about 1.5 km upstream from the bridge.

Johnston Creek on the northern shore of Oyster Harbour and Yakamia Creek in the south west are only estuarine for a short distance. An extensive sedge swamp north of Emu Point is inundated at high tide.

LAGOON Oyster Harbour is a large deep lagoon, 15.6 km^2 in area, which shelves from the eastern shore to over 5 m on the western side. It is elongate, 5.5 km long in a north-south direction and 3 km wide. The sand dune peninsula of Emu Point forms the unstable western shore of the mouth. North of this there is a wide swampy area where the Lake Seppings and Yakamia Creek valleys drain to the harbour. North again a steep slope capped with laterite extends for 2 km from Bayonet Head along the western shore to a swampy foreshore south of King River. The north shore is again steep, only descending to flat land where Johnston Creek enters the harbour. A wide swampy stretch with beach

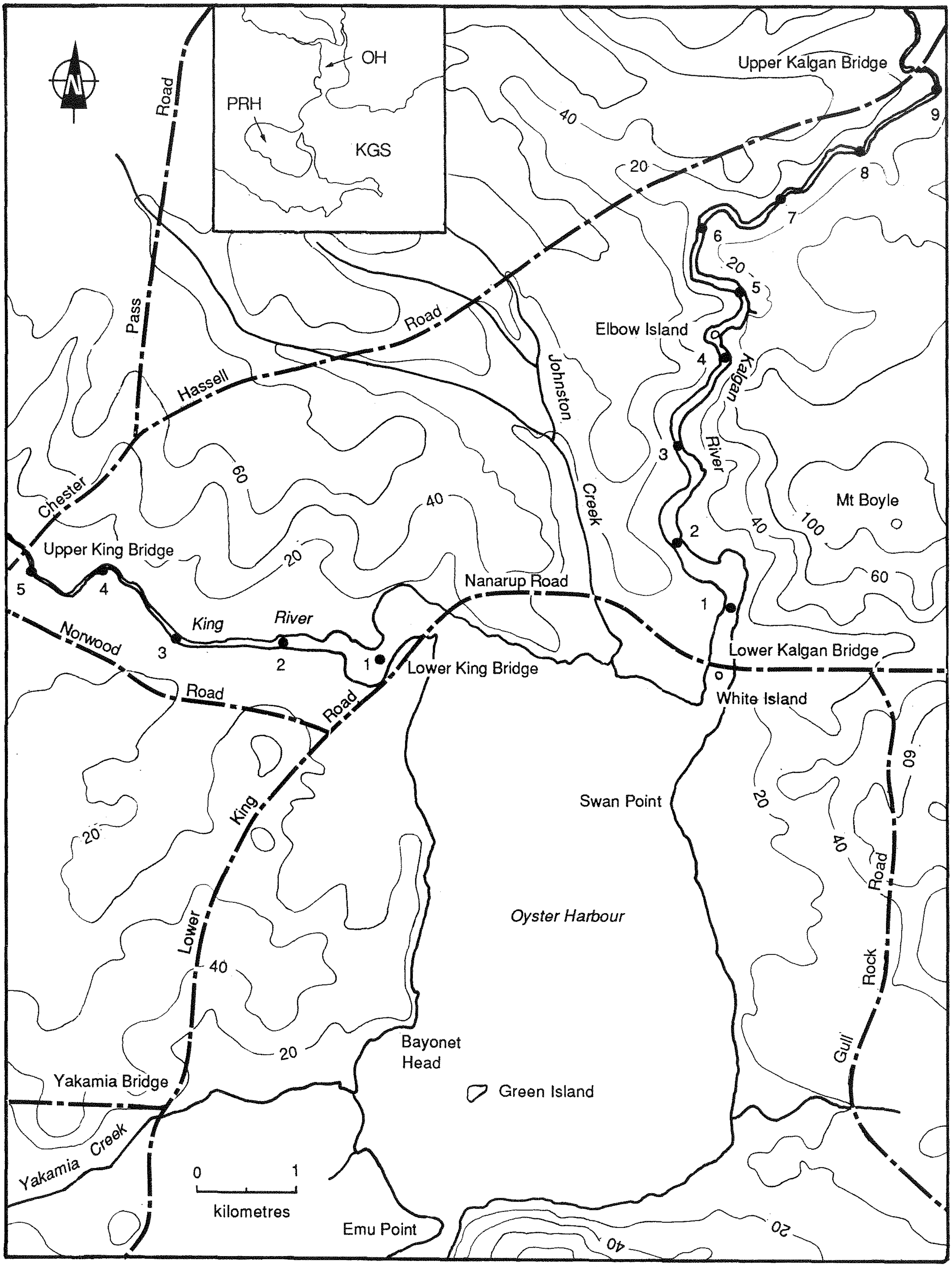


Figure 3.11 Oyster Harbour. Topography of the surrounding area. Contours in metres. Distance in kilometres from the river mouths.

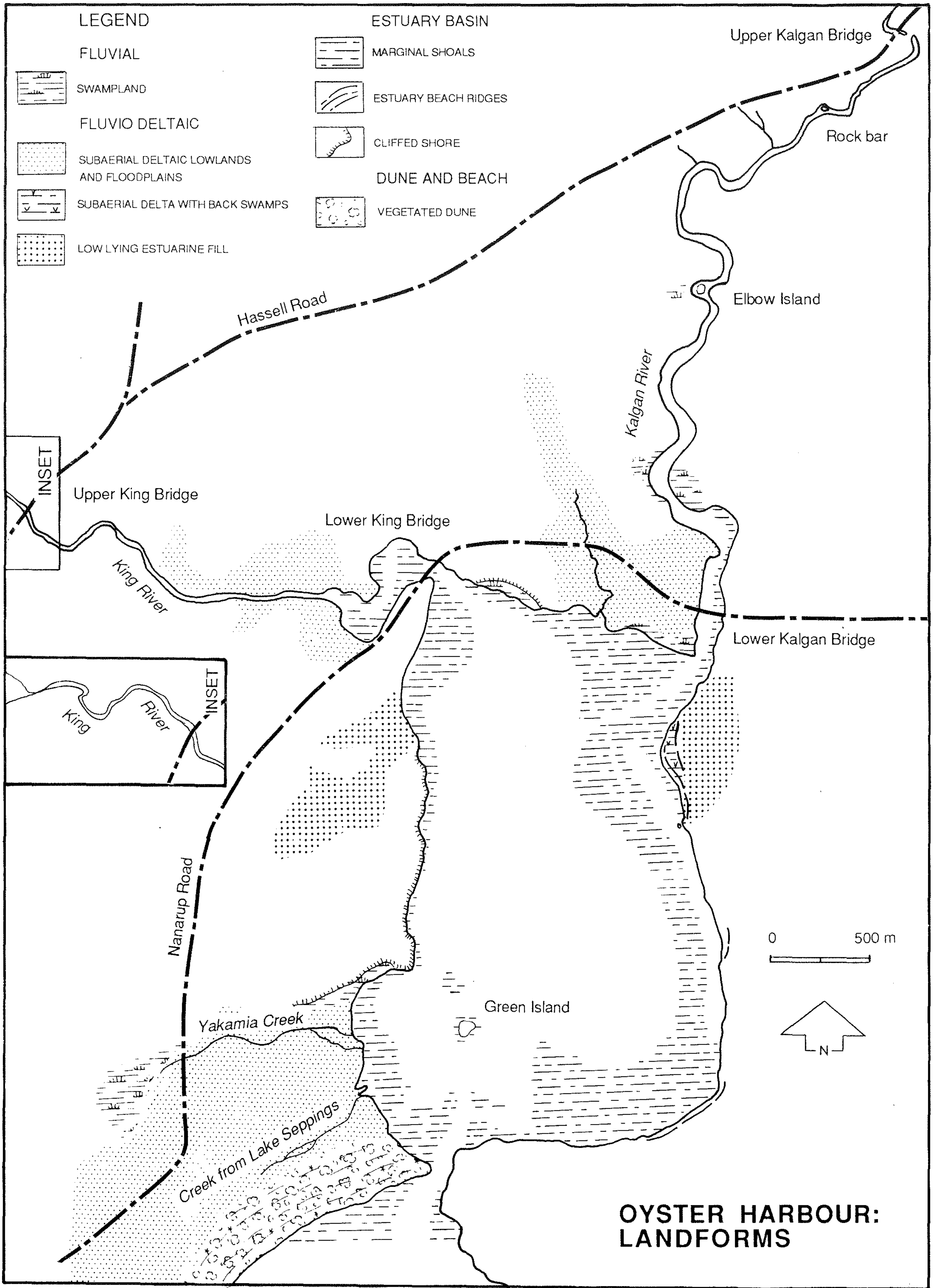


Figure 3.12 Oyster Harbour. Landforms.

ridges borders the north western shore round Swan Point at the foot of Mount Mason and in the south west the shore rises steeply to Mount Martin. The granite rock of Green Island rises from the deep southern part of the harbour. The shallows are sandy and there are extensive shell beds around much of the shoreline and scattered laterite rocks below the steep hillsides.

There are urban developments at Emu Point, on Bayonet Head, at King River, and on the north shore. Farmlets are being developed on the slopes of Mount Mason. The forested slopes of Mount Richard are part of a proposed National Park that extends east almost to Taylor Inlet.

THE ENTRANCE This is less than 200 m wide between the granite rocks of Mt Martin and the Emu Point peninsula. Through this tidal flow scours a 100 m wide deep channel that extends 1.2 km between the southern shallows to the deep water of the harbour (Figure 3.12). Emu Point is an eroding sandy spit at the eastern end of the unconsolidated dunes between the northern shore of King George Sound and the Lake Seppings swamps. The Point has been partly walled with rock and a groyne that extends into the Sound to reduce damage by storm waves which have eroded the Point on a number of occasions. There were breakaways in 1914, January 1939 and in 1950. Lake Seppings is reported to have flowed to the sea at Middleton Beach in the 1880s.

3.2 WATER DEPTHS

The small ocean tide is little damped in Oyster Harbour and in the rivers. Water level varies 0.3 to 1.2 m daily and the extreme range in water level is about 2 m. A third of the area of the harbour lies between 0 and 5.5 m depth and wide areas of sand flats along the eastern, northern and southern shores are exposed on low tides. Shoals from the eastern shore divide a small northern from the larger southern deep water part of the harbour, with a 10 m deep channel connecting them close to the western shore (Figure 3.2). Only one fifth of the area is more than 5 m deep. The entrance channel is scoured to 12.5 m.

The lower reaches of the Kalgan River are only about 1 m deep, but the river deepens to 2-3 m along most of its length and is 4 m on some bends. The rock bar is exposed across the width of the river at low tide and there are rocks in the river upstream. The pool downstream of the Upper Kalgan Bridge is 3 m deep. The King River is 1.5 - 2 m deep along most of its length, but the channel through the shallows above the Lower King Bridge is not navigable at low tide. Granite rocks obstruct the river immediately downstream of the Upper King Bridge.

3.3 SEDIMENTS

The sediments of Oyster Harbour are described by McKenzie (1964). They are medium-coarse to fine grain, silty sands derived from the rocks of the catchment together with 30% carbonate material mainly from broken marine shells. They are relatively coarse (median grain size 400 μm) along the western cliffed shore, finer on the gently sloping eastern shore and grade to fine (less than 100 μm) in deep water, and with increasing organic content. The sediments are better sorted in the shallows than under seagrass cover which forms a screen against wave sorting and abrasive processes. There are extensive shell beds round the margin of the harbour, at Emu Point they extend inland for over 100 m and to 3 m depth where the marina channel was dredged.

Shell beds with oyster, cockle and many other mollusc shells extend to nearly 6 km from the mouth of the Kalgan River and extensively for over 1 km

The 'Silver Star' cruising up the Kalgan River. Undated photograph, Albany Public Library.

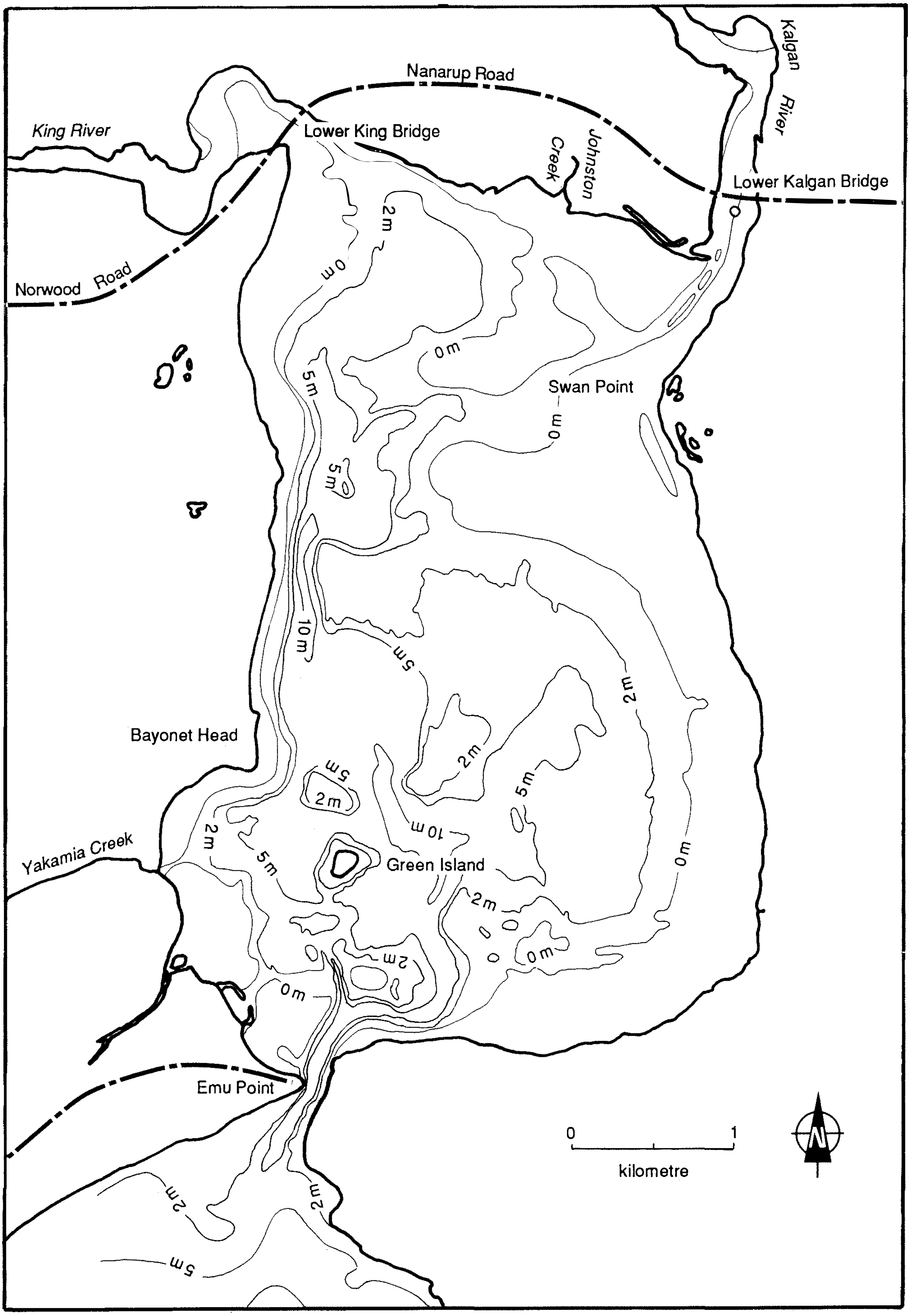


Figure 3.2 Oyster Harbour bathymetry. Depths in metres below mean sea level. (redrawn from PWD, WA map 52659)

from the King River mouth. These indicate that there were much more marine conditions at some previous date.

3.4 WATER CHARACTERISTICS

Oyster Harbour is unique among the estuaries of the south coast in having a deep, though narrow, mouth so that there is good tidal exchange between the lagoon water and the sea water of King George Sound. The estimated flushing time is less than about 10 to 20 days, during periods of low river flow, in contrast to months or years in other estuaries of the south west. The harbour water is generally close to sea water salinity and provides a much more marine environment for the diverse fauna and flora (Chapter 11). However the estuarine reaches of the King and Kalgan rivers, although always tidal, experience marked seasonal changes in salinity and they have few species.

McKenzie (1964) figures the summer (1960) and winter (1961) hydrological regimes in Oyster Harbour. Simpson and Masini (1990) give a general account of the hydrology and nutrient input and D'Adamo et al. (1990a, b) give a more technical account of the hydrology and circulation.

SALINITY The salinity of Oyster Harbour water is close to that of sea water (35-37 ppt*) most of the time (Figure 3.41). The small river flows of summer mix with harbour water in the tidal rivers and surface water in the harbour may then be slightly less (34 ppt in the northern part) than the wedge of tidal sea water beneath. Wind mixing rapidly breaks down this weak stratification and the water is mixed to the bottom (10 to 12 m) within 5-10 hours by winds greater than about 20 knots.

* ppt = parts per thousand

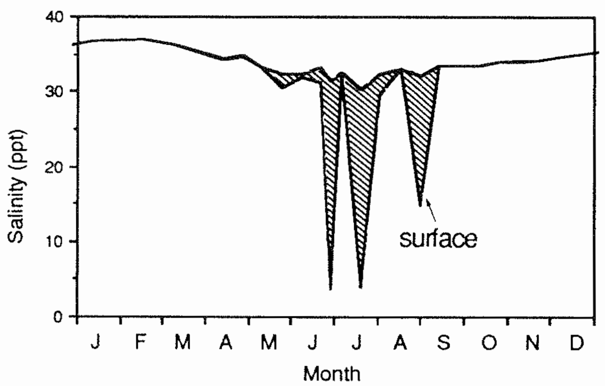


Figure 3.41 Oyster Harbour. Salinities at surface and 2 m in the centre of the harbour in 1988. (Hillman et al, 1990a)

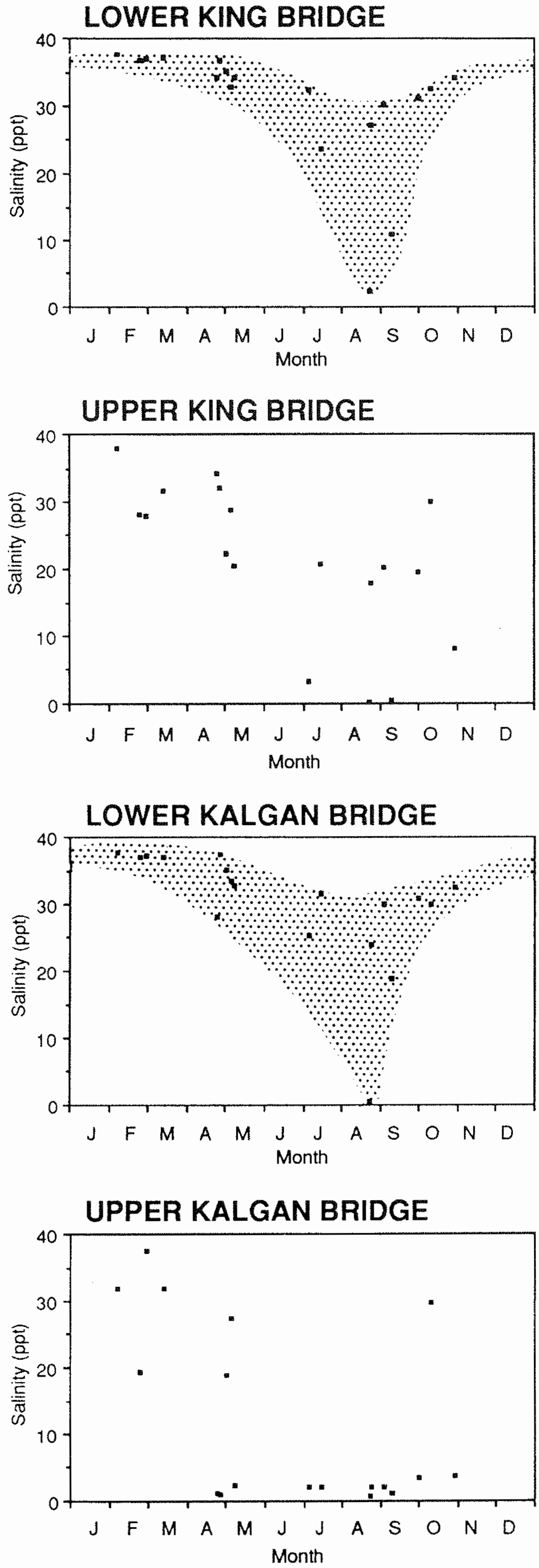


Figure 3.42 Surface salinities in the King and Kalgan rivers between 1945 and 1952. (Spencer, 1952). Stipple: envelope of observed salinities.

Within 12 to 48 hours after heavy rain in the catchments flood flow from the rivers rapidly spreads nearly fresh water (less than 5 ppt) in a layer less than 1 m thick over the harbour. Under calm conditions this lighter water soon flows out into King George Sound and does not mix with the denser sea water below. Strong winds of over 24 knots for a continuous 6 hours are required to break down this intense stratification and mix the water to 6-8 m deep. Some stratification may persist briefly following flood flow but surface water is probably seldom less than about 30 ppt for more than a week (Figure 3.41), except near the river mouths, and tidal exchange ensures that the deep water is always greater than 33 ppt.

The riverine reaches of the King and Kalgan rivers experience similar seasonal changes to other estuaries of the high rainfall south west (Figure 3.42). The water can be fresh or nearly so in winter, there is a gradient of salinity along their length when flow slackens, and the water is often stratified (Figure 3.43). It should be noted that the 1945-52 data shown in Figure 3.42 were obtained before extensive clearing in the catchments; also that the Upper Kalgan Bridge is at the head of the estuary, above the rock bar, whereas the Upper King Bridge is half way along the estuarine reach of the King River.

WATER TEMPERATURE McKenzie (1964) records temperatures from 12.5°C to 25°C , but more extreme temperatures will be experienced in the shallows on hot days or cold nights. This leads to strong horizontal differences in temperature and density which could drive appreciable horizontal density currents complementing wind and tidally induced circulation patterns.

3.5 NUTRIENTS AND EUTROPHICATION

Both Oyster Harbour and Princess Royal Harbour are eutrophic. A survey of the marine plant communities in 1984 found a considerable build-up of attached and unattached algae and an extensive loss of seagrasses since 1961 (Bastyan, 1986). Studies in 1988-89 showed further loss of seagrasses and the report (Simpson and Masini,1990) concludes that:

> In recent years the rate of seagrass loss in the harbours has accelerated due to a proliferation of macroalgae which shade and smother the seagrass meadows. The growth of macroalgae has been stimulated by excessive nutrient inputs to Princess Royal Harbour from industrial, rural and urban sources, and to Oyster Harbour from rural and urban sources.

