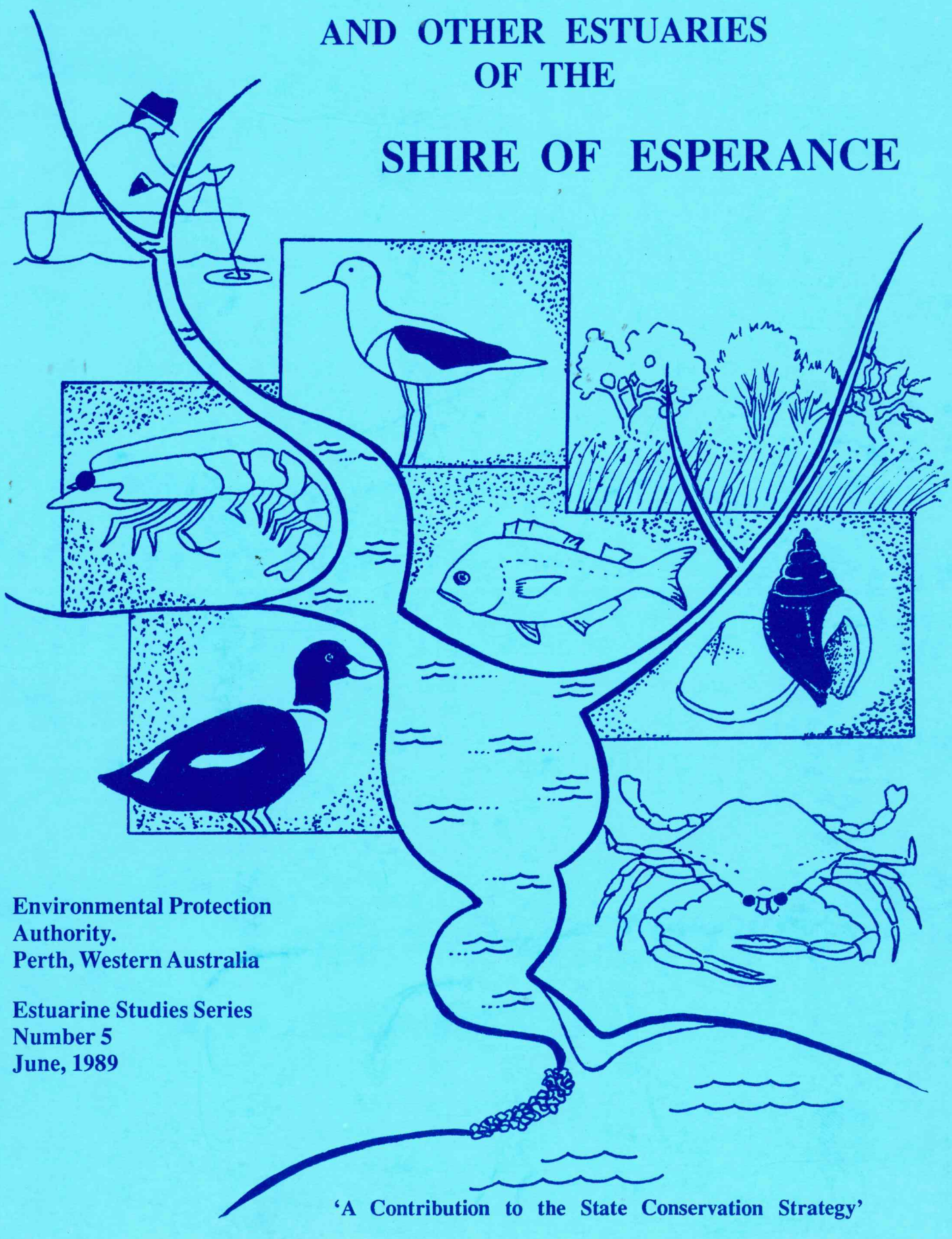
ESTUARIES AND COASTAL LAGOONS OF SOUTH WESTERN AUSTRALIA

STOKES INLET

AND OTHER ESTUARIES OF THE

SHIRE OF ESPERANCE



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'A Contribution to the State Conservation Strategy'

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An Inventory of Information on the

Estuaries and Coastal Lagoons of South Western Australia

ESTUARIES OF THE SHIRE OF ESPERANCE

STOKES INLET, OLDFIELD ESTUARY AND TEN OTHERS

By Ernest P. Hodgkin and Ruth Clark

Stokes Inlet December 1988

Photo: Land Administration

Environmental Protection Authority
Perth, Western Australia

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Estuarine Studies Series No. 5
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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