By 1988 almost 90% of the seagrass meadows in Princess Royal Harbour and 80% in Oyster Harbour had been lost since 1961. The loss was initially from areas deeper than 2 m, where seagrassses previously grew to 5 m, possibly because increased turbidity and eiphytic algae had reduced the light available for photosynthesis. Then between 1981 and 1984 the

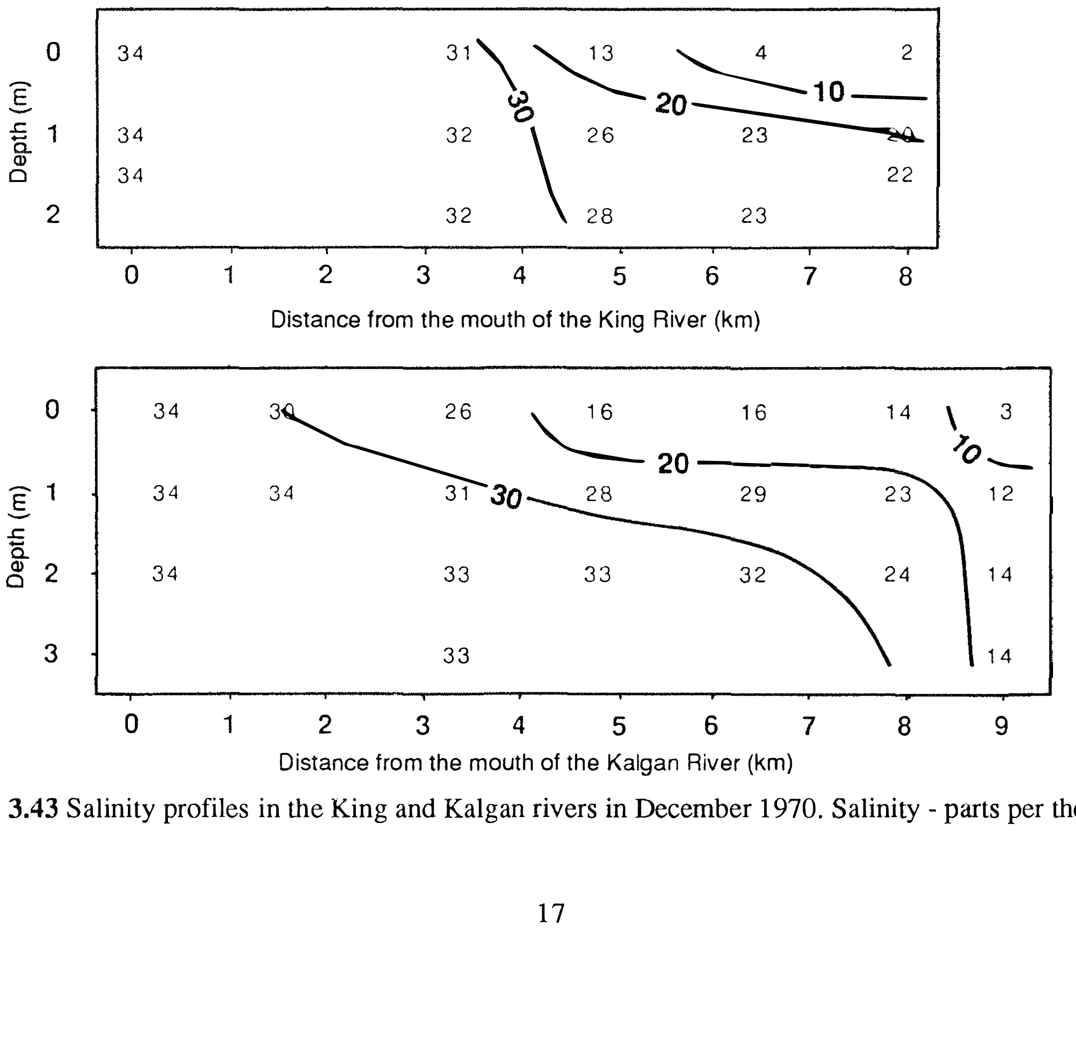


Figure 3.43 Salinity profiles in the King and Kalgan rivers in December 1970. Salinity - parts per thousand.

macroalga *Cladophora prolifera* increased greatly and smothered healthy seagrasses growing in the shallows. In 1988 Oyster Harbour produced 1 200 tonnes dry weight of macroalgae (PRH 12 000 tonnes). This was mainly in the most sheltered area in the south east and was 92% of the total plant biomass.

Until recently the two harbours have received similar mean annual nutrient loadings: Princess Royal Harbour about 30 tonnes of phosphorus a year (now considerably reduced), Oyster Harbour an average of 25 tonnes. However the sources of the nutrients and their availability to the algae differ greatly. The input to Princes Royal Harbour is mainly from local sources and comes throughout the year, the water is well mixed and residence times are long so that most of the incoming nutrients remain in the harbour long enough for macroalgae to use them for growth. The input to Oyster Harbour comes mainly from the river catchments in sporadic flow and much of this is carried straight out to sea in surface flow before it can be mixed into the water body and used for algal growth.

The major nutrient inputs to Oyster Harbour originate from the broadscale use of phosphatic fertilisers and of leguminous pastures in the catchment. Urban sources and piggeries make a minor contribution. Input varies greatly from year to year depending mainly on the volume and pattern of river flow. In 1987 less than 5 tonnes of total phosphorus is estimated to have entered the harbour but in 1988 the load was 70 tonnes; 1987 was a very dry year and 1988 a very wet year (Figure 2.33). The January 1982 flood is estimated to have brought over 17 tonnes of phosphorus to the harbour in 3 days. Nutrient concentrations are generally low in river water, about 0.05 mg/L phosphorus in Kalgan River water, but under flood conditions nutrient levels can be very high, especially following the first heavy winter rain. In the flood of May 1988 phosphorus was briefly 3.3 mg/L and even though the flow was only 5% of that for the year it brought 42% of the total phosphorus load from the Kalgan River for the year. However, little of this phosphorus probably remained in the harbour because much of the flood water was rapidly lost to the sea. With low river flow and weak stratification vertical mixing by wind is rapid and the contained nutrients may contribute more to plant growth than the flood water nutrients.

About half the phosphorus in river water comes as phosphate, the inorganic form in which it is readily available for plant growth. Concentrations of both phosphate and inorganic nitrogen (nitrate-nitrite and ammonia) in Oyster Harbour water were low in 1988, except during and shortly after the May-July period of high river flow (Figure 3.5), and the ratio

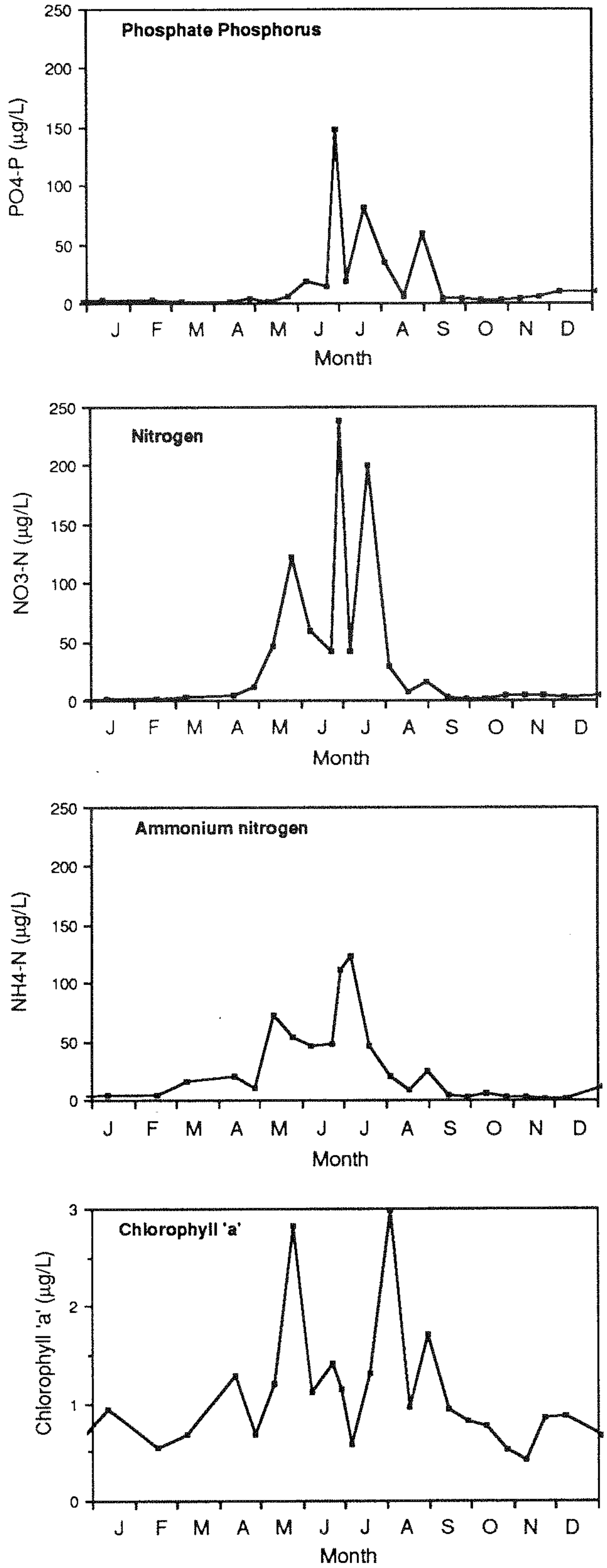


Figure 3.5 Nutrients and chlorophyll 'a' concentrations in Oyster Harbour water in 1988. (Hillman et al, 1990a)

Table 3.5 Nutrient concentrations (µg/L) in Oyster Harbour and in King River and Kalgan River water in 1974 and 1975. (Lenanton and Edmonds pers. comm.)

			NO3	Tot N	PO4	Tot P	S‰
Oyster Harbour	29.8.74	S	<20	270	10	20	31.4
		B	50	2200	30	280	34.4
	20.2.75	S	<20	270	10	20	36.92
		B	<20	710	10	40	36.75
King River	29.8.74	S	30	970	80	240	1.6
		B	30	1100	70	310	22.5
	20.2.75	S	20	800	170	340	30.04
Kalgan River	29.8.74	S	30	1000	10	50	3.5
		B	50	1100	<10	40	3.5
	20.2.75	S	40	760	20	50	2.0
		B	<20	920	10	50	2.0

of nitrogen to phosphorus was low except during the 3 months March to May. River flow appears to be the main source of nitrate-nitrite nitrogen but ammonia is probably mainly recycled from the sediments. The sediments are the largest pool of both nutrients and contain at least 80% of the total nitrogen and total phosphorus. The sediment phosphorus only becomes available as phosphate if the bottom water becomes anoxic, probably a rare event.

Detailed results of the investigations into the nutrient status of the harbours and their seagrass meadows are published in Hillman et al. (1990a and b) and in other papers listed in the Albany Harbours Environmental Study (Simpson and Masini,1990).

Table 3.5 records nutrient concentrations in water samples taken in Oyster Harbour and the two rivers in 1974-75.

Healthy seagrass (*Posidonia*) meadow. Photo: Jennie Cary.

Seagrass smothered by *Cladophora*. Photo: Jennie Cary.

4 TORBAY INLET - PHYSICAL FEATURES

Torbay Inlet is a small shallow lagoon with a narrow channel to the sea at the eastern end of Perkins Beach where the mouth is sheltered from south westerly swells by Torbay Head. The mouth is closed by beach sand most of the time but breaks or is broken several times each year. The Inlet is the estuarine part of a drainage system, now largely artificial, that includes Lake Manarup, Lake Powell (previously called Lake Grasmere), and drains from swampy cultivated alluvial flats east and west of the Inlet (Figure 4.11). Only the channel to the sea, the lagoon, and Marbelup Brook to the High Level Drain are now estuarine, with sea water intrusion.

The swampy valley between Torbay Inlet and Princess Royal Harbour has a fertile soil and was developed for cultivation of a variety of crops during the 19th Century. Potatoes, tomatoes, cabbages and other vegetables were grown and shipped from Albany and from the 1890s to the 1930s supplied the goldfields market. Such crops are still grown and sheep and cattle are agisted on the swamps. Much of the land is only 0.5 to 1 m above mean sea level (MSL), up to 10 km from the sea, and it was subject to flooding, sometimes with salt water. Drains were dug diverting the water from the swamps to the Inlet but failed to keep water off land. They had the unfortunate effect of making the Seven Mile Swamp (now Ewart Swamp) acid and infertile. To quote Woodward (1917): The poisonous mineral solutions in the soil of the "Seven Mile Swamp" are due to the oxidation of the iron pyrites in the soil itself owing to the mineral being brought in contact with the air by drainage and cultivation.

A barrage with floodgates was built half a kilometre from the bar in 1912 in an unsuccessful attempt to prevent salt water backing up onto the farm land. It was built of Californian redwood and worked fairly well until about 1920. However sand built up against the downstream side, shallowing it from 5 m on the upstream side to 60 cm on the downstream side. Gaps between the timbers allowed sea water to flow back into the Inlet and attempts to block these with sheets of iron obstructed outflow so that water did not get away fast enough and flooding continued. The decking was first burnt about 1928 and repaired and subsequently burnt several times before the barrage was blown up by the army in 1985 as a

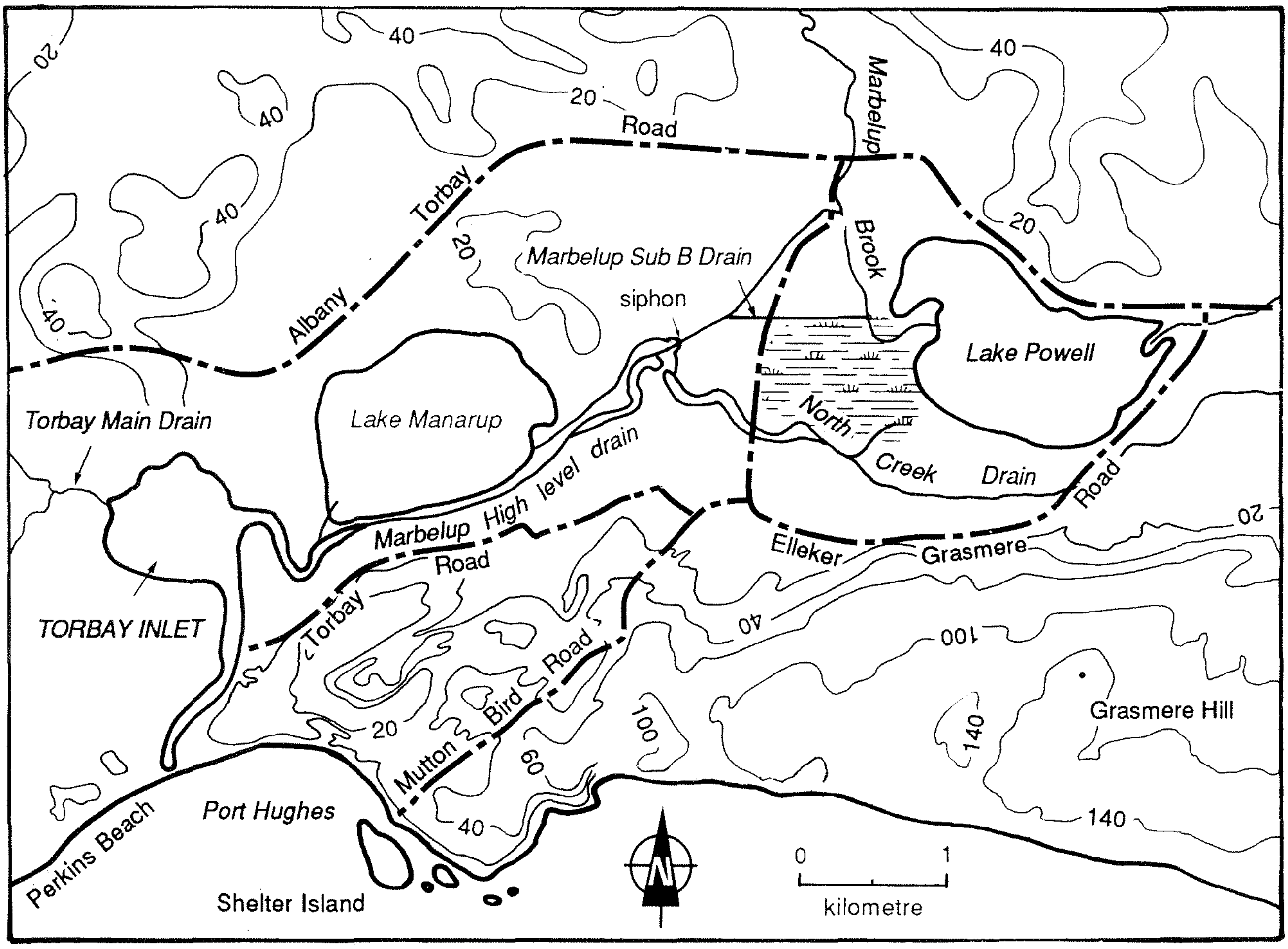


Figure 4.11 Torbay Inlet. Topography of the surrounding area. Contours in metres.

Torbay Inlet barrage and floodgates, built 1912. Photo: A. Shirley.

demolition exercise and became derelict. Some of the piles still stand.

The present drainage system has been developed progressively to prevent salt water flooding paddocks east of Elleker Grasmere Road and maintain a fairly constant water level on them throughout the year. This has involved: diverting Marbelup Brook direct to Torbay Inlet; diverting the Five Mile and Seven Mile creeks and Five Mile Swamp to Lake Powell; installing floodgates on a drain connecting Lake Powell to the Marbelup Drain; draining Seven Mile Swamp and the swamps south of Lake Powell to a siphon under the Marbelup Drain to Lake Manarup; installing floodgates on the outlet from Lake Manarup. It also necessitates breaking the bar periodically when the water cannot get away.

Lake Powell was previously about 1 m deep but is now only half that depth and the water level varies between 0.3 and 0.9 m above MSL. The water is fresh but is now highly eutrophic, and there are no longer either freshwater mussels or the Murray Cod which were introduced into it in the 1880s. The fish flourished for a time throughout the system, probably until the water became too acid (pH 3.5 from the 1910s to 1940s). Lake Manarup is now also shallow, it acts as a compensation and evaporation basin and often dries out in summer.

4.1 LANDFORMS

The land surrounding Torbay Inlet is very low lying, with Lake Powell and the swamps around it only half to 1 m above sea level (Figure 4.12). Shell beds with a diversity of marine species were excavated along the Marbelup Drain indicating that the Inlet was previously more marine and of greater extent. The Grasmere Valley eastwards to Princess Royal Harbour, with its lakes, swamps and lunette dunes appears to have been a former seaway (Jutson and Simpson, 1917). The presence of "crystalline rocks at varying depths of 50 to 150 feet ... proves it to be a narrow granitic trough which at one time probably formed a shallow strait connecting King George's Sound with the sea at Torbay" (Woodward, 1917). The valley lies between the high coastal hills of granite, coastal limestone and dunes and the hills to the north. The coastal dunes that cover the granite to the south are still largely forested along their lower slopes and covered with coastal scrub elsewhere. The northern spongolite and sandplain hill slopes and valleys are cleared, mostly for grazing.

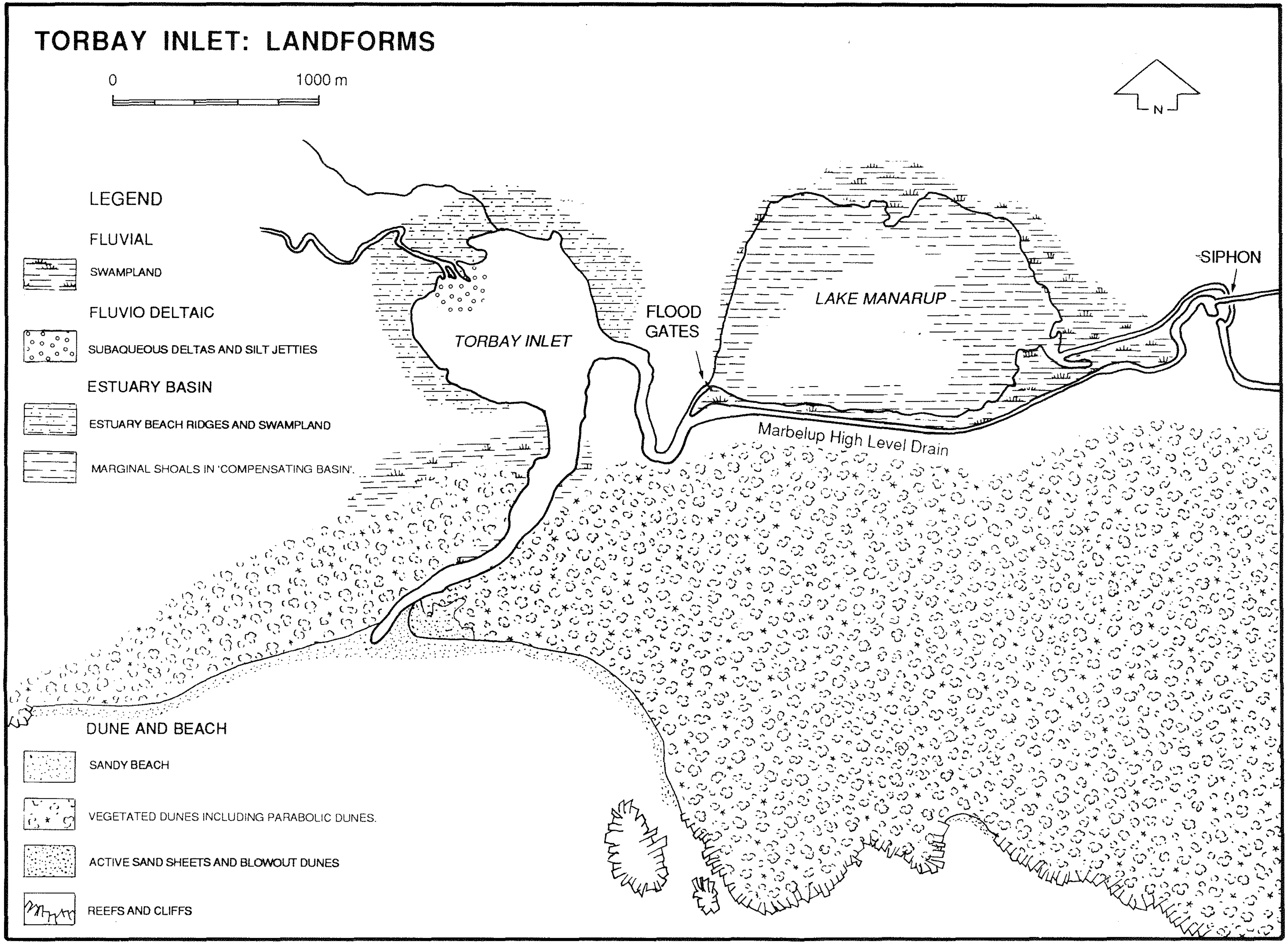


Figure 4.12 Torbay Inlet. Landforms.

DRAINAGE Torbay Inlet now receives fresh water from four catchments:

> Low lying land west of the Inlet drains to Torbay Main Drain which discharges through a natural winding creek to the west shore of Torbay Inlet.
>
> The 117 km^2 catchment of Marbelup Brook drains hilly sandplain to the north, which is mostly dairy and cattle farming country. The Brook now flows via Marbelup High Level Drain to rejoin its old channel 1 km from Torbay Inlet. The natural channel to Lake Powell is blocked by a plug, though a pipe with a sliding flap valve now allows some water to flow through to flush the old channel.
>
> Grasmere Drain takes flow from Five Mile Creek and Seven Mile Creek (from the northern hills) and drainage from Five Mile Swamp into Lake Powell. Water from the Lake flows by Marbelup Sub B Drain to Marbelup High Level Drain. Floodgates at the Elleker Grasmere Road retain water on adjacent paddocks in summer and prevent salt water flooding them.
>
> Seven Mile Swamp (Ewart Swamp) and paddocks south of Lake Powell drain via North Creek Drain to the old Marbelup Brook (originally from Lake Powell), to a plug in the Brook and a siphon under the Marbelup High Level Drain, and to Lake Manarup. A flap valve on the outlet from Lake Manarup prevents salt water entering it from Torbay Inlet. The valve is sometimes held open to allow water from the Inlet to flood the lake when it dries up.

The drainage system has changed little since the floodgates at the Elleker Grasmere Road were built in 1950 and the siphon under Marbelup High Level Drain was constructed at about the same time. Figure 4.13 shows the drainage system as it was in 1917 when Marbelup Brook still flowed into Lake Powell.

RIVER Only two short stretches of Marbelup Brook are now estuarine between the plug at the siphon and the lagoon. They meander through low lying land and are connected by the Marbelup High Level Drain alongside Lake Manarup.

LAGOON This is shallow, with less than 1 km^2 of open water surrounded by a wide fringe of paperbark trees and sedges.

INLET CHANNEL The 1.2 kilometre long channel narrows from about 150 m wide at the lagoon to 50 m near the beach. There are dunes along the eastern side and from the site of the old barrage on the west. The channel ends on Perkins Beach 1.5 km west of Shelter Island. There is no hard rock on either side of the mouth, only a soft black sandy rock on the west, however the position of the mouth appears to be stable at present. The flow channel across the beach varies about 100 m east or west.

4.2 THE BAR

The bar is part of the beach which is about 200 m wide and builds up to 1.2 to 1.5 m above sea level. It is a moderately well sorted medium to fine sand (Figure 4.2). The bar may break naturally or be broken by the Water Authority when water level rises to about 1.1 m above mean sea level (AHD) to prevent flooding of the potato paddocks. It opened and closed 10 times between November 1984 and October 1986, it remained open for lengths between 5 and 53 days and closed for as little as 8 days and as long as 2.5 months. It generally stays open longer when opened in winter (July-August) and usually stays closed over summer. While the bar is open the daily tidal range is 0.2 to 0.3 m in the Inlet.

4.3 WATER DEPTHS AND SEDIMENTS

The Inlet has a sandy bottom which is nowhere more than about 1 m below mean sea level and a shallow delta at Torbay Main Drain. Beach sand washes back into the inlet channel when the bar is closed but most must scour out again when the bar breaks because there is only a poorly developed flood tide delta. The channel scours to almost 3 metres upstream of the old floodgates and to 5 metres downstream. During 1988/89, water levels in Torbay Inlet fluctuated between just below AHD to 1.1 m above AHD. Marbelup Brook is 2 to 4 m deep where it winds naturally into the Inlet, with a soft black muddy bottom. The Marbelup High Level Drain was dug through sandy shell beds.

4.4 WATER CHARACTERISTICS

SALINITY The estuary can presumably be fresh throughout when the river flows to sea or have a gradient from sea water near the bar to fresh water in the Marbelup Drain. Table 4.4 lists observed salinities in the lagoon. In March 1987 the inlet channel was stratified vertically, surface water was 10 ppt and 25 ppt at the bottom (3 m), and was 9 ppt throughout the 1.5 m depth in the Marbelup Drain.

NUTRIENTS AND POLLUTION Much of the drainage to the estuary is from cultivated land to which fertilizers are applied. The Albany Wastewater Treatment Plant No.2 discharges to Five Mile Creek and there is a piggery on Seven Mile Creek. In consequence nutrient loads to the Inlet are high: an estimated 12 tonnes of phosphorus in 1988 (a wet

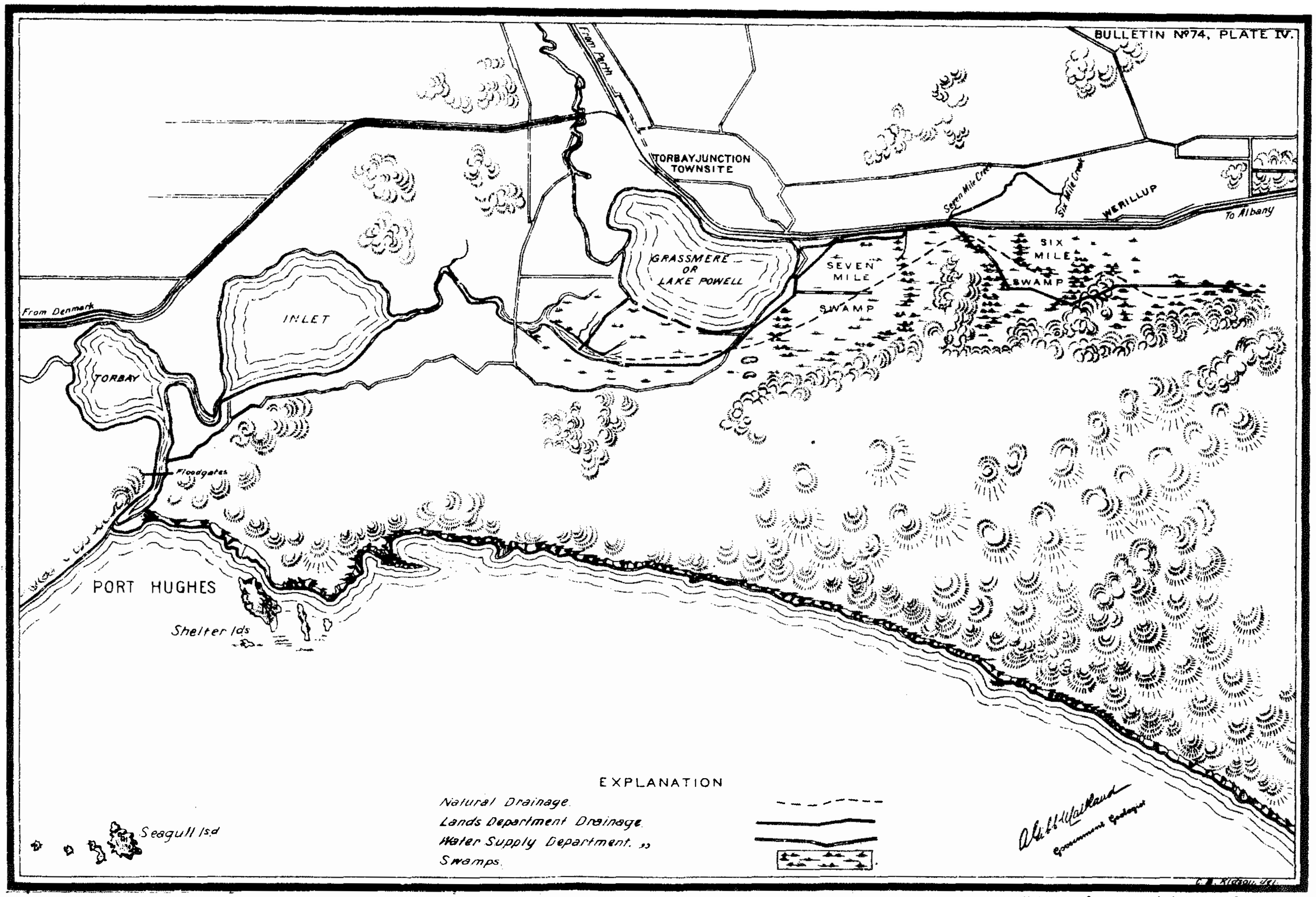


Figure 4.13 Torbay Inlet drainage in 1917. Scale: 80 chains to the inch. (Woodward,1917)

H.J. Pether, Government Lithographer, Perth, W.A.

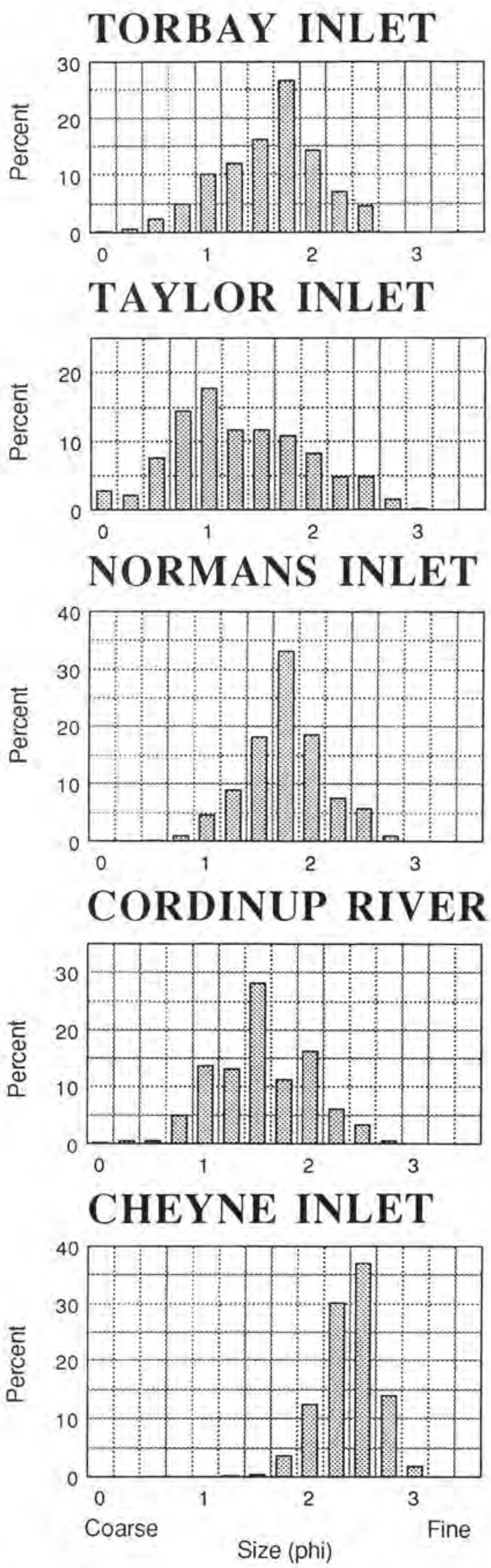


Figure 4.2 Sand size distributions from the bar crests. Sizes are in phi units. -1 phi = 2 mm, 3 phi = 0.125 mm.

year) and a yearly average of 6 tonnes (Bott, unpublished). Samples of Torbay Inlet water taken between October 1988 and June 1990 showed high nutrient concentrations: an average of 132 µg/L Total Phosphorus (310 µg/L in July 1989) and 1235 µg/L Total Nitrogen (Table 4.4). The ratio of nitrogen to phosphorus was low, only about 10:1, and nitrogen rather than phosphorus may be the limiting nutrient – an unusual condition in estuaries of the south west.

The estuary is clearly seriously nutrient enriched, although not overtly highly eutrophic. Green macroalgae are not abundant, perhaps because the water is brown tannin stained, but recently there has been a rich growth of a wire-like red alga (*Gracilaria* sp.). There have also been brief, but dense, blooms of planktonic algae and there are reported to have been dense blooms of bluegreen algae in the Inlet before the floodgates were blown up in 1985. Lake Powell is highly eutrophic, there are often floating mats of bluegreen algae and it causes a serious midge problem.

Table 4.4 Nutrient concentrations in Torbay Inlet water (µg/L) and salinity (ppt). (G.M. Bott, pers. comm.).

Date	Total P	Total N	Salinity
27.10.88	40	1040	5.6
14. 7.89	310	-	5.8
3. 8.89	100	-	6.8
21. 9.89	180	1600	2.3
29.9.89	90	1800	3.0
20.10.89	120	1000	6.2
21.11.89	120	1400	8.1
10.5.90	40	-	6.0
11.6.90	190	570	3.5

Remnants of the Torbay barrage, 1989.

5 TAYLOR INLET - PHYSICAL FEATURES

Taylor Inlet is a small lagoon at Nanarup 7 km east of Oyster Harbour, close to Mount Taylor and at the western end of the 20 km long Nanarup Beach from Mount Gardner (Figure 5.11). It is elongate, roughly parallel to the shore behind the dunes through which there is a short channel to the beach. The beach forms the low bar which is closed most of the time. The entrance faces south east near Islet Point and a small island which, with the rocky headlands of Mount Taylor and offshore Michaelmas and Breaksea islands, shelter it from the south west. Nearshore reefs also break the force of waves and swell.

The few salinity records suggest that the water is mainly sea water and is probably only briefly less than about half seawater salinity. In the 1890s oysters were brought from Sydney and were farmed along the rocky shores on the north side of the lagoon on a non-commercial basis.

The catchment is only 10 km^2. One creek drains from the eastern face of Mount Taylor and Mount Richard and two smaller creeks drain from sandplain to the north. The surrounding land was taken up in the 1870s and fenced for cattle but was not cleared until the 1960s; the catchment is now largely cleared, with only a narrow Recreation Reserve round the margin of the Inlet. There are several fishermen's cottages near the eastern shore and one on the western shore of the Inlet. East of the mouth a large blowout from the beach is encroaching inland; this is outside the reserve.

5.1 LANDFORMS

The lagoon, the inlet channel and a few metres of creek constitute the estuary (Figure 5.12). It is essentially a saline lake which has survived as an estuary because of the relatively sheltered location of the entrance. The north western creek has recently been canalised and dammed blocking flow to the Inlet and the access of Black bream to the creek.

LAGOON This is kidney shaped in the hollow of the surrounding hills. On the eastern shore the hills are principally the coastal dunes, the north western shore is a steep well wooded slope rising to about 30 m, and on the western shore the dense narrow fringe of saltwater paperbark trees is backed by a gentle slope before the steep rise to Mount Taylor. Most of the lagoon is 2 to 3 m deep, but it shallows near the margins and towards the entrance channel.

INLET CHANNEL This is 300 m long and 100 m wide between the dunes. It is shallow and is being

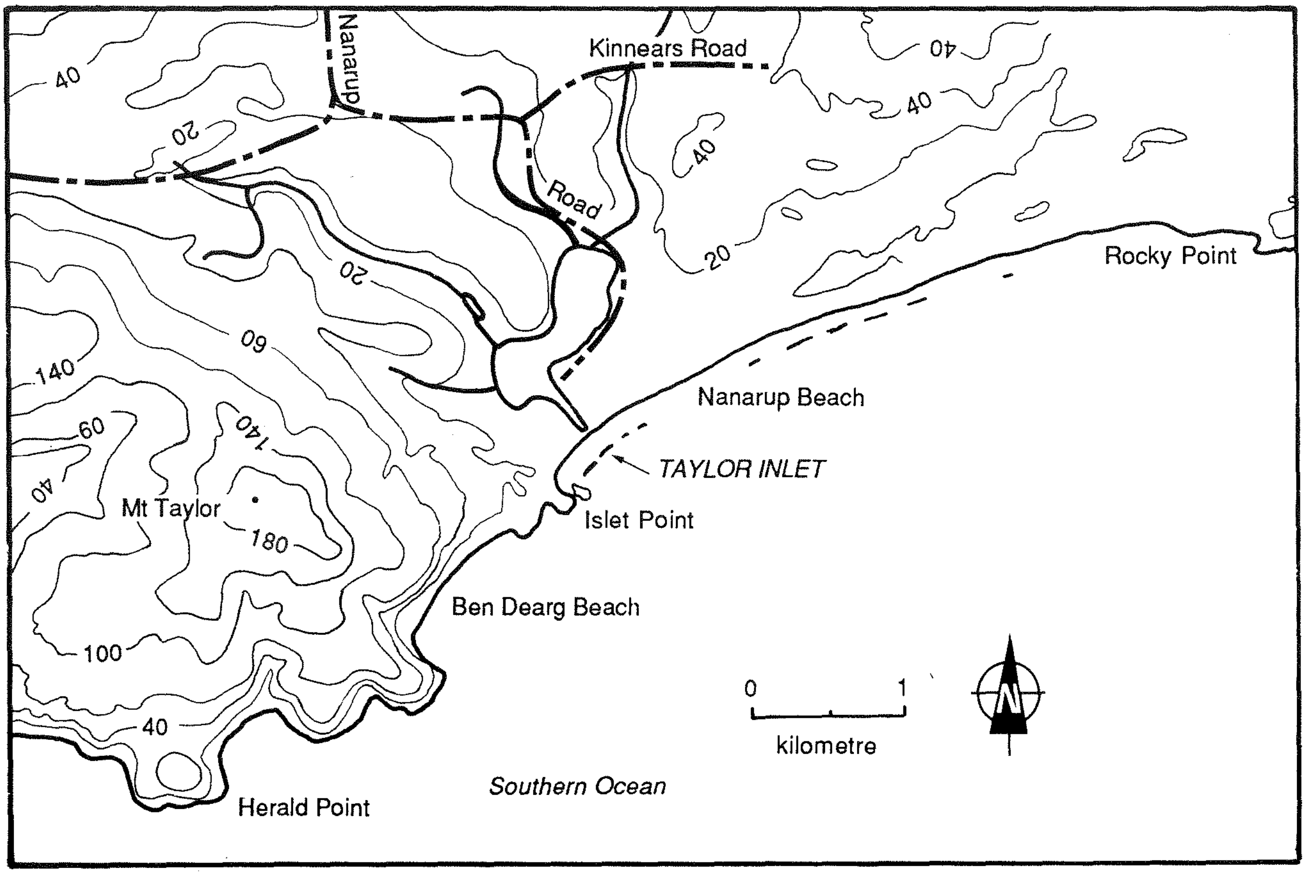


Figure 5.11 Taylor Inlet. Topography of the surrounding area. Contours in metres.

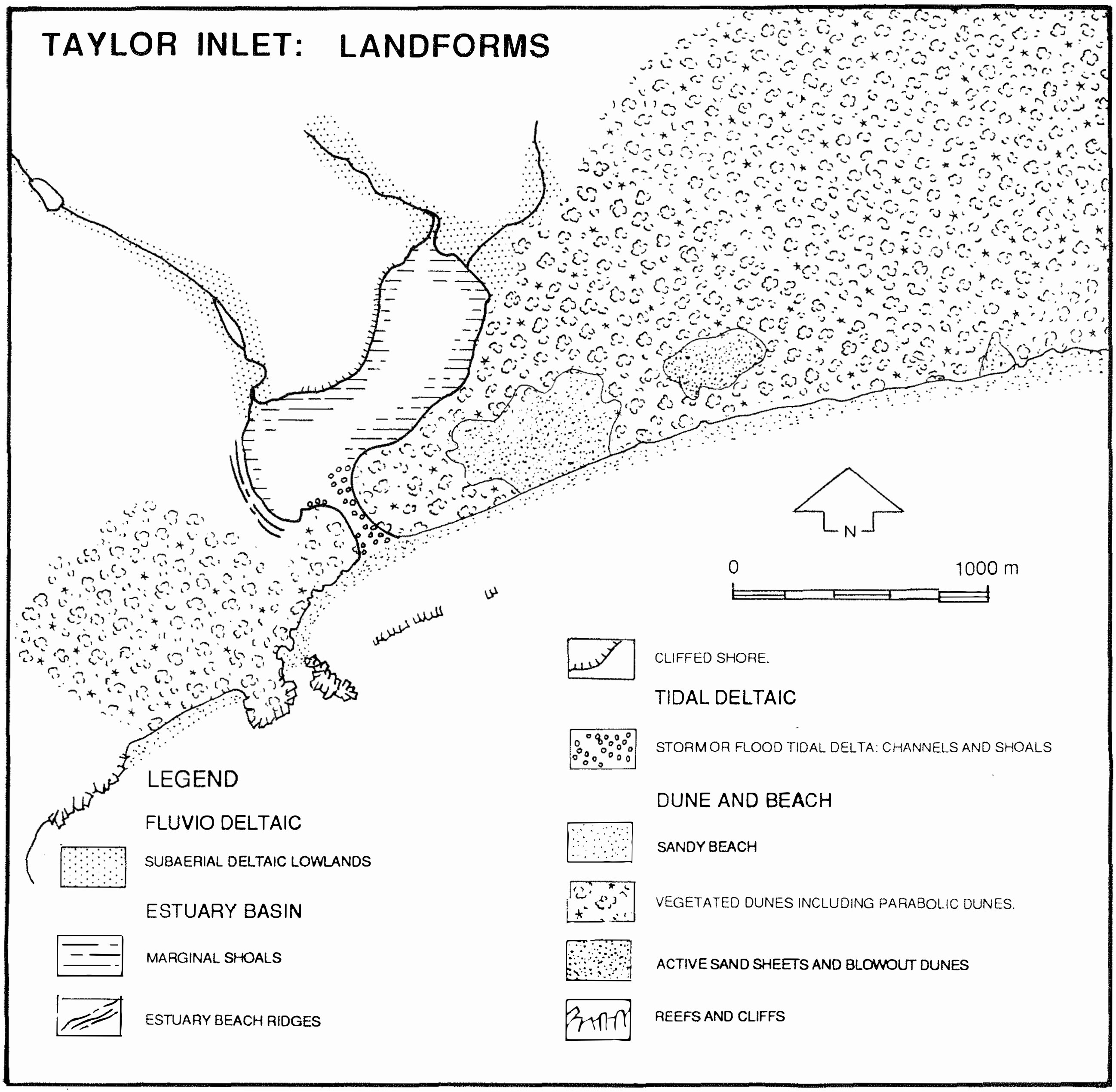


Figure 5.12 Taylor Inlet. Landforms.

filled with beach sand which forms a flood tide delta that extends through the length of the channel into the lagoon.

5.2 THE BAR

The bar is part of the gently sloping beach and is only about 1 m above sea level. It is in the shelter of Islet Point and the small island (both granite-gneiss) 600 m south along the beach and there is a broken limestone reef about 200 m offshore. The dunes on either side of the mouth are only stabilised by vegetation. The beach is a poorly sorted coarse to fine sand (Figure 4.2).

The bar has often been broken since the 1890s, originally to let salt water in for oyster cultivation. It is seldom open more than twice a year, only stays open for a few weeks, and is closed most of the time. It opens naturally or is opened by the Albany Shire to lower the water level to prevent salt water intruding into shallow bores and to prevent flooding the road, which is only about 1 m above sea level. It is sometimes broken by fishermen without permission. It is reported that if the bar is allowed to break naturally about September it only stay open for days, up to a week, but when opened artificially in summer, without an adequate head of water, it may stay open for several weeks and then a lot of sand comes in.

5.3 WATER DEPTHS AND SEDIMENTS

The Inlet is shallow, 2-3 m below mean sea level with shallow marginal shelves. There are said to be 5 m deep holes near the northern creek mouth and near the inlet channel. Water level can vary nearly 2 m from 1 m above sea level when full to 1 m below sea level at the end of summer as the result of evaporation.

The shallows and the inlet channel sediment are sandy. The central basin has mud with some shell debris.

5.4 WATER CHARACTERISTICS

SALINITY Salinity appears to vary from about sea water salinity (35 ppt) probably to less than half during winter. The few available records of surface salinity are: December 1970 - 20 ppt, March 1987 - 23 ppt, January 1988 - 32.5 ppt, December 1989 - 16 ppt, June 1990 - 22 ppt (bar open), September 1990 - 23 ppt. There is likely to be some stratification briefly near the creeks when they are flowing. The water is tannin stained.

NUTRIENTS AND POLLUTION Analyses of a water sample taken in January 1988 are shown in Table 5.4. Higher levels of Total Phosphorus were found in Inlet water in September 1987 (200 µg/L) and October 1988 (120 µg/L), and in fresh water in the NW creek (630 µg/L)

There are reported to have been blooms of bluegreen algae, but not in recent years.

Table 5.4 Nutrient concentrations in Taylor, Normans and Cheyne inlets, 19 January 1988, µg/L (J.M. Chambers)

	Taylor	Normans	Cheyne
PO_4	13	10	4
Tot P	89	37	116
NH_4N	22	35	1
NO_3N	2	3	1
Tot N	379	576	1267
Salinity	-	8	38

6 NORMANS INLET - PHYSICAL FEATURES

Normans River flows to a small estuarine lagoon in a gap in granite hills at the western end of the Mount Manypeaks range (Figure 6.11). The short channel to the sea opens near the middle of the 4 km long Normans Beach where there is an onshore limestone reef. There is also a small outcrop of rounded granite in the beach 200 m west of the mouth. A steep ridge separates Normans Inlet from King Creek barely 0.5 km to the west in a deep valley against Boulder Hill. The Creek then flows as a narrow stream behind the high foredune to the extreme western end of the beach where it flows continuously across rocks in the beach.

The Inlet is in a small Albany Shire reserve that extends from its eastern side to Normans Beach Road on the western side. The Mount Manypeaks Nature Reserve extends almost to the eastern shore of the river and lagoon and the ridge to the west is fenced private land. King Creek is in Betty's Beach Reserve which has been nominated for inclusion in the National Estate. Camping is permitted among paperbarks near the water's edge at the end of the road at Normans Inlet.

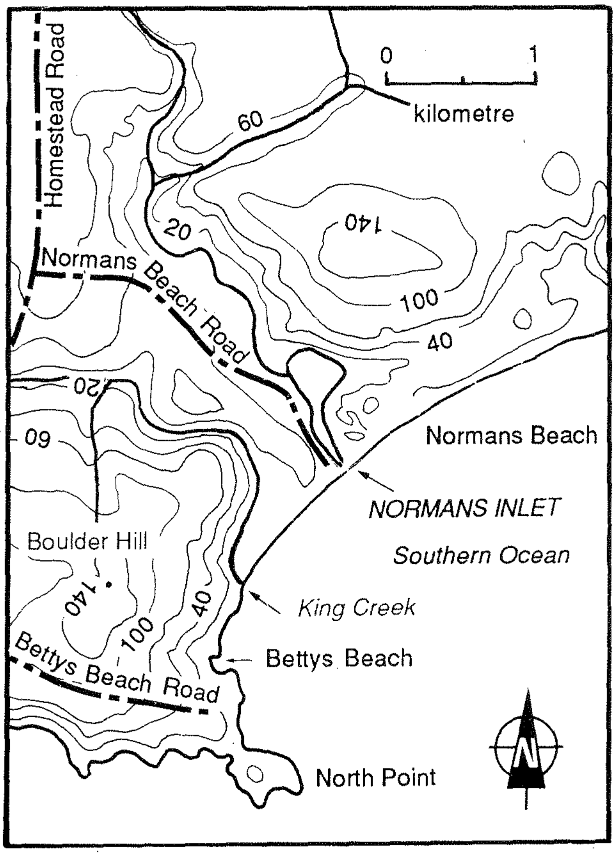


Figure 6.11 Normans Inlet and King Creek. Topography of the surrounding area. Contours in metres.

Normans Inlet has only an 18 km^2 catchment that drains farm land on the spongolite plain to the north and the western slopes of the Mount Manypeaks range where a creek descends through a steep rocky gorge. Two small patches of Karri trees on private property in the catchment are the most easterly occurrence of this species.

6.1 LANDFORMS

The land rises steeply to the granite hills on either side of the small valley in which the river and lagoon lie, but dunes and soft coastal limestone border the channel to the sea (Figure 6.12). Except for a small area of grazing land on the west the valley is all still uncleared bush.

RIVER This is navigable for about 1 km through a narrow valley with swamps on one side or the other. It narrows from about 25 m where it discharges into the lagoon to 3 m where it is blocked by a tangle of paperbark trees.

LAGOON This is very shallow except for a narrow channel along the eastern shore, and when the bar breaks the greater part dries out or retains only a few centimetres of water. The ground rises steeply from the tree covered slope of the eastern shore, both to the range and to the back of the coastal dune with its dense scrub. The western shore is low lying land with a low scrubby vegetation.

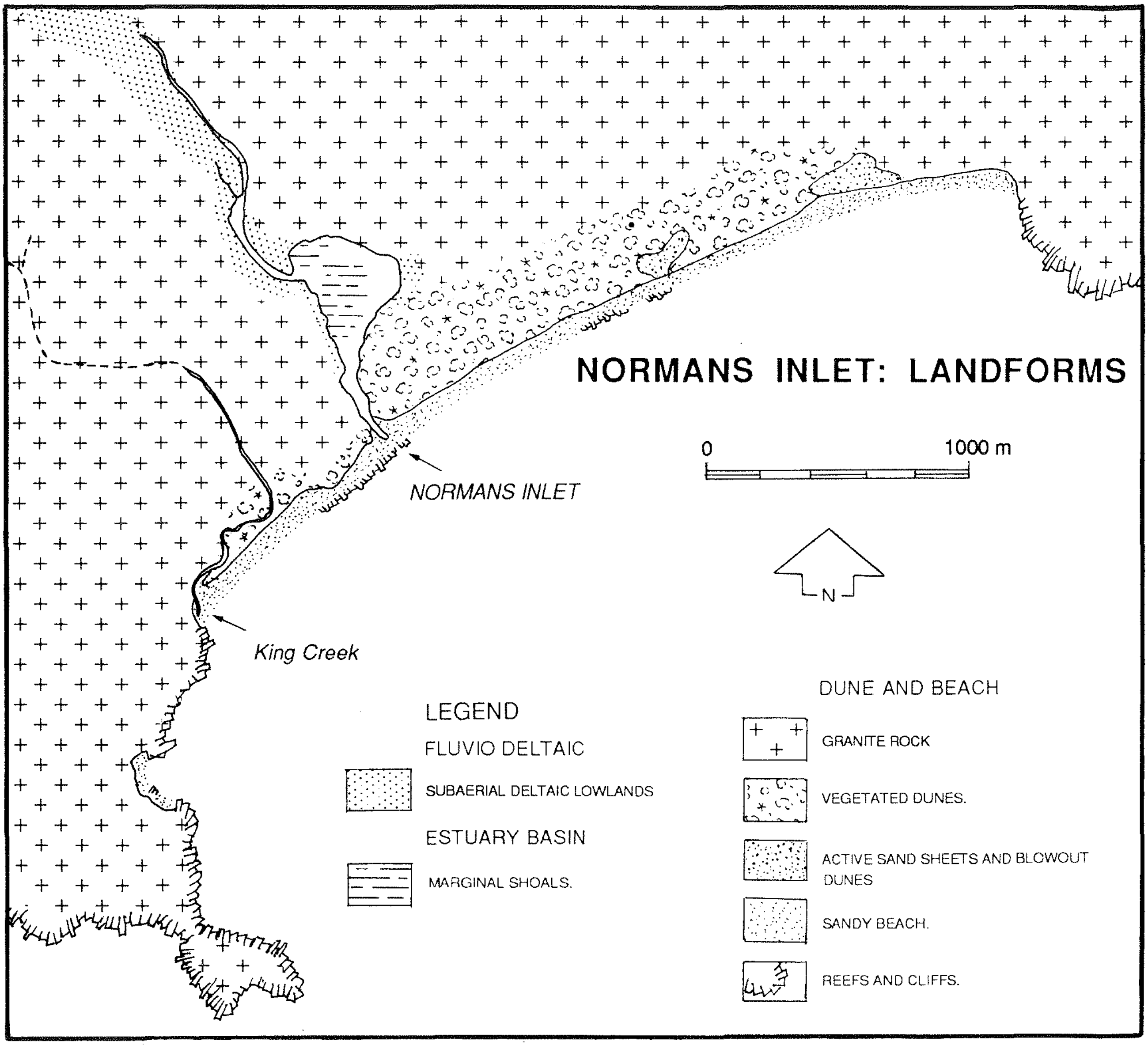


Figure 6.12 Normans Inlet and King Creek. Landforms.

INLET CHANNEL The channel is about 200 m long from the lagoon to the beach and 20 m wide between steep dunes. The eastern bank is sand, covered with dense scrub and trees to the water's edge. The western side is a cliff of soft dune limestone, with a high proportion of silica grains, which is being eroded along the water line. Paperbark trees (*Melaleuca cuticularis*) line the water's edge, increasing in density towards the lagoon, with sedges (*Juncus kraussii*) in places.

6.2 THE BAR

The bar generally opens naturally every year in about October and only stays open for a few days. It is reported to have been closed for about 4 years in the 1960s. It appears to close again before the Inlet water has drained to sea level, probably because there is not sufficient volume of flow to keep it open. The bar is part of the beach and is about 1.5 m above sea level and 2 m above the level of the exposed onshore limestone platform which fringes the beach opposite the mouth. Mr Gordon Norman reports that he has seen the beach devoid of sand and the limestone exposed back to the dunes along the whole length of the beach after storms.

The beach sand is a well sorted medium to fine sand, of predominantly quartz grains (Figure 4.2). The dunes on either side of the mouth are steep and have been recently eroded, perhaps from the 1984 storms, but are now regenerating from the base. Granite rocks at the top of the beach west of the bar are well rounded by wave action.

6.3 WATER DEPTHS AND SEDIMENTS

The greater part of the lagoon seldom has more than about 50 cm of water and must be about mean sea level. The narrow channel along the eastern shore is slightly deeper. The river is 1 to 1.5 m deep and the inlet channel the same.

The lagoon has a firm sandy-muddy bottom with a ridge of soft rock in it and soft mud along the western shore. The river has sandy or muddy banks.

6.4 WATER CHARACTERISTICS

The river water is fresh and tannin stained. The few observations made indicate that the lagoon water is seldom more than about a quarter sea water salinity and less in the riverine part. Evidently there is only limited sea water intrusion during the short times the bar is open or from waves washing over the bar.

SALINITY Observed salinities in the lagoon are: March 1987 - 2 ppt; January 1988 - 8 ppt; October 1988 - 5 ppt; December 1989 - 8 ppt; June 1990 - 6 ppt; September 1990 - 16 ppt (bar recently open). In January 1988 salinity at the head of the river was 2.5 ppt on the surface and 6.5 at 0.75 m deep.

NUTRIENTS AND POLLUTION Analyses of a water sample taken in January 1988 are shown in Table 5.4.

There is no evidence of pollution.

Normans Inlet, December 1989.

7 CORDINUP RIVER - PHYSICAL FEATURES

The small estuary of the Cordinup River opens to a bay in the rocky coastline between Hassell Beach and Cheyne Bay (Figure 7.11). The river drains a 104 km^2 catchment south of South Coast Highway with largely uncleared land on the northern face of Green Range and Warriup Hill and recently cleared sandplain. A small area of hilly land near the estuary was cleared for grazing in the early 1970s, this and a larger area has more recently been taken over for commercial forestry and planted with *Eucalyptus globulus* and other trees. A stone cottage near the head of the estuary was built by H.W. Hassell in 1931. There are two small Nature Reserves on Green Range - Tinkelelup and Mullocullop.

7.1 LANDFORMS

The Cordinup River has carved a narrow valley through the granite rock on the east side of Warriup Hill to the coast. The riverine part of the estuary winds through alluvial flats to the lagoon between the granite hillside on the east and limestone on the west (Figure 7.12). A narrow channel through the dune leads to the middle of a 2 km long bay between projecting rocky headlands. The beach and a dune blowout expose a wide area of unstable sand through which there is no fixed channel. There is an onshore limestone reef to which the water flows and broken reefs on either side of it.

RIVERS The river is estuarine for about 1 km and is nowhere more than about 10 m wide. A small creek enters the lagoon from behind the dunes to the east. There are granite slopes on the east bank near the lagoon but most of the banks are sandy and clothed with paperbark trees and other vegetation.

LAGOON The river has built a delta with samphire flats and paperbark swamps in small bays on either side of the river channel into the lagoon. Silt jetties with paperbark trees line the sides of this channel. Dead paperbark trees in the samphire flats are reported to have been dead a long time. The western shore of the lagoon is a steep slope from the limestone to a fringe of paperbark trees (mainly *Melaleuca cuticularis*). The eastern shore has a swamp at the end of the creek. Dune sand is advancing from the beach into the lagoon and is reducing its area.

INLET CHANNEL The channel is only about 100 m long and 20 m wide between the steep slopes of the vegetated dunes. Beyond that flood water cuts a narrow channel across the loose sand of the blowout for 300 m to the beach, where it may turn behind the beach before flowing over the reef to the sea.

7.2 THE BAR

The bar is part of the beach through which flood water breaks. A wide limestone reef platform fronts the beach here and there are broken reefs on either

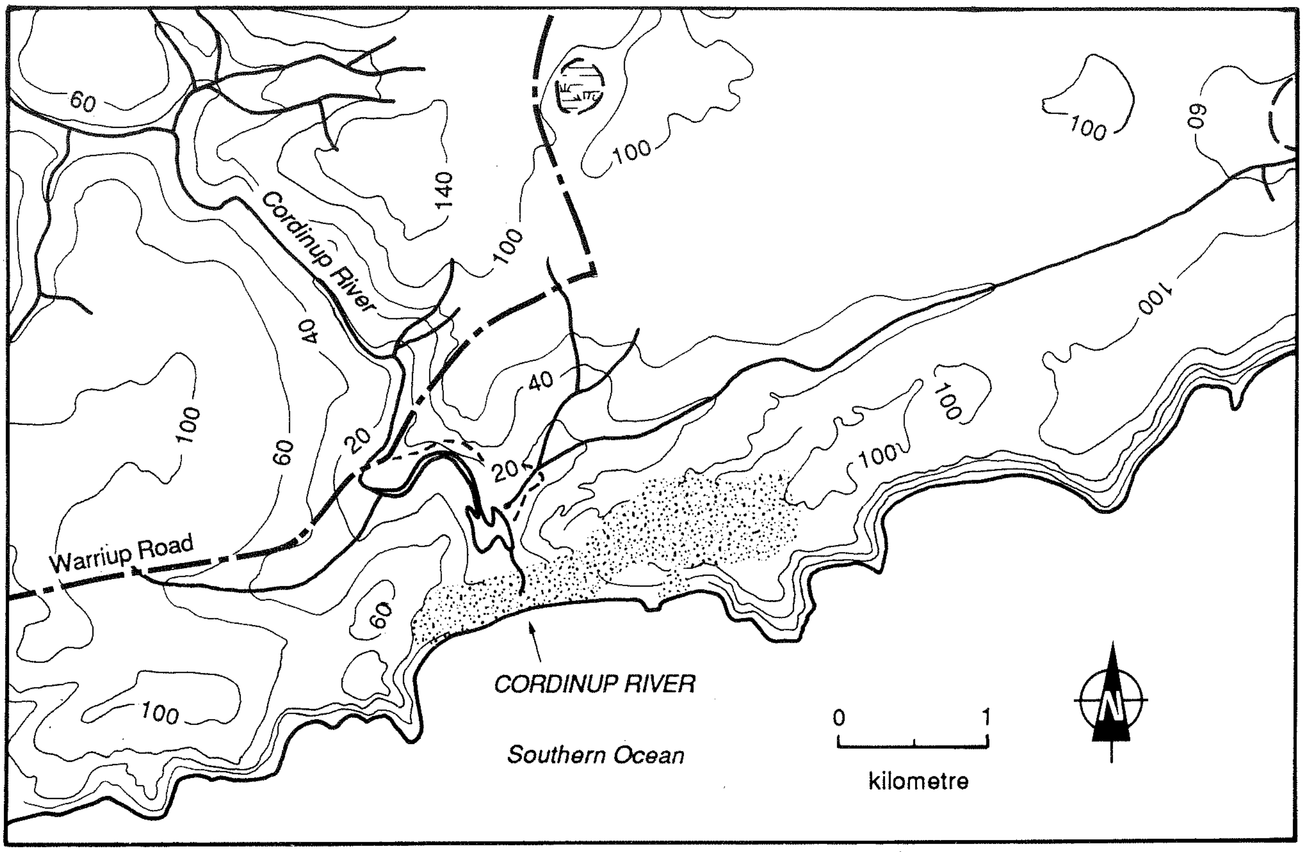


Figure 7.11 Cordinup River. Topography of the surrounding area. Contours in metres.

side of it along the bay shore. The reef platform is at about MSL with a part rising another 1 m.

The bar is reported to break every 2 or 3 years, sometimes every year, and waves wash over it in winter. When seen in October 1989 the beach was 2.0 m above the level of the rock platform and flow from the lagoon had cut a channel to 0.7 m above the level of the rock. The water level in the lagoon had been at least another 0.7 m higher before the bar broke, i.e. about 1.5 m above MSL.

The estuary is reported to have been full of water before the May 1988 rains when river flow broke the bar, but no sea water came in and the water remained low and muddy. In the January 1989 storm waves broke the bar and brought sea water in, the bar built up again and the water was clear. In May 1989 the bar had only recently closed and waves had washed over it into the channel, about 1 m above sea level. In October 1989 water was flowing across the beach to the sea and in December the beach had built up and the estuary water level was about a metre below it. In June 1990 the water was almost to the crest of the beach and waves were washing over into the channel.

The beach is built of a well sorted medium grain sand (Figure 4.2).

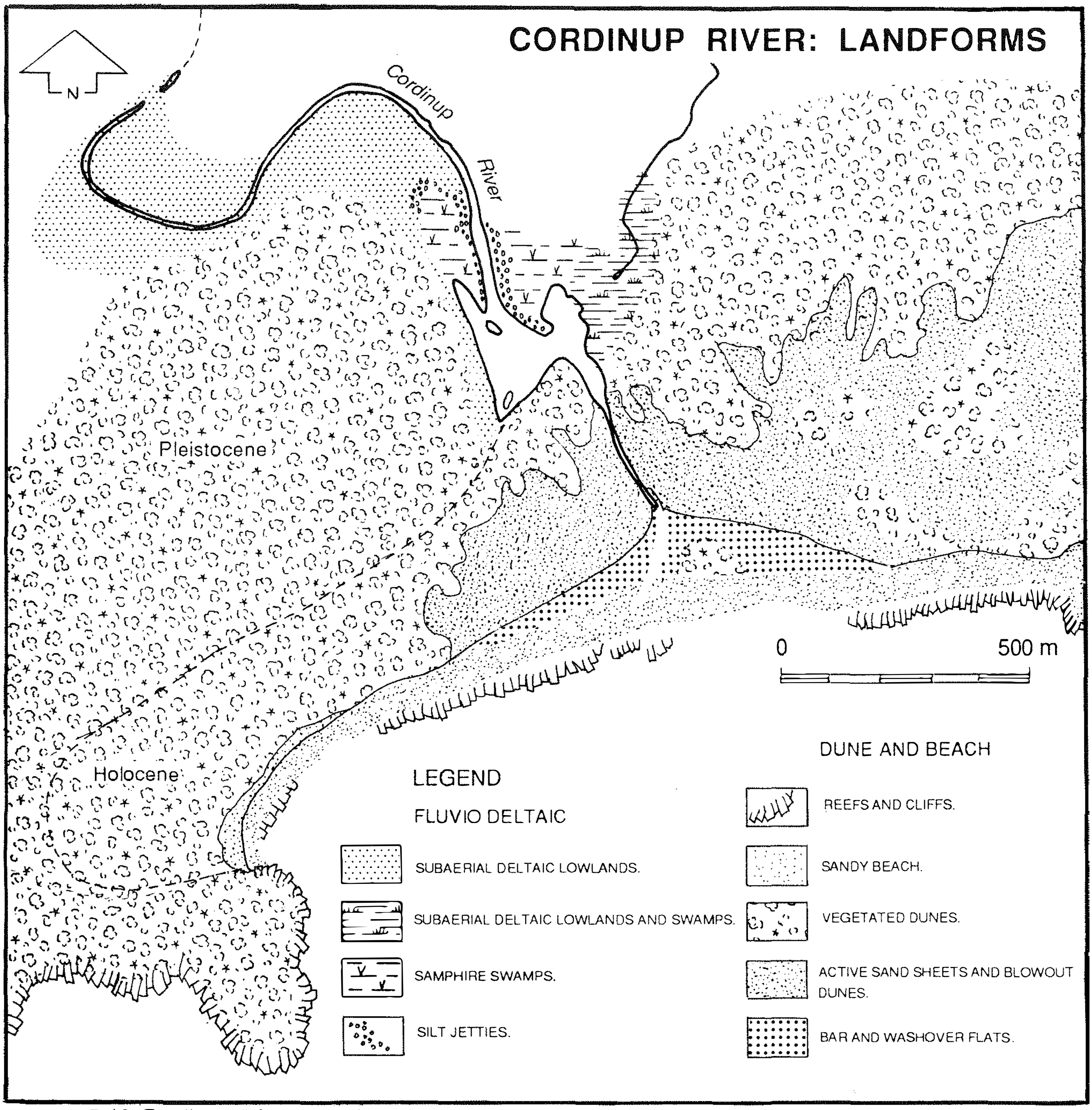


Figure 7.12 Cordinup River. Landforms.

7.3 WATER DEPTHS AND BOTTOM SEDIMENTS

The lagoon can be 2 m deep before the bar breaks but probably only about 0.5 m when open to the sea. The riverine reach is about 2 m deep. Although the lagoon is so shallow the bar probably closes before it ever dries out. The lagoon has a hard sandy bottom and the river reach has black mud.

7.4 WATER CHARACTERISTICS

The river water is fresh and dark tannin stained. The lagoon water is probably seldom much more than half sea water salinity.

SALINITY Recorded surface salinities in the lagoon are: May 1989 - 4 ppt; October 1989 - 22 ppt (bar open); June 1990 - 6 ppt; September 1990- 4 ppt. The water is reported to have been more salty before the recent clearing in the catchment.

NUTRIENTS AND EUTROPHICATION It is reported that little fertiliser has been applied to the afforested land. There is no evidence of eutrophication.

8 CHEYNE INLET - PHYSICAL FEATURES

Cheyne Inlet is the estuary of the Eyre River, which opens into a small bay on the north side of Cape Riche against the granite rock of the headland (Figure 8.11). Here the mouth faces north east near the south end of the 12 km long Cheyne Bay and in this sheltered position the bar is low. The river has cut a narrow valley through the soft spongolite rock and about 4.5 km is estuarine, including the small narrow lagoon. Upstream there are small pools in the river and these are reported to hold fresh water.

The area to the south of the Inlet has been farmed since 1839, first by George Cheyne and since by the Moir family who still graze sheep and cattle on farm land south of the river. Crown Land north of the river is proposed for vesting as a Conservation Park. The small headland immediately north of the lagoon is private land, mostly still bush.

8.1 LANDFORMS

Cape Riche is the eastern end of a range of granitic hills which rise to over 100 m along its southern shore. The land slopes down to the alluvial valley in

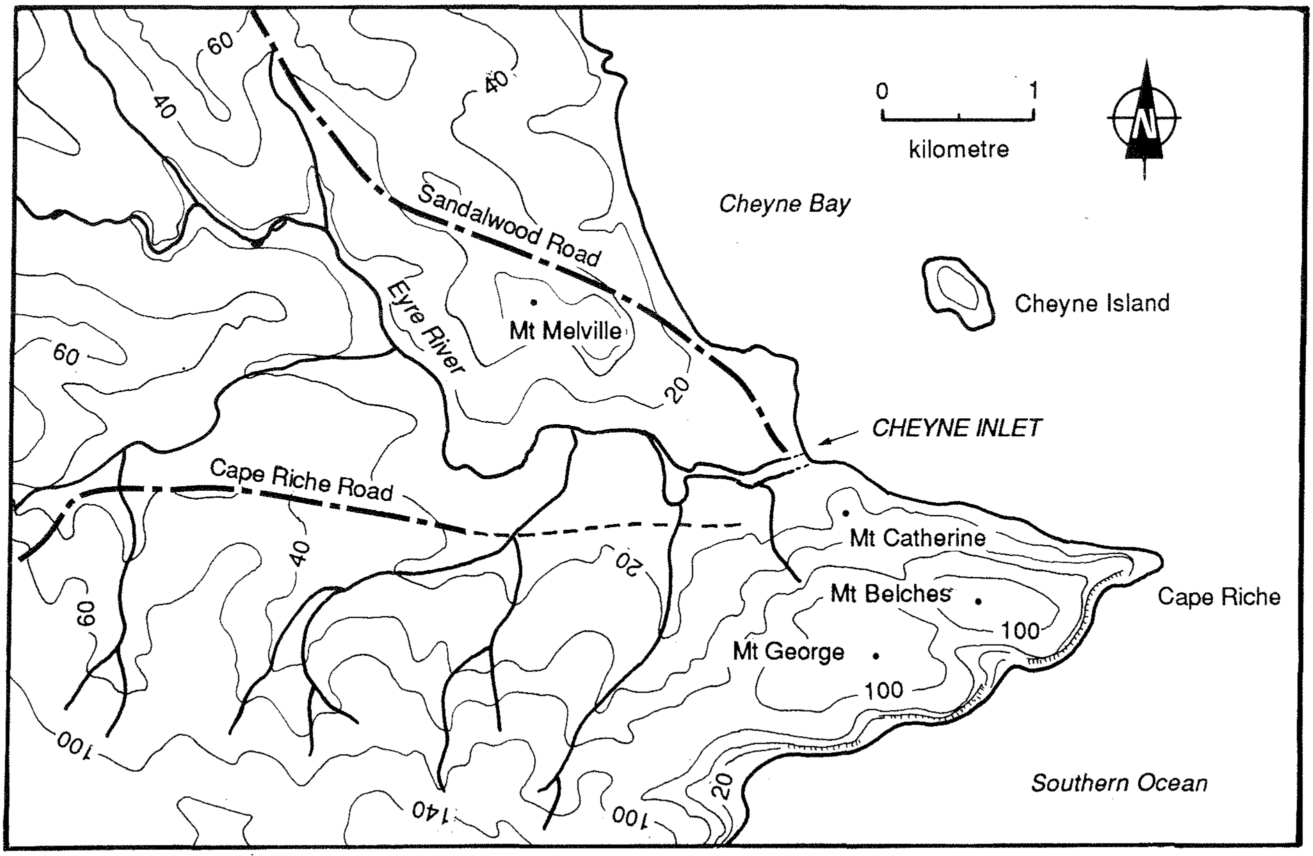


Figure 8.11 Cheyne Inlet. Topography of the surrounding area. Contours in metres.

which the farm and Inlet lie. North and west of the river the terraced spongolite hill slopes are still bush (Figure 8.12). The upper half of the catchment extends onto grazing land at about 80 m above sea level and 61% of the 77 km^2 catchment is cleared (Table 2.31).

RIVER The Eyre River is estuarine and navigable for 4.5 km from the bar to where it narrows to 3 m and passage is blocked by trees in the water. It widens to about 20 m where it opens out into the lagoon 1 km from the bar. Spongolite outcrops at intervals along the steep sandy banks but gives way to alluvial sediments with a hard cap on the south bank approaching the lagoon. The river banks are well vegetated with paperbarks and sedges.

LAGOON This is 1 km long and only 100 to 200 m wide, except where a small swampy bay forms a loop at the upstream end. It is shallow but never dries out and deepens upstream. There are shell beds along the banks. The lagoon narrows to the inlet channel which is 60 m wide between dune on the north and granite and dune on the south. The channel is filled for 130 m with sand which has washed in from the beach and slopes gradually down into the water of the lagoon.

8.2 THE BAR

The mouth is at the south end of a small beach that faces east between rocky headlands (Figure 8.12). The bar is only about 1.5 m above MSL and is composed of a well sorted fine white, predominantly quartz sand (Figure 4.2) which becomes quicksand when saturated. Much decaying seagrass has washed up on the beach and become incorporated in the bar, apparently helping to stabilise it.

The bar now breaks naturally most winters following heavy rain and occasionally in summer following cyclonic rains such as those of February 1955 (243 mm), November 1971 (198 mm) and January 1982 (241 mm). It generally only stays open for a few weeks, but once in the 1940s and again in the 1950s it remained open for about 18 months. It was broken artificially for the first time in 1975. A big flood can scour the channel across its whole width to a depth of 2.3 m to rock, as in February 1955.

Bignell (1977) quotes Surveyor General J S Roe as saying the bar was open in January 1849 with a 10 m wide stream nearly a metre deep. Fisheries Department files record that in June 1930 the bar was reported to have been closed for 9 years and that Black bream were the only remaining fish.

8.3 WATER DEPTHS AND SEDIMENTS

The lagoon is now mostly less than 1 m deep below MSL, deepening slightly away from the entrance, but may hold water to over a metre above sea level as evidenced by the presence of worm tubes on the rocks. The south western bay is very shallow, with emergent vegetation. The riverine part is 1.5 to 2 m deep below MSL. The lagoon is reported to have formerly been about 2.5 m deep, with 6 m near the bar.

The lagoon bottom is silty sand and there is mud and sand in the riverine part.

8.4 WATER CHARACTERISTICS

SALINITY The salinity of lagoon water probably varies between 10 ppt or less in winter to about 50 ppt in summer. The following surface salinities have been recorded: December 1971 - 34 ppt; April 1977 - 42 ppt; January 1979 - 36 ppt; March 1987 - 44 ppt; January 1988 - 38 ppt; February 1988 - 48 ppt. Water in the riverine part of the estuary is probably often stratified: in January 1988 surface water at 2 km was 38 ppt and bottom water 42 ppt; in October 1989 surface water at 4 km was 10 ppt and at 2.5 m was 18 ppt. Waves sometimes wash over the bar taking sea water into the lagoon.

NUTRIENTS Analyses of a water sample taken in January 1988 are shown in Table 5.4. The sometimes abundant growth of green algae suggests that nutrient levels may be high at times.

Spongolite rock in the Eyre River.

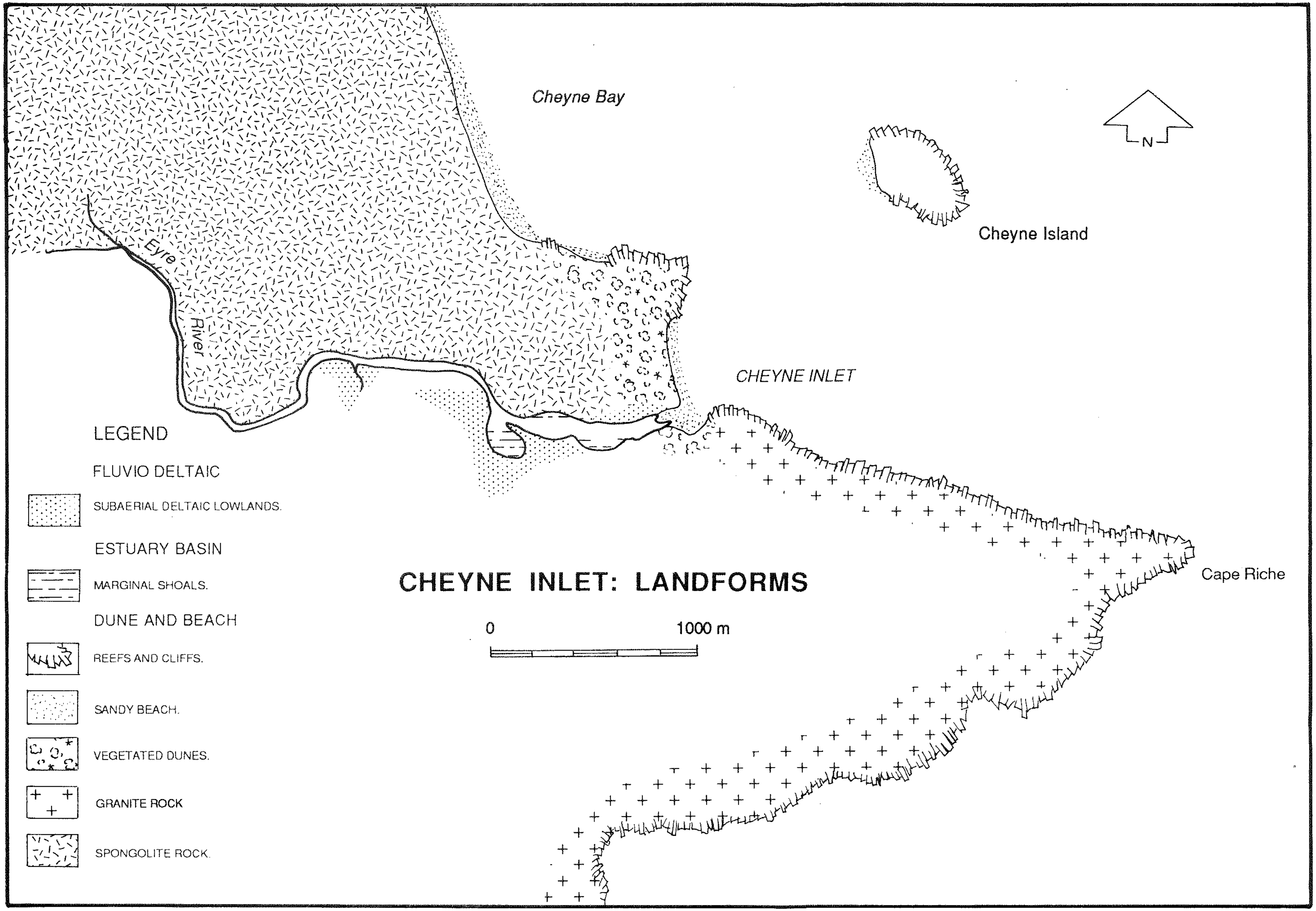


Figure 8.12 Cheyne Inlet. Landforms.

9 OTHER ESTUARIES AND RIVERS

Many small rivers and creeks flow to the coast, a few to small bays on the cliffed coasts and one, the Waychinicup River, is unique in being a gorge carved through a fault in the granite. Most flow to Cheyne Bay, Hassell Beach and Two Peoples Bay where coastal dunes and beach sand obstruct flow to the sea. None of them are now of much significance as estuaries, though sea water enters some from time to time and they have a restricted estuarine fauna. Some are the focus of recreational activities and with improved access to the coast others will come under greater pressure. Recent clearing in the catchments, particularly along Cheyne Bay, is likely to increase sediment loads and change the character of the creeks.

The coastline has changed greatly during the Holocene (the last 10 000 years) and the three large bays, Cheyne Bay, Hassell Beach and Two Peoples Bay, show different erosional and depositional features. There are dunes along the northern shore of Cheyne Bay, but eroding spongolite cliffs line its southern half and the shoreline is retreating rapidly. Hassell Beach also has a spongolite hinterland, but dunes and dune limestone line its whole length. The dunes are wide in the north with large blowouts which block flow from the creeks, but they narrow southwards to fixed dunes and limestone through which the creeks have permanent channels.

The shoreline of Two Peoples Bay appears to have advanced from the surrounding hills into the bay and to have trapped Gardner and Angove lakes and swamps behind the low dunes that separate them from the shore. Deposits of marine shells in Lake Gardner have not yet been dated. Jutson and Simpson (1917) discuss the effects of sand bar building in the Albany area. They conclude that the Lake Seppings and Yakamia Creek swamps have been trapped behind Middleton Beach and that the coastline was formerly along the hills to the north. Shell beds in Lake Seppings are of mid Holocene age (Kendrick, pers. comm.) and so too presumably are the dunes and swamps. Gull Rock Lake may also be a Holocene enclosure. The Grasmere Valley between Torbay Inlet and Princess Royal Harbour holds Holocene estuarine sediments and lunette dunes, and is probably a former seaway to which creeks flowed from the hills; Jutson and Simpson (1917) term it the 'Grassmere Strait'.

The small rivers and creeks discussed below are a part of the geological history of the coast and as such they merit brief review, in the hope that this will stimulate further study. The following account

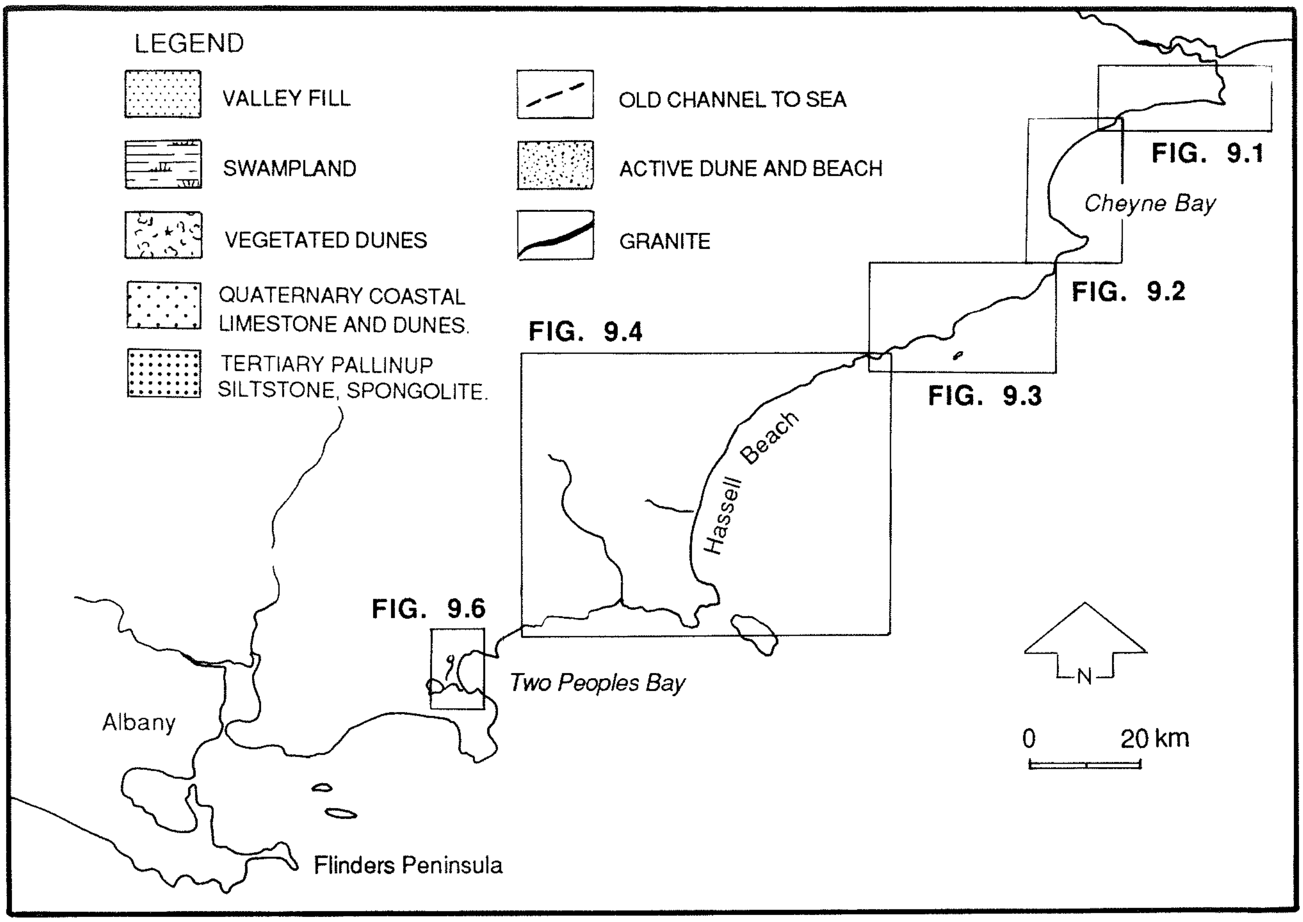


Figure 9 Location of, and legend for, Figures 9.1-9.4 and 9.6.

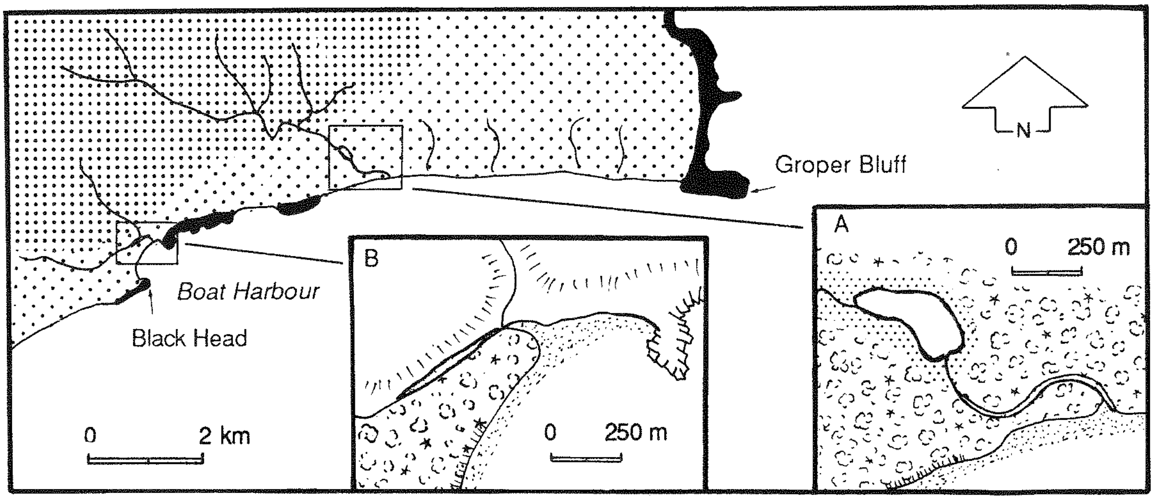


Figure 9.1 Creeks between Groper Bluff and Black Head.

considers them in sequence along the coast from east to west in relation to the different types of coastline described briefly in Section 2.2 and shown in Figure 2.1. It has not been possible to visit some of the less accessible creeks and they are only described as seen from the air and from study of air photographs. Figure 9 shows the location of the places described below.

9.1 GROPER BLUFF TO BOAT HARBOUR

Mount Groper and Groper Bluff shelter the mouth of Beaufort Inlet from the prevailing south westerly winds and swell. Westwards the 10 km long, south facing coastline between the granitic (gneiss) headlands of Groper Bluff and Black Head has a narrow beach with an onshore limestone reef (Figure 9.1). Small gullies with insignificant catchments are carved through the dunes and coastal limestone. Only one (Figure 9.1A) drains a substantial catchment (about 27 km^2) on the spongolite hills to a small lake and a dry creek that curves behind the dunes to the sea. The lake has a fringe of trees and other emergent vegetation. The water is probably fresh but becomes saline as it dries up in summer.

The deep embayment of Boat Harbour shelters between Black Head and a rock and tombolo on the east. Here another creek, with a 21 km^2 catchment from the spongolite, winds behind the dunes and retains water for 300 m in its narrow bed to the beach (Figure 9.1B). There it is blocked by beach sand except when flood flow breaks through and sea water probably washes back into it.

9.2 CHEYNE BAY

The 12 km long curve of Cheyne Bay from Boat Harbour to Cape Riche faces south east and east (Figure 9.2). Here ten creeks drain to the beach from the spongolite hills through which they have carved narrow valleys. The Eyre River at the south end of the Bay is the largest of these (Chapter 8). A narrow belt of stable dunes and limestone front the northern part of the beach but there are low spongolite cliffs along much of the coast. There are fallen rocks on the narrow beach below the cliffs which appear to be eroding rapidly. The geology of this coast is described and illustrated in an unpublished thesis by Hodgson et al. (1962).

About the middle of the bay one creek flows to Swan Gully which has a narrow estuarine reach nearly 1 km long through a sandstone rock (probably Werillup Formation) and stable dunes to the beach (Figure 9.2A). Flood water flows from this over the beach and sea water washes back into it. Further south several small creeks hold temporary pools where they have cut narrow gullies through the spongolite rock to the beach and cliffs.

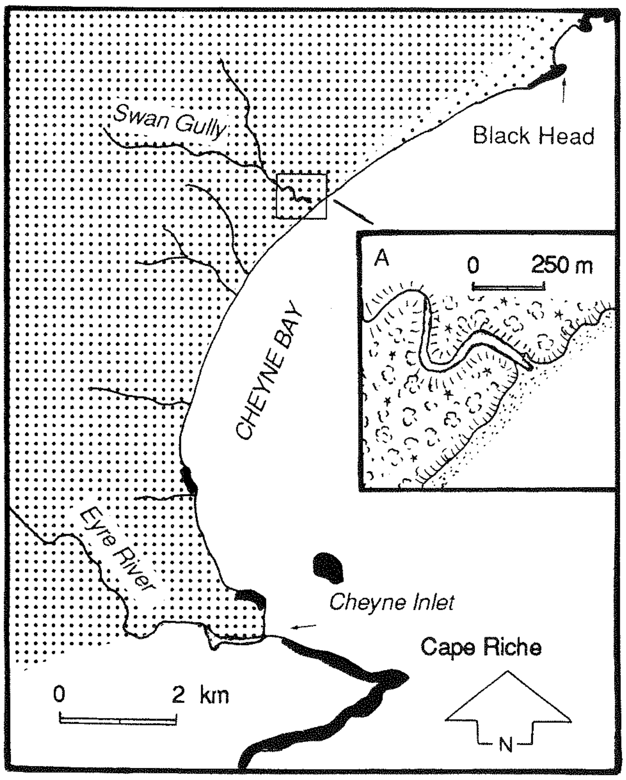


Figure 9.2 Creeks between Black Head and Cape Riche.

Spongolite cliff in Cheyne Bay.

9.3 CAPE RICHE TO GREEN RANGE

West of Cape Riche the 30 km long line of cliffs face south east (Figure 9.3). From the Cape to Giants Causeway the cliffs are gneiss, but westwards gneiss headlands alternate with limestone cliffs. The cliffs are interrupted by two small bays to which creeks flow in narrow valleys. The eastern of these, 'Cowla' Creek near Giants Causeway, flows to a bay in a half kilometre long break in the cliffs where there is a sandy beach and a blowout. Behind the beach and blowout there are steep slopes in the limestone through which the creek flows. The catchment is small and the creek seldom flows to the sea. Wilyunup Creek has a catchment of about 112 km^2 on the sandplain, with its headwaters in farm land near South Coast Highway. The creek flows to a large blowout, the sand from which blocks the creek and holds back a narrow pool about 200 m long (Figure 9.3A). In flood the creek flows across the blowout to the beach.

From here to the Cordinup River (Chapter 7) granite cliffs and headlands alternate with shallow bays backed by steep dune slopes with onshore limestone reefs that protect them in some places. West of Cordinup, Warriup Creek flows from Green Range to a V-shaped blowout between the cliffs. Here the small Oven Lake has been trapped behind stable dunes over which the creek occasionally floods.

9.4 HASSELL BEACH

The 20 km long curve of Hassell Beach faces south east then east at its southern end where it is sheltered by the Mount Manypeaks range and Bald Island (Figure 9.4). It repeats the topography of Cheyne Bay with a dozen creeks that flow in parallel valleys

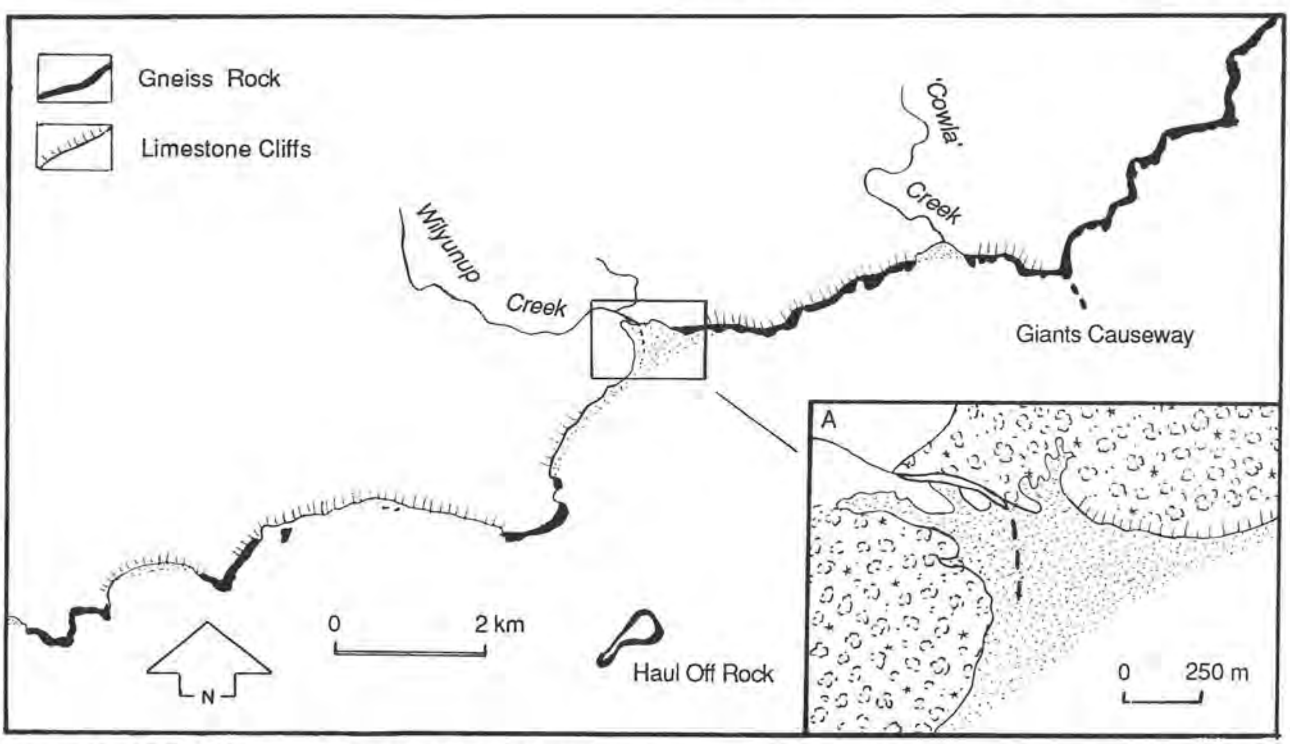
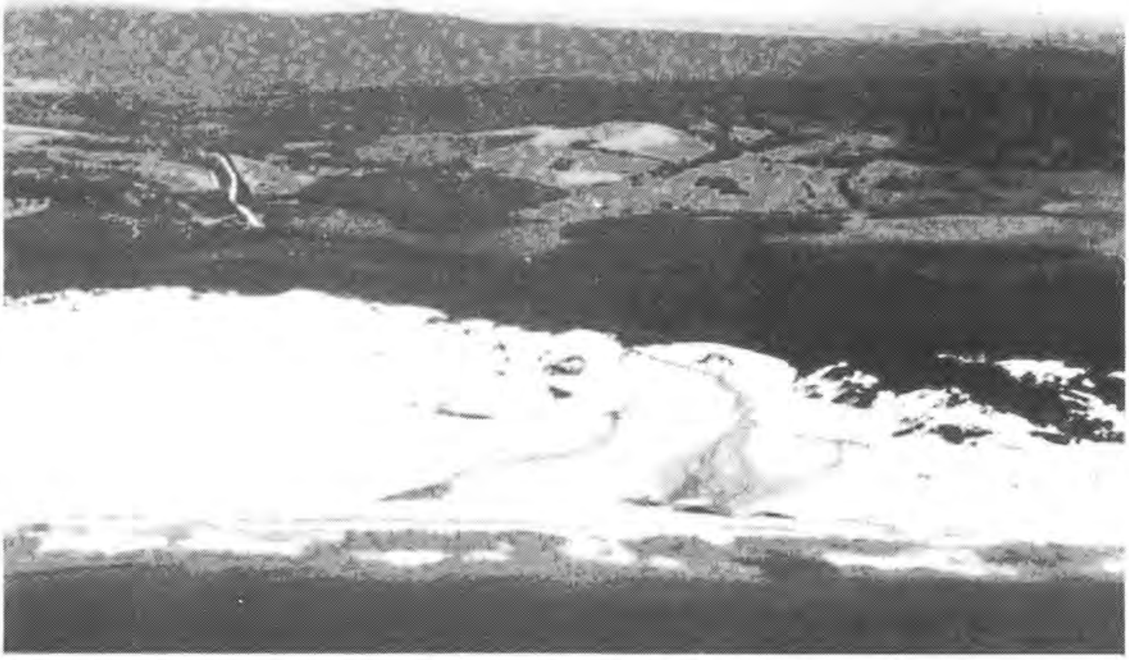


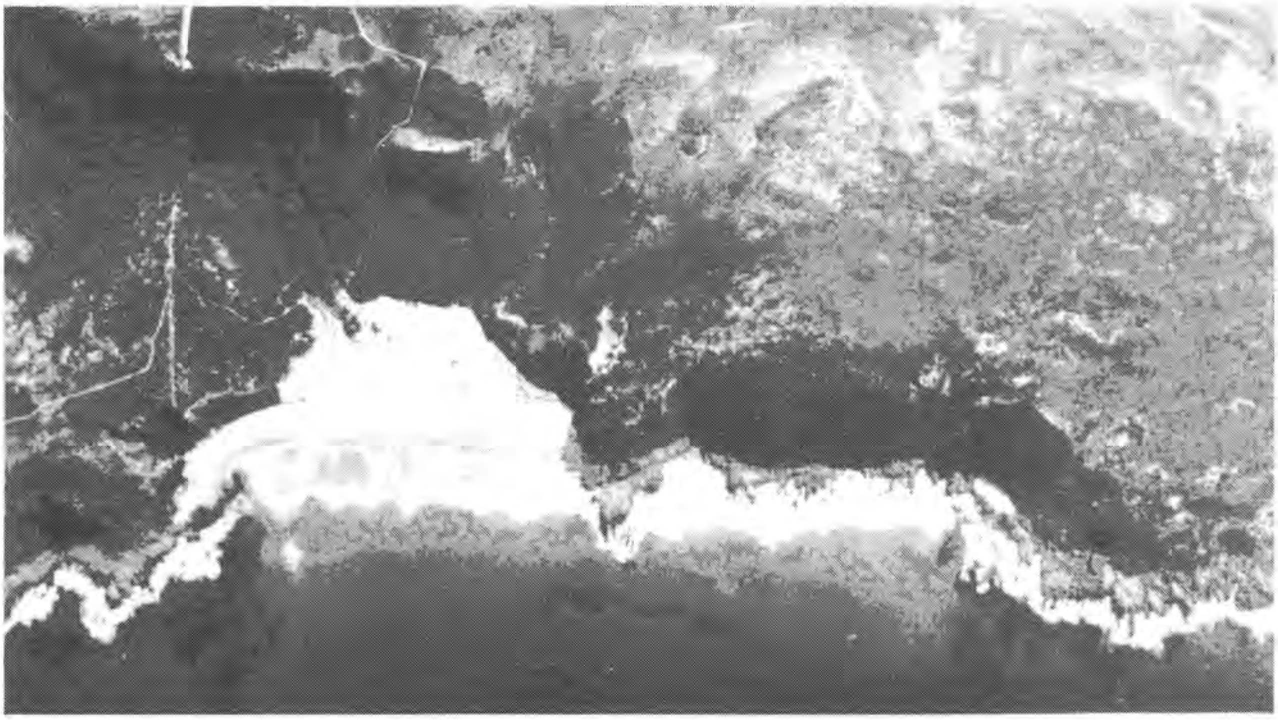
Figure 9.3 Creeks between Cape Riche and Green Range.



Mirrambeen Lake water flowing over the dunes, October 1978. Photo: Durant Hembree.

towards the coast from the spongolite hinterland. However the belt of blowouts, stable dunes and limestone between the spongolite and the beach blocks normal flow from many of the creeks, and there are small lakes and swamps in the narrow valleys.

At the north end of the bay two lakes have formed where creeks from Green Range end against stable dunes and a large blowout (Figure 9.4A). The larger, Mirrambeen Lake (on Mullocullop Creek), is 1.5 km from the beach and about 8 m above sea level. Swan Lake is about 4 m higher. The lakes have no connection with the sea but after



'Cowla' Creek, July 1977 (Department of Land Administration).

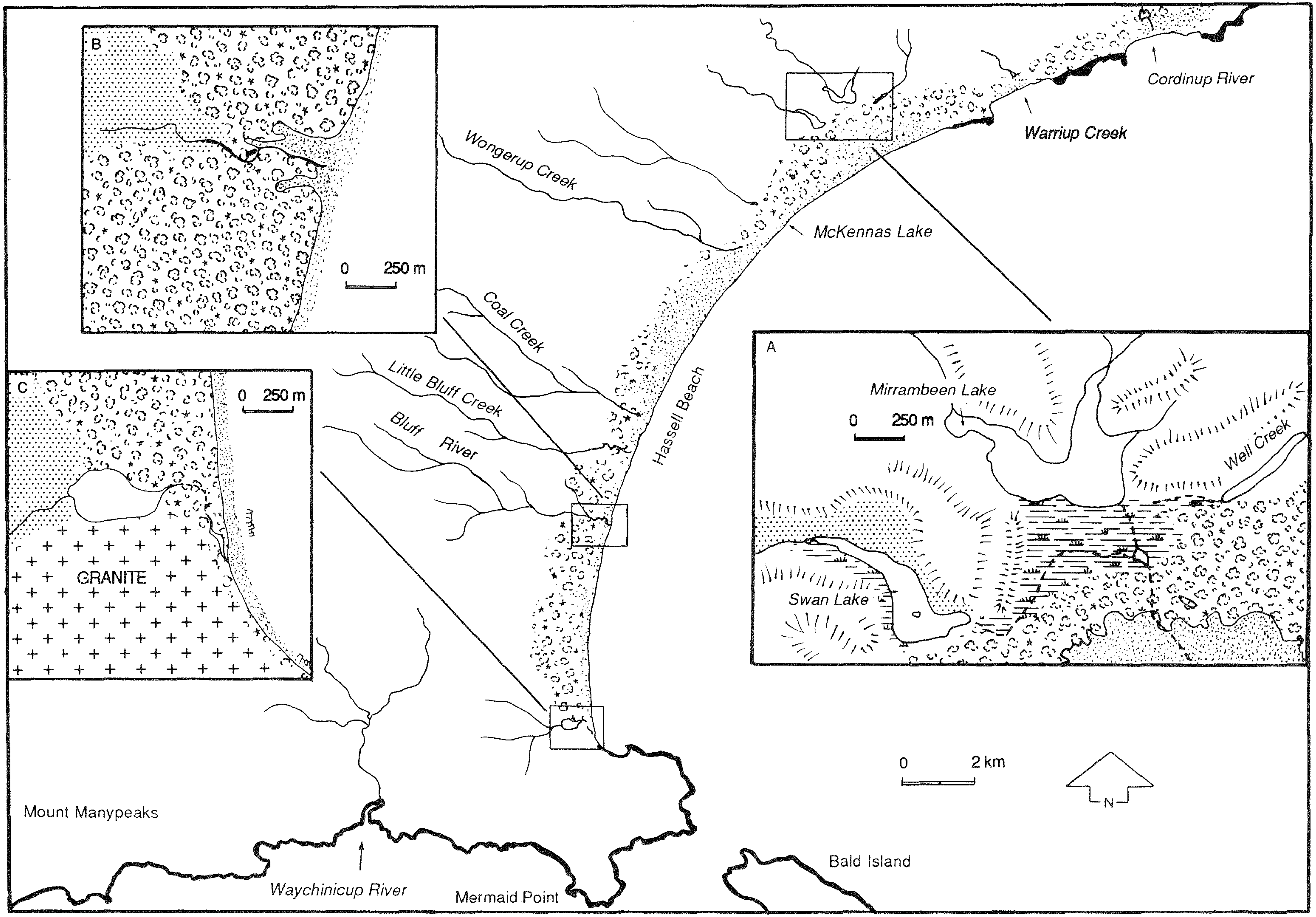


Figure 9.4 The estuaries of Hassell Beach and the Mount Manypeaks range.

exceptionally heavy rain, such as that of October 1978, lake water flows through the dense dune vegetation, through a small swamp, and across the blowout to the sea. Flow from the swamp is normally absorbed by the mobile dune. Well Creek is a narrow trough on a small creek from Green Range; it lies between the dune and a spongolite hill and may fill to a depth of about 3 m. The catchment area of these creeks is about 150 km^2. Lake water is slightly saline (about 5 ppt) from the creek water flowing into them.

McKenna's Lake is at the end of a small creek in the spongolite where it is blocked by the limestone and dunes. There does not appear to be any flow from it. The water is fresh. Wongerup Creek rises west of South West Highway and finishes where it reaches a blowout, but flows across this when in flood. Further south, Coal Creek flows through the vegetated dunes and across a narrow blowout. Little Bluff Creek and Bluff River have narrow pools where they wind to sand filled gullies in the stable dunes and flow to the narrow beach across which flood water flows (Figure 9.4B). At the south end of Hassell Beach a small lake drains through the dunes to a 250 m long creek behind the foredune, into which waves wash sea water over the beach (Figure 9.4C).

9.5 MOUNT MANYPEAKS RANGE

The rocky coast of the Mount Manypeaks range continues to Boulder Hill at the north end of Two Peoples Bay. The granite cliffs of the range face south and the rocky gorge of the Waychinicup River estuary is the only break in them (Figure 9.5). The gorge is essentially an arm of the sea with no sand or rock bar at the entrance, more a fiord than an estuary, and is thus unlike any other estuary in the south west. The water is only significantly diluted by fresh water briefly when there is strong river flow.

Waychinicup River, Frank Cooper's Hut.

The Waychinicup River is 17 km long and has a number of small pools along its length. The valley is incised some 40-60 m deep into the granite for 3 km from the coast with smooth slopes and occasional rock outcrops. Upstream, beyond the granite, the valley has a flat swampy floor in the spongolite and sandplain with the headwaters of the 145 km^2 catchment on grazing land north of South Coast Highway at an elevation of 100 m. The lower valley is in the Waychinicup River Catchment Area, an unvested reserve which it is proposed to be vested as Stage 2 of the Waychinicup National Park. The estuary is in a former Shire Reserve which is now included as part of Stage 1 of the Waychinicup National Park along with Mount Manypeaks Nature Reserve and other reserves and former Vacant Crown Land between Normans Beach and Bald Island. Access is from Cheyne Road off South Coast Highway, then west along Waychinicup Road (gravel) and south to the gorge.

Normans Inlet (Chapter 6) and King Creek flow into the small bay between the western end of the Mount Manypeaks range and Boulder Hill. King Creek flows in a narrow valley in the granite then behind a high foredune to the western end of the bay where it flows, almost continuously, over the beach against the rocky shore of Boulder Hill in the shelter of North Point (Figure 6.12). The 17 km^2 catchment is gauged and the dark tannin stained water is of marginal salinity, 600 mg/L TSS (WA Water Resources Branch, PWD, 1984).

9.6 TWO PEOPLES BAY

The deeply indented Two Peoples Bay faces due east between the rocky (granite) headlands of Mount Gardner and Boulder Hill (Figure 9.6). Two rivers flow towards the low lying swampy land behind low dunes where most of the flow is absorbed by two coastal lakes and swamps. Angove River (with a gauged catchment of 29 km^2) flows to Angove Lake and the surrounding swamp at the north end of the bay. Water from the swamp now drains via the Gardner Lake creek to the south end of the bay but may earlier have drained to the north end of the bay where the swamp is close to the beach.

Goodga River (gauged catchment 45 km^2) flows to Moates Lake from which there is a small creek through dune sand and swamp to Gardner Lake. Moates Lake is deep but Lake Gardner is shallow and has shell beds. The creek from Gardner Lake turns behind the foredunes to the south end of the bay where it flows across the beach in most years, or the beach is cut to drain water from the swamps. Sea water and stranded seagrass debris wash back into the creek. Gardner Lake is in the Two Peoples Bay Nature Reserve.

9.7 MOUNT GARDNER TO WILSON INLET

West of Mount Gardner the eastern shoreline of Nanarup Beach has limestone onshore reefs and cliffs

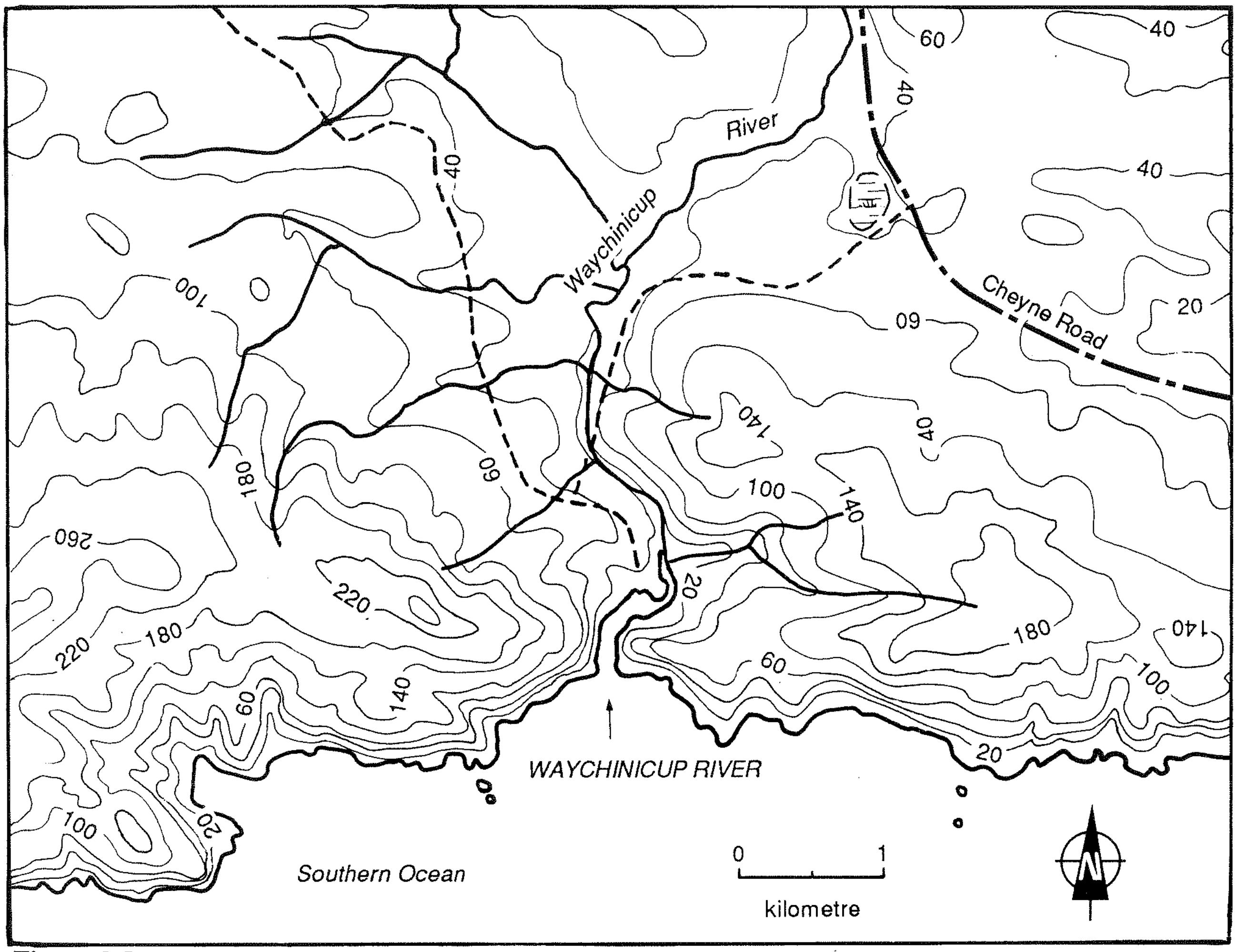


Figure 9.5 Waychinicup River. Topography of the surrounding area. Contours in metres.

and a large blowout of mobile sand which cascades into Moates Lake. Taylor Inlet is at the western end of the Beach and from there to Oyster Harbour the rugged granite shores of Mount Taylor and Mount Martin alternate with small sandy beaches. Here the small Gull Rock Lake is cradled between the slopes of Mount Richard and Mount Martin behind the dunes of Ledge Bay. A creek drains from the lake to a swamp at the western end of the bay where it is blocked by dune sand.

The Flinders Peninsula shelters King George Sound from the south west and south making the entrance to Oyster Harbour the most protected mouth of any estuary in the south west.

The granitic cliffs of the Flinders Peninsula, of Torbay Head and West Cape Howe, and of Knapp Head are each at the eastern ends of three long limestone cliffs over 100 m high, with Perkins Beach, the small Lowlands Beach, and the entrance to Wilson Inlet at their western, sheltered ends. The long line of the Nullaki Peninsula with its high dunes shelters Wilson Inlet and the small lakes which drain to its eastern shore. Torbay Head is the southernmost point of Western Australia.

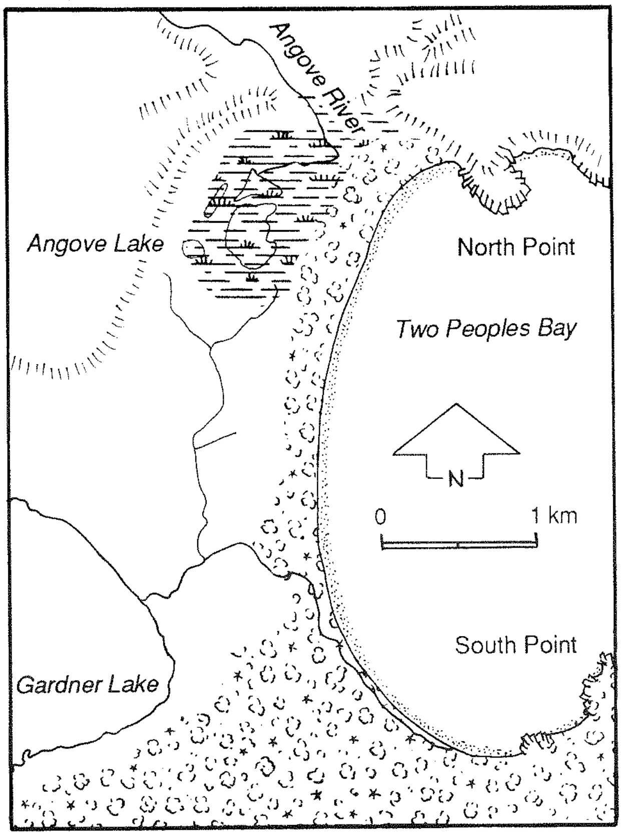


Figure 9.6 The lakes of the Two Peoples Bay area.

10 ESTUARINE VEGETATION

The following account is compiled mainly from the findings of G.R. Bastyan, who studied the distribution and abundance of seagrasses and macroalgae in Oyster Harbour, and of J.M. Chambers who surveyed the vegetation of Oyster Harbour, Torbay, Taylor, Normans and Cheyne Inlets in January 1988. Bastyan's findings are reported in greater detail in Hillman, et al. (1990b).

10.1 AQUATIC PLANTS

Oyster Harbour. Although the seagrass meadows have decreased greatly in recent years (as described in Section 3.5) marine seagrasses still cover substantial areas in shallow water throughout the harbour. The densest cover is in areas 1-1.5 m deep, where light availabilty is greatest, and the two species are now sparse in deeper water where once they grew to 5 m deep (Figure 10.11). The two principal species, *Posidonia australis* and *P. sinuosa*, are present in roughly equal quantities. *P. australis* is found near the shoreline, usually at a depth of less than 1 m, and *P. sinuosa* in slightly deeper parts (Figure 10.12).

Amphibolis antartica is present in a narrow, 5-8 m wide band on a sand bank near the entrance and along the western shore at depths between 1.8-4.5 m. It has the potential to colonise and become dominant where *Posidonia* has died out. *Heterozostera tasmanica* is confined to an area near the entrance and is not found in the northern half of the harbour where the water is too fresh and turbid. It is sparse and only replaces *Posidonia* that has died and been scoured out. The smaller *Heterozostera* sp. grows in the shallow trough on the eastern shore and as a narrow band on the western shore from Bayonet Head to King River where there is a larger patch south of the river mouth. Two estuarine species, *Ruppia megacarpa* and *Halophila ovalis* grow sparsely in the harbour. *Ruppia* has increased recently in shallows near the north shore, but only traces of *Halophila* grow around Green Island at 6-7 m deep where *Posidonia* has thinned.

The macroalga *Cladophora prolifera* is now dominant over a large area of shallow water (1-2 m deep) in the south eastern part of the harbour to which it is confined by the prevailing winds and currents. Blooms of the nuisance algae *Enteromorpha*, *Chaetomorpha* and *Ulva* now occur more frequently in spring near the King River mouth. The algae are broken up easily and are deposited on the north shore near the picnic ground where they decay on the beach. They are all common estuarine species of green algae. The brown algae *Hormosira banksii* and *Cystophyllum muricatum* are marine species, now sparse but common in 1961 (Figure 10.11) *Hormosira* attaches to bivalve shells and rubble in intertidal shallows and *Cystophyllum* in slightly deeper water. (Bastyan, 1986).

Torbay Inlet. *Ruppia megacarpa* is reported to have formerly been abundant in the Inlet and drains but is now sparse and has been largely replaced in the Inlet by the red alga *Gracilaria* sp.. Recently there have been brief, massive blooms of planktonic algae.

Taylor Inlet. The alga *Chaetomorpha aurea* was found in large clumps near the mouth of the western creek in January 1988.

Normans Inlet. *Ruppia* forms dense beds in the estuary up to 1.5 km from the mouth; in the riverine reaches it was free of epiphytes but in the basin was laden with epiphytic algae (January 1988). Beds of the stonewort *Lamprothamnium papulosum* were also found in the riverine part of the estuary.

Cordinup River. *Ruppia* and *Lamprothamnium* are the common aquatic macrophytes in the estuary.

Cheyne Inlet. In January 1988 *Ruppia* was common in the shallows up to 3 km upstream from the bar, often with the epiphytic red alga *Polysiphonia*. The macroalgae *Cladophora and Enteromorpha paradoxa* are sometimes abundant in shallow water in the lagoon near the bar.

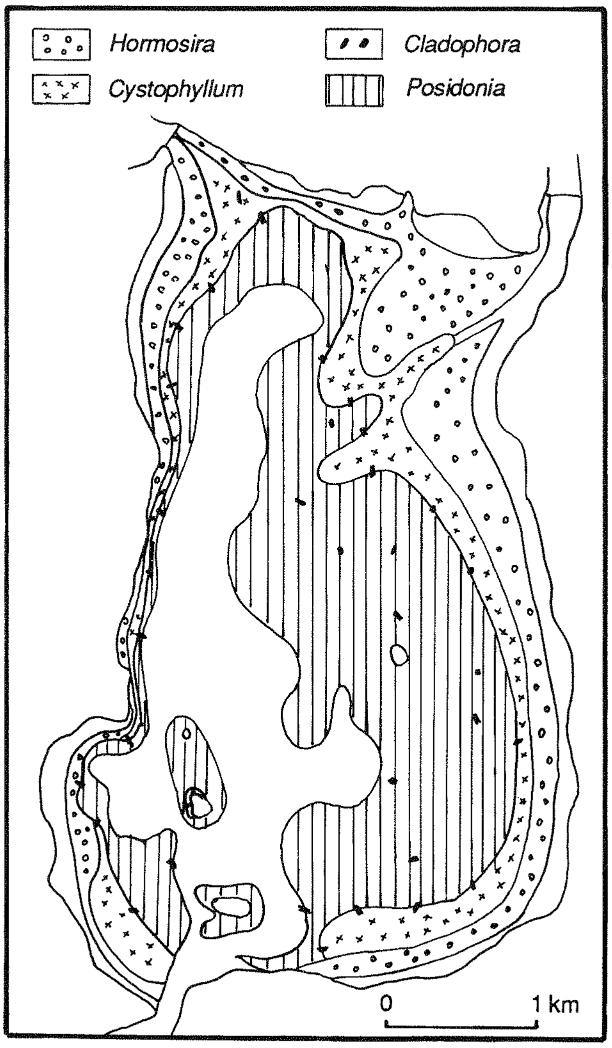


Figure 10.11 Distribution of Posidonia and macroalgae in Oyster Harbour in 1961-2 (Redrawn from McKenzie, 1964).

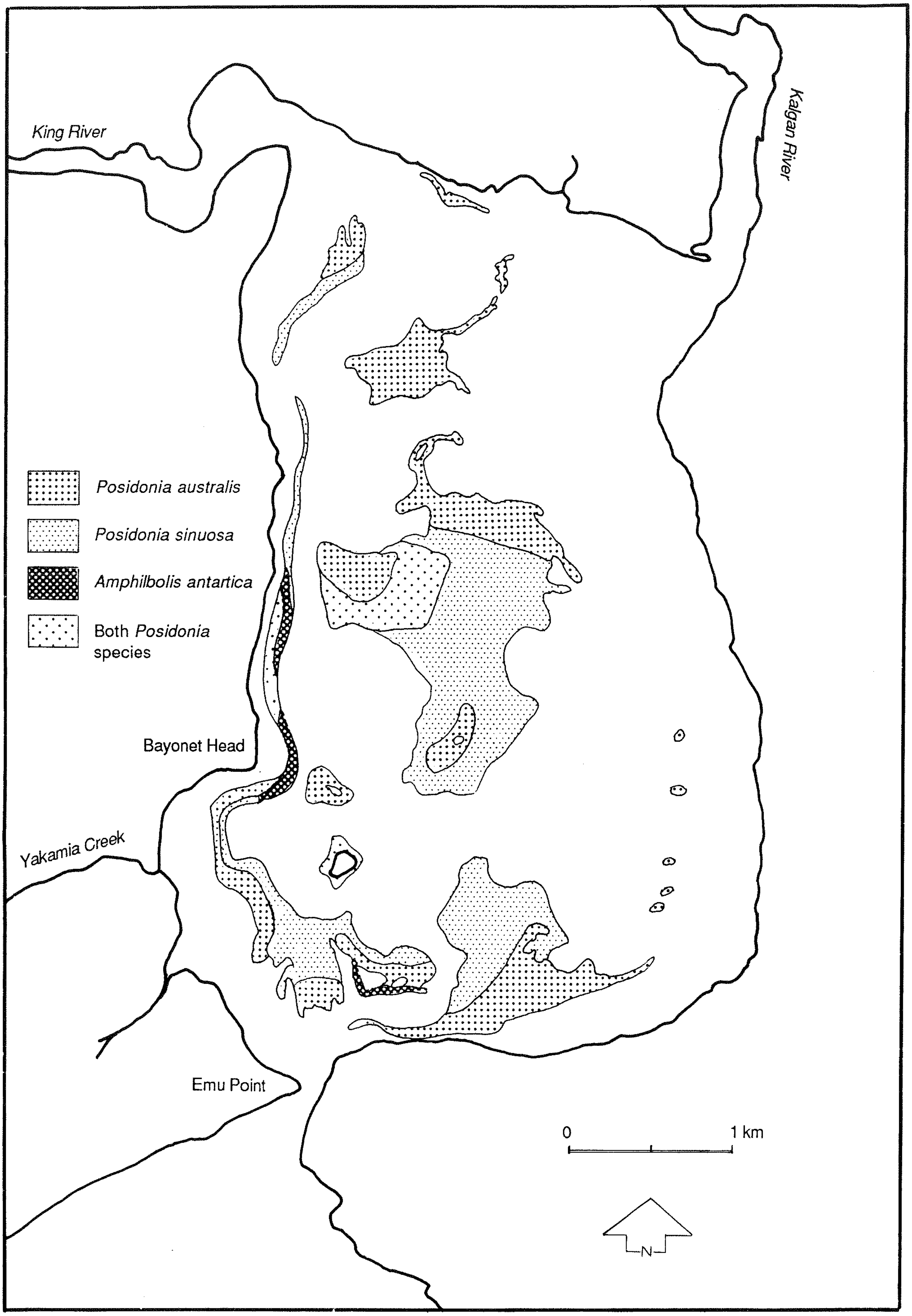


Figure 10.12 Distribution of the seagrasses in Oyster Harbour in 1988 (Redrawn from Hillman et al. (1990a)

10.2 SALT MARSH AND FRINGING VEGETATION

Oyster Harbour. Table 10.2 lists species found in the extensive wetland area of the south western creeks which is dominated by *Astartea* sp. with *Acacia* sp. and *Oxylobium lanceolatum*. *Juncus kraussii* dominates the outer fringe, with occasional *Melaleuca cuticularis* trees and *Baumea juncea* behind.

Table 10.2 Flats vegetation (J.M. Chambers).

Gahnia trifida	*Hakea* sp.
Lepidosperma gladiatum	*Acacia* sp.
Lepidosperma aff. striatum	*Daviesia* sp.
Schoenus sp.	*Jacksonia horrida*
Lyginia barbata	*Oxylobium lanceolatum*
Restio sp.	*Pimelea* sp.
Kingia australis	*Agonis flexuosa*
Johnsonia sp.	*Astartea* sp.
Anigozanthos sp.	*Calytrix* sp.
Allocasuarina sp.	*Melaleuca striata*
Casuarina obesa	*Melaleuca* sp.
Adenanthos sp.	*Leucopogon* sp.
Banksia attenuata	*Lysinema ciliatum*

There are extensive samphire flats in the shallows upstream and downstream of the Lower King Bridge with a succession of salt marsh plants dominanted by *Sarcocornia blackiana* and *Suaeda australis* in the wetter parts to *Halosarcia lepidosperma*, the larger *Halosarcia* sp. on the drier parts, and *Juncus kraussii* and *M. cuticularis* on rising ground behind.

There is a narrow samphire fringe on the south eastern shore of the harbour with *Sarcocornia blackiana*, *Suaeda australis* and *Halosarcia* sp., and patches of *J. kraussii* and *Melaleuca cuticularis* marsh behind.

M. cuticularis and *J. kraussii* form a generally sparse fringe along the steep banks of the Kalgan River with patches of samphire. At the Upper Kalgan Bridge the banks are dominanted by *Oxylobium lanceolatum*, *Lepidosperma gladiatum*, *J. kraussii*, *Agonis juniperina* and *A. flexuosa* with a Jarrah/Marri (*Eucalyptus marginata*, *E. calophylla*) community behind.

In the King River there is a dense fringe of *J. kraussii* along low lying banks between the two bridges with sparse *M. cuticularis*. Both species only form a narrow fringe along the steeper banks upstream .

Torbay Inlet. The marginal vegetation around the open water of the Inlet is a dense stand of *Melaleuca cuticularis* and *Juncus kraussii*. There is a wide band of *J. kraussii* on the western bank of the channel to the sea backed with *Lepidosperma gladiatum* nearer the coast and a *M. cuticularis* overstorey nearer the basin.

Between Torbay Inlet and Lake Manarup the river has a fringe of *L. gladiatum* with *Cynodon dactylon* (couch) and occasionally *J. kraussii*. This is backed by *Agonis juniperina*, *A. flexuosa*, *Oxylobium lanceolatum*, the sedge *Gahnia trifida* and the occasional *M. cuticularis*. On the bank of the Marbelup Sub B Drain near the Elleker Grasmere Road *M. rhaphiophylla*, *Baumea articulata* and *J. kraussii* are dominant with *Eucalyptus cornuta* (Yate) and *A. flexuosa* (Peppermint) behind.

Taylor Inlet The Inlet is fringed by *Melaleuca cuticularis* with an understorey of *Juncus kraussii*, *Samolus repens*, *Isolepis nodosa* and *Atriplex cinerea* backed by *Gahnia trifida* and *Baumea juncea*. Further back there are freshwater species of *M. rhaphiophylla* and *Oxylobium lanceolatum*. The river banks are dominated by *M. rhaphiophylla* and *Agonis juniperina*.

Normans Inlet The basin is fringed by *Melaleuca cuticularis* and *Juncus kraussii* with *Baumea juncea* and then *Isolepis nodosa* behind. Upstream of the basin *B. juncea* replaces *J. kraussii* as the dominant rush. Further upstream *M. rhaphiophylla* replaces *M. cuticularis* with an understorey of *J. kraussii* and *B. juncea* with *Gahnia trifida* further back.

Cordinup River *Melaleuca cuticularis* forms a fringe along the margin of the lagoon and lower riverine part of the estuary, and along the two spits in the lagoon, with generally sparse *Juncus kraussii*, except in the more open parts. There are samphire flats in the two bays of the lagoon with predominantly *Sarcocornia* and living and dead *M. cuticularis* (Photo page 55).

Cheyne Inlet The fringing vegetation is dominated by salt marsh with *Melaleuca cuticularis*, *Juncus kraussii*, *Suaeda australis*, *Atriplex cinerea* and *Sarcocornia blackiana* in the lower estuary. Further upstream, about 2 km from the bar, the banks carry a fringe of *M. cuticularis* and *J. kraussii* with *Gahnia trifida* behind, and bullrushes (*Typha*) near the head of the estuary.

10.3 TERRESTRIAL VEGETATION

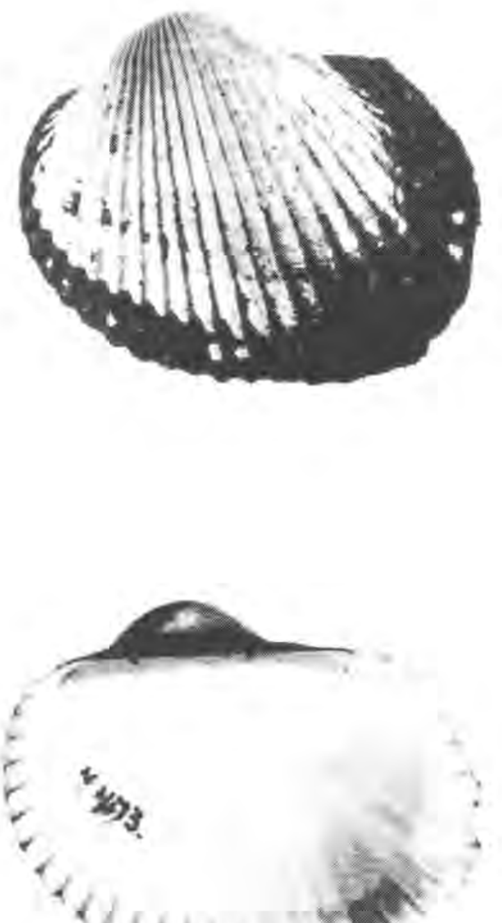
The bars are colonised by *Cakile maritima*, *Arctotheca populifolia* and *Ammophila arenaria*. On the dunes *Spinifex hirsutus* and other larger shrubs dominate. The bar and dune species are listed in

Table 10.3 Coastal dune vegetation near the estuaries (J.M. Chambers).

Ammophila arenaria	*Pelargonium capitatum*
Polypogon monspeliensis	*Euphorbia paralias*
Spinifex hirsutus	*Spyridium globulosum*
Isolepis nodosa	*Hibbertia cuneiformis*
Lepidosperma gladiatum	*Pimelea ferruginea*
Rhagodia baccata	*Leucopogon parviflorus*
Carpobrotus sp.	*Scaevola crassifolia*
Cakile maritima	*Arctotheca populifolia*
Acacia cyclops	*Calocephalus brownii*
Daviesia sp.	*Olearia axillaris*

Table 10.3. This typical coastal scrub is present on the dunes at the mouths of the estuaries . Inland from Oyster Harbour on the eastern side is a mosaic of *Agonis flexuosa*, (Peppermint) communities and Jarrah/Marri communities dominated by *Jacksonia horrida* and Peppermint further back again.

Behind the dunes at Taylor, Normans and Cheyne inlets there is a lower heath with some elements of the coastal scrub (e.g. *Spyridium, Olearia*) together with the species associated with the flats (Table 10.2). Torbay Inlet has taller trees (e.g. *Casuarina obesa* with an occasional *Banksia attenuata*) present in the flats. Taylor and Normans inlets have other inland species such as *Kingia australis*, *Adenanthos* sp., *Lyginia barbata* and *Hakea* sp. and Cheyne Inlet has low Eucalypt mallee.



Anadara trapezia. Photo: Clayton Bryce.

11 ESTUARINE FAUNA

Oyster Harbour is essentially a sheltered marine embayment and it is only near the mouths of the two rivers that surface salinity is ever less than about 30 ppt for more than a few days. As is to be expected, the fauna is much more diverse than in other estuaries of the south west and includes many marine species that are rare in them. Major floods are reported to have killed cockles and other fauna in the shallows but the populations soon recover.

The estuarine reaches of the King and Kalgan rivers are similar hydrologically to the other estuaries of the Shire, where salinity may change seasonally from fresh to marine, and they have a similar fauna dominated by a few common estuarine species. However, being permanently open to the marine water of Oyster Harbour, they also have some 'marine affinity' species (see below, 11.2) not found in other estuaries of Albany Shire. One such species, *Anadara trapezia*, is of special interest; it is a common bivalve in eastern Australian estuaries where there are seagrass meadows, but Oyster Harbour is now the only place in WA where it is found alive. Although *Anadara* shells are common in Pleistocene shell deposits of south coast estuaries they are not present in the extensive shell beds of estuaries east of Albany which have been dated as being Holocene (G. Kendrick, pers. comm.).

The planktonic animals depend mainly on plant plankton for food. Some of the bottom living invertebrates feed on diatoms in the sand and mud and on the seagrass, but most derive their nourishment directly or indirectly from the bacteria and other microscopic organisms that decompose the organic detritus. Very few fish are plant feeders; the larvae of many species feed on animal plankton, but most adult fish feed on the larger invertebrate animals and Sea mullet feed on microscopic organisms in the detritus.

11.1 PLANKTON

Plankton tows were made in the King and Kalgan rivers on a number of occasions between February 1970 and March 1972 (mesh size 125/200 μm). The true zooplankton is dominated by three species of calanoid Copepoda (Crustacea) any of which may be abundant in water of appropriate salinity. They were more abundant in the Kalgan River than in the King River, possibly because of the generally higher salinity water sampled there. *Gladioferens imparipes* is a strictly estuarine species which tolerates the wide range of salinities experienced in south west estuaries, from less than 3 ppt to about 60 ppt. *Acartia tranteri* (?) and *Oithona nana* (?) are common in coastal waters and in estuaries, but seldom in water of less than about 20 ppt;. The King and Kalgan rivers are always open to sea water intrusion and *Acartia* and *Oithona* (sometimes also *G. inermis*) generally replace *G. imparipes* in higher salinities, both along the salinity gradients of the rivers and vertically when the water is stratified. Small numbers of several other more marine species of copepod were also caught in high salinity water. *Sulcanus conflictus* is a brackish water species that is abundant in many Australian estuaries and is common in river pools where salinity is between 4 and 15 ppt. However it was seldom caught in estuarine reaches of the two rivers, but was common in samples taken in the river pool above the Upper Kalgan Bridge.

The plankton tows also caught considerable numbers of the immature stages of bottom fauna, especially the veliger larvae of bivalve and gastropod molluscs and the larvae of barnacles, prawns, crabs and polychaete worms, and of fish.

11.2 BOTTOM FAUNA

No systematic surveys have been made of the bottom fauna of the estuaries reviewed here, however the results of opportunistic collecting during brief visits indicate the species likely to dominate the fauna of individual estuaries; these are summarised in Table 11.2. There are obvious major gaps in the list, especially of polychaete worms other than the tube worm *Ficopomatus*; two species were identified (by Margaret Platell) from Taylor Inlet: *Leitoscoloplos normalis* and *Neanthes vaalii*. The composition of the fauna is influenced both by the salinity range experienced and by the availability of suitable substrate types — rock, water plants, sand, mud.

Table 11.2 Bottom invertebrate fauna at King (KI) and Kalgan (KA) rivers, Torbay (TB), Taylor (TY), Normans (NO) and Cheyne (C) inlets.

		KI	KA	TB	TY	NO	C
POLYCHAETA:							
Serpulidae							
Ficopomatus enigmaticus		-	+	+	-	-	+
MOLLUSCA - GASTROPODA:							
Littorinidae							
Bembicium auratum	MA	+	+	-	-	-	-
Hydrobiidae							
Hydrobia buccinoides	E	-	-	-	-	+	-
Tatea preissii	E	-	-	-	+	-	-
Nassariidae							
Nassarius burchardi	MA	+	+	-	+	-	-
MOLLUSCA - BIVALVIA:							
Arcida							
Anadara trapezia	MA	+	-	-	-	-	-
Mytilidae							
Brachidontes erosus	MA	+	-	-	-	-	-
Xenostrobus securis	E	+	+	+	-	-	-
Leptonidae							
Arthritica semen	E	-	-	-	-	+	+
Mactridae							
Spisula trigonella	MA	+	-	-	-	-	+
Tellinida							
Tellina deltoidalis	MA	+	-	-	-	-	-
Sanguinolariidae							
Sanguinolaria biradiata	MA	-	-	-	+	-	+
Trapeziidae							
Fluviolanatus subtorta	E	-	+	+	-	+	-
Veneridae							
Katelysia scalarina	MA	+	-	-	-	-	-
CRUSTACEA:							
Cirripedia							
Balanus amphitrite		+	+	+	+	-	-
Amphipoda							
Melita sp.		-	+	+	-	+	+
Isopoda							
Sphaeroma sp.		-	+	+	-	+	+
Decapoda							
Palaemonetes australis		-	-	+	-	+	+

MA - marine affinity species, E - estuarine species. See text for definitions.

The fauna of Oyster Harbour is probably as varied as that of Princess Royal Harbour to which there is no significant freshwater input. Wells and Bryce (1984) list 133 species of molluscs found in Oyster Harbour (of which about 55 have been found alive) most of which they regard as 'marine' species, "species which only enter estuaries for short periods or at irregular intervals", or 'marine affinity' species, "molluscs with an essentially marine distribution which frequently are found in estuaries". A variety of other characteristically marine fauna, such as starfish, are recorded from the harbour and the sea urchin *Temnopleurus michaelsenii* has been found grazing on seagrasses. McKenzie (1962) found 134 species of Foraminifera though only a dozen were common and one, *Elphidium* sp., was much the commonest and present throughout the harbour.

Few such species live in the King and Kalgan rivers. Several marine affinity species of mollusc live on the shell beds in the lower King River, but not further upstream. In the Kalgan River the snail *Bembicium*, barnacles (*Balanus*) and tube worms(*Ficopomatus*) are abundant on rocks and logs downstream of the rock bar and there are mud oysters (*Ostrea angasi*) in the lower reaches. The estuarine mussel *Xenostrobus securis* is common in both rivers. *Elphidium* sp. was again the dominant species of Foraminifera, with only two other species in the Kalgan River and six in the lower reaches of the King River. Two of these, *Ammobaculites agglutinans* and *Ammonia beccarii*, dominate low salinity environments in the Blackwood River estuary (Quilty, 1977).

The fauna of Torbay Inlet, Normans Inlet and the Cordinup River estuary appears to be dominated by 'estuarine' species, "species only found in estuaries and not in the adjacent marine and freshwater areas". The estuarine shrimp *Palaemonetes* is common among seagrass (*Ruppia*) and algae and other species listed are all common in estuaries. Larvae of freshwater insects (damselflies and caddisflies) live in Normans Inlet where the water is often almost fresh. The higher salinity of Cheyne Inlet favours marine affinity species such as cockles (*Katelysia*) and *Sanguinolaria* which sometimes grow to maturity in the lagoon close to the bar, but estuarine species are also present. Taylor Inlet probably also supports other marine affinity species.

It is of interest to note that water rats are reported to be common in Torbay Inlet and turtles in Cordinup Inlet.

11.3 FISH

Oyster Harbour is a rich feeding ground for the wide variety of fish listed in Table 11.3. With the exception of Black bream, the commercial species are common coastal marine fish which spawn at sea and use estuaries as nursery feeding areas. Black bream are confined to the estuaries and saline rivers. The harbour supports a considerable commercial fishery, principally for the eight species shown in Figure 11.3, and for squid. Most of these fish penetrate the Kalgan and King rivers as far as the rock bars, but only Black bream and Sea mullet are found upstream, also Mulloway in the Kalgan River.

Many of the marine species also enter the small estuaries, but the principal species caught by fishermen are Black bream, Sea mullet and sometimes Yellow eye mullet. However the composition of the fish fauna varies greatly from year to year, with the time and duration of opening of the

Table 11.3 Commercial and non commercial estuarine and marine species of fish caught in Oyster Harbour (Lenanton, R.C.J. & G.M. Cliff)

Commercial	
Engraulididae:	Australian anchovy *Engraulis australis*
Plotosidae:	Cobbler *Cnidoglanis macrocephalus*
Platycephalidae:	Flathead Platycephalus spp.
Sillaginidae:	King George whiting *Sillaginodes punctatus*
Pomatomidae:	Tailor *Pomatomus saltator*
Carangidae:	Sand trevally *Pseudocaranx wrighti.*
Arripidae:	Australian herring *Arripis georgianus*
	Western Australian salmon *Arripis truttaceus*
Sparidae:	Black bream *Acanthopagrus butcheri*
	Tarwhine *Rhabdosargus sarba*
Mugilidae:	Yellow eye mullet *Aldrichetta forsteri*
	Sea mullet *Mugil cephalus*
Bothidae:	Small toothed flounder *Pseudorhombus jenynsii*
Pleuronectidae:	Long snouted flounder *Ammotretis rostratus*
	Elongate flounder *Ammotretis elongatus*
Monacanthidae:	Six-spined leatherjacket *Meuschenia freycineti*
	Rough leatherjacket *Scobinichthys granulatus*
	Horseshoe leatherjacket *Meuschenia hippocrepis*
	Velvet leatherjacket *Parika scaber*
Gempylidae:	Barracouta *Leionura atun*
Soleidae:	Harrowed sole *Strabozebrias cancellatus*
Non commercial	
Rhinobatidae:	Fiddler ray *Trygonorhina fasciata*
Torpedinidae:	Numbfish *Hypnos monopterygium*
Congridae:	Eel *Conger wilsoni*
Non commercial	
Ophichthidae:	Serpent eel *Ophisurus serpens*
	Fringe-lipped snake eel *Cirrhimuraena calamus*
Echelidae:	Short-headed worm eel *Muraenichthys breviceps*
Elopidae:	Giant herring *Elops machnata*
Gonorynchidae:	Beaked salmon *Gonorhynchus greyi*
Atherinidae:	Hardyhead Atherinid spp.
Trachichthyidae:	Roughy *Trachichthys australis*
Syngnathidae:	Wide bodied pipe fish *Stigmatophora nigra*
	Port Phillip's pipe fish *Syngnathus phillipi*
Scorpaenidae:	Soldierfish *Gymnapistes marmoratus*
	Little scorpion fish *Maxillicosta scabriceps*
Aploactidae:	Velvet fish *Aploactisoma milesii*
Terapontidae:	Striped trumpeter *Pelates sexlineatus*
Apogonidae:	Gobbleguts *Apogon rueppellii*
Echeneidae:	Stout suckerfish *Remora remora*
Cheilodactylidae:	Dusky morwong *Dactylophora nigricans*
Odacidae:	Weedwhiting Neoodax sp.
Clinidae:	Southern crested weedfish *Cristiceps australis*
	Yellow crested weedfish *Cristiceps aurantiacus*
	Common weedfish *Heteroclinus* sp.
Gobiidae:	Long finned goby *Favonigobius lateralis*
	Sculptured goby *Callogobius mucosus*
Gerreidae:	Roach *Gerres subfasciatus*
Monacanthidae:	Mosaic leatherjacket *Eubalichthys mosaicus*
Diodontidae:	Globe fish *Diodon nicthemerus*

bars. The Pouched lamprey (*Geotria australis*) is caught migrating through Torbay Inlet to Marbelup Brook. Black bream were introduced to the closed Mirrambeen Lake but did not long survive there and Sea mullet are reported to have entered the lake during floods and grown to a large size.

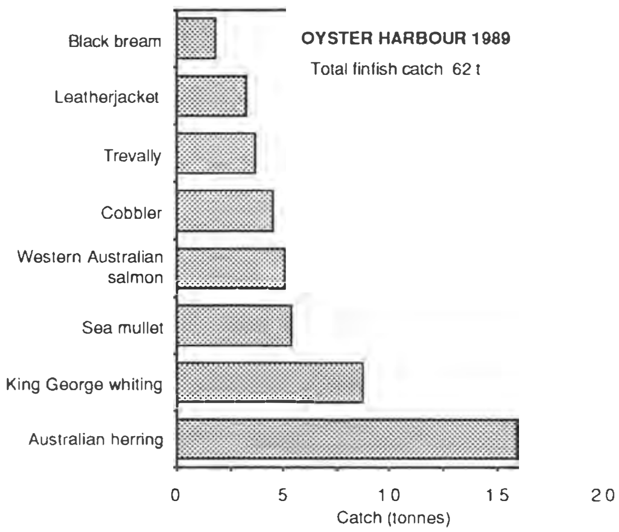
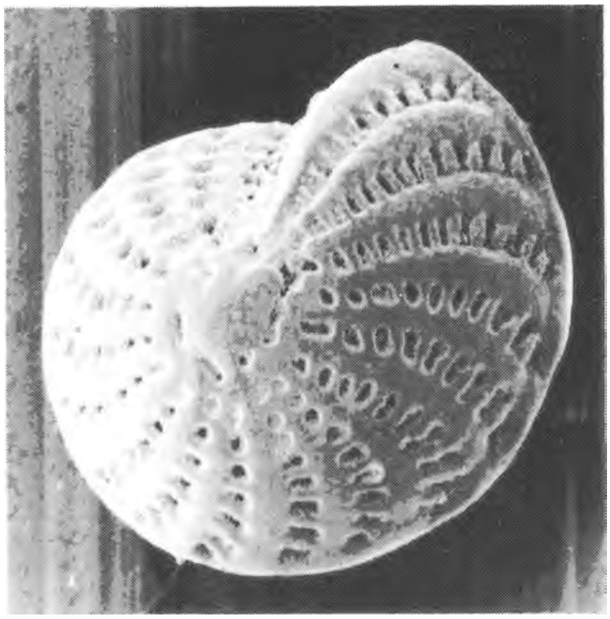


Figure 11.3 Commercial fish catch for the eight most plentiful species in 1989 at Oyster Harbour (Lenanton, pers. comm.)

11.4 BIRDS

Waterbird surveys of the estuaries are confined to the yearly counts by the Royal Australasian Ornithologists Union in March since 1986. The waterbirds observed at four estuaries are listed in Table 11.4. Pelicans nested on Green Island in Oyster Harbour in 1985-86.



Foraminifera, *Elphidium* sp. magnification: 130X Photo: G. Milner, Electron Microscopy Centre, The University of Western Australia.

Table 11.4 Waterbirds observed at Torbay (TB), Oyster Harbour (OY), King River (KI), Kalgan River (KA), Taylor (TY), Normans (N) and Cheyne (C). (RAOU) Numbers indicate highest recorded.

Common name	Scientific name	TB	OY	KI	KA	TY	C
Australian Pelican	*Pelecanus conspicillatus*	30	39				1
Great Egret	*Egretta alba*	5	15			3	1
Black Swan	*Cygnus atratus*	6	113	3		36	20
Australian Shelduck	*Tadorna tadornoides*	290	-				20
Pacific Black Duck	*Anas superciliosa*	25	10	4	35	116	-
Grey Teal	*Anas gibberifrons*	11	1	210	24	17	6
Chestnut Teal	*Anas castanea*	3				4	2
Australian Shoveler	*Anas rhynchotis*	3					
Musk Duck	*Biziura lobata*	2				6	
Eurasian Coot	*Fulica atra*	72					
Osprey	*Pandion haliaetus*	2			2		
Red-capped Plover	*Charadrius ruficapillus*	3					
Silver Gull	*Larus novaehollandiae*	10	30		20	10	
Caspian Tern	*Hydroprogne caspia*	2				2	

12 MANAGEMENT

The major immediate management problem is control of eutrophication in Oyster Harbour and to a lesser extent in Torbay Inlet and Cheyne Inlet. A problem common to many south coast estuaries relates to management of the bars of the smaller estuaries of the Shire. The long term problem of sedimentation is important here as elsewhere on the south coast, especially in areas of low rainfall east of Albany.

EUTROPHICATION As discussed in Chapter 3 the abundance of plant nutrients entering Oyster Harbour has produced a eutrophic condition that is manifested by the excessive growth of algae and loss of seagrass meadows. Superphosphate applied to pastures in the King and Kalgan river catchments is the principal source of phosphorus and leguminous pastures are probably the main source of nitrogen. The nature of the problem and possible solutions are discussed in the Albany Harbours Environmental Report (Albany Technical Advisory Group, 1990) which recommends that "Annual nutrient loading to Princess Royal Harbour and Oyster Harbour from all sources should not exceed the assimilative capacities of these waterbodies".

It is clear that for Oyster Harbour the prime requirement is to reduce the input of one or both nutrients from the catchments to the point at which algae no longer smother the seagrasses. However it will be evident from the report and from the Environmental Protection Authority (1990) recommendations that much further investigation will be necessary before the 'nutrient assimilative capacity' of the harbour can be properly assessed. This is not the place to pursue the matter further except to stress that it is urgent: "If current pollutant loadings into the harbours continue, most of the remaining seagrasses will be lost within five years in Princess Royal Harbour, and within five to ten years in Oyster Harbour, and the general ecology of the harbours will continue to deteriorate".

Seagrasses are, or were, the main primary producers in the ecosystem and they are at the base of the food chain. The seagrass meadows are an important habitat for small fish and for a great diversity of the invertebrate fauna on which most fish feed. Their roots bind the sediments and prevent erosion by waves and currents, and the foliage traps fine particulate matter which, when in suspension, reduces the light available for photosynthesis and growth of the seagrasses. Once lost, natural regeneration is likely to be very slow and efforts to reestablish seagrass meadows elsewhere have met with little success.

Torbay Inlet also receives a big load of nutrients from agricultural fertilizers applied to the catchment. Nutrient levels are high in Inlet water, but there is generally little overt evidence of eutrophication in the Inlet. There are brief blooms of phytoplankton and there have been reports of bluegreen algae in past years. The dark tannin stained water from Marbelup Brook may well inhibit photosynthesis by green algae. The red alga *Gracilaria* is often abundant in the Inlet and *Ruppia* is reported to be less plentiful than previously. Water flow from the eastern creeks and swamps is routed through Lake Powell or Lake Manarup making the former highly eutrophic with massive blooms of bluegreen algae.

There is often considerable growth of filamentous green algae in Cheyne Inlet, but not in the riverine part and the estuary does not appear to be seriously eutrophic. There are not the data on which to assess its nutrient status adequately. Taylor Inlet, Normans Inlet and the Cordinup River estuary at present show little evidence of eutrophication.

BAR MANAGEMENT

The sea bars of south coast estuaries are often broken prematurely for a variety of reasons related to the short term interests of particular pressure groups. Breaking the bars presents no special problems if there is a good head of water when they break and a sufficient volume of river flow to scour incoming beach sand from the channels to the sea. That is seldom the situation on the south coast and tidal flow can bring more beach sand into the estuaries than is flushed to sea. Decisions as to when, especially, where and how the bars should be opened generally aim to resolve conflicting social pressures with little consideration being given to the long term future of the estuaries. Unfortunately as yet there is little factual basis on which to predict the effect of alternative management strategies on the estuarine ecosystems and there won't be until the dynamics of sand and water movement in and out of the estuaries are investigated.

There are conflicting interests with respect to management of the Torbay Inlet and Taylor Inlet bars. The Torbay Inlet bar is managed by the Water Authority principally to prevent farm land in the Elleker area being flooded. This involves breaking the bar several times a year, often before it has had time to build to its full height and the water level in the Inlet is still below the top of the bar. Local fishermen contend that this premature opening of the bar does not allow the outflow to scour as deep a channel as when the bar breaks naturally, the bar does not stay open as long, and there is less recruitment of fish stocks.

Access to the popular Nanarup Beach is along the margin of the Taylor Inlet channel. Vehicle traffic appears to be encroaching on the dunes on both sides and widening the channel. When the Inlet fills, the tracks to the beach are flooded (sometimes also the road) and the bar is opened by the Shire. With little river flow from the small catchment effective scouring of the channel must depend primarily on the first flush when the bar breaks. In this situation prolonged bar opening must be expected to increase sand transport into the Inlet. The natural growth of the flood tide delta appears to have been accelerated and the delta now extends well into the lagoon. On a small scale this parallels the position in Wellstead Estuary and Wilson Inlet in both of which there are massive flood tide deltas (Estuarine Studies Numbers 1 and 3).

The Taylor Inlet bar is sometimes also opened by fishermen to allow recruitment of marine species of fish. On the other hand it is in the interests of local residents to keep the bar closed in summer so as to maintain high water levels in the shallow bores on which they depend.

The Cheyne Inlet bar appears to be growing into the small lagoon and this is reported to have become much shallower in recent decades, though it is not clear how this could have been accelerated by human activities. The Eyre River opens into the most sheltered part of Cheyne Bay and the small river flow seldom scours the bar effectively.

SEDIMENTATION The increased rate of sedimentation following clearing in the catchments is a serious problem in a number of estuaries of the south coast, however as yet this does not appear to be a major problem in any of the estuaries discussed here. No doubt there has been increased sediment transport in the Kalgan River with fine sediment reaching Oyster Harbour and coarse sediment moving down the river bed. Soil washing from cleared land is contributing to the sediment load in the river delta of the King River which is now very shallow.

The Cordinup River is threatened from the seaward end where a dune is encroaching on the small lagoon. Vegetation on the lagoon side of the dune is being smothered by sand blown from the blowout on the beach and the lagoon is being invaded by dune sand.

Behind Hassell Beach much of the higher ground on the spongolite has been cleared for cultivation in the last decade; this is likely to cause erosion with the sediment being deposited in the valley swamps. The equally vulnerable hills and creeks in Cheyne Bay should be protected by the proposed Conservation Park when this is established.

FISHING Regulations controlling recreational net fishing in the estuaries are listed in a booklet, Fisheries Department, WA (1989). In Oyster Harbour net fishing is restricted to between 90 minutes before sunset and 90 minutes after sunrise and the area of the entrance to Oyster Harbour is closed at all times. The King and Kalgan rivers, upstream from the lower King and Kalgan bridges, Torbay Inlet and Taylor Inlet are closed at all times. There are no restrictions on fishing in the other estuaries.

Commercial fishing is confined to fishermen licensed to operate in the South Coast Estuarine Fishery. Of the 65 units licensed to operate in the 14 commercially fished estuaries only about six units fish regularly in Oyster Harbour, the only estuary of the Albany Shire that is fished commercially.

GENERAL Excessive plant nutrient input and increased sediments are not the only dangers to estuarine waters from cultivation of the catchments. Insecticides and herbicides applied to crops may enter river water to the detriment of animal and plant life in the rivers and estuaries. Insecticides applied to oil seed paddocks are thought to account for the disappearance of small fish and a deterioration of the mollusc fauna in Cheyne Inlet in the 1970s.

Waychinicup River's honorary ranger, Frank Cooper, lived in a shack perched on the steep bank of the gorge for almost 30 years until his death in December 1987. His dedicated care of this beautiful estuary limited the damage done to the surroundings by the increasing influx of visitors. Since his death friends have continued to maintain his old home and rangers from CALM have begun to manage the area. However vehicle tracks have multiplied and rubbish is now harder to control due to the lack of a permanent presence. The area needs sympathetic management if the public is to continue to have access to it. Waychinicup River was formerly in a Shire Reserve but as of 1990 has been included in Stage 1 of the Waychinicup National Park.

13 FURTHER INVESTIGATION

The most important problems requiring further investigation are how best to reverse the present eutrophic condition of Oyster Harbour and the urgent need to prevent further loss of the seagrass beds has been stressed above. These will be the responsibility of the newly formed Albany Waterways Management Authority and are not discussed here.

The need for a more rational approach to management of the bars has been advocated in several previous studies (Numbers 1,3,4,5,6), especially in relation to the controversial Wilson Inlet bar (Number 3). At present most bars are managed primarily in the immediate interests of particular pressure groups with little consideration given to the long term future of the estuarine ecosystems.

Flood tide deltas are growing into the lagoons and delta growth appears to have been accelerated by breaking the bars before they are ready to break naturally; for example in Taylor Inlet where the delta is encroaching into the lagoon and the inlet channel is widening at the expense of the dunes. We are not aware of any documentation of sand movements in the inlet channels or of changes to the flood tide deltas and it would be valuable to have records on which to determine the effects of breaking the bars and to base management decisions. There are recent records of openings of the Torbay Inlet bar which, if continued, could provide data on which to assess the effects of bar breaking on the size of channel, the duration of the opening, and controversial questions with respect to the success of the fishery especially.

The estuaries are slowly filling with sediment from the land and the process has been greatly accelerated by clearing in the catchments. The only data on the current rate of sedimentation are from estuaries with low rainfall catchments, Stokes Inlet (Hodgkin and Clark, 1989) and Beaufort Inlet (Hodgkin and Clark, 1988b). It is important to determine sedimentation rates in other estuaries, especially some with high rainfall catchments.

It will have been obvious from previous chapters that knowledge of many aspects of the ecology of the estuaries is scanty, especially the smaller estuaries. The few records of their hydrology and nutrient status and the scanty observations on the fauna and flora need to be augmented if rational judgments are to be made about management. Apart from what some older residents can recall there is no record of the history of how they have changed in the 160 years since Albany was settled and the effects of catchment clearing and other human activities on them.

The Blackwood River estuary is the only south coast estuary about which there are adequate data on which to interpret the geological history of the brief six thousand years since the post glacial rise in sea level flooded the Pleistocene valleys. That estuary is in the highest rainfall area and the river flow is the largest of any in the south west. Similar sedimentary studies need to be extended to other estuaries, especially to those in lower rainfall areas, in order to understand how they have changed from open estuaries to the present day shallow, closed systems. The processes at work during that period are still at work today, often accelerated by human activities as in Beaufort Inlet and Stokes Inlet where sediment accumulation is now rapid (Hodgkin and Clark, 1988b and 1989). Some estuaries appear to have a very limited future even on the human time scale.

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Taylor Inlet, the bar and beach. Flinders Peninsula in the background.

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Cordinup estuary, samphire and dead paperbark trees.

Kalgan River, shell bed on the bank at 5 km from the mouth.

King Creek with granite outcrop on the hillside.

Normans Inlet and King Creek, January 1990 (Land Administration, WA)

Waychinicup River, January 1990 (Land Administration, WA)

Swan Gully, September 1990.

Cheyne Inlet, October 1978. Photo: Durant Hembree.

Cordinup River, May 1989.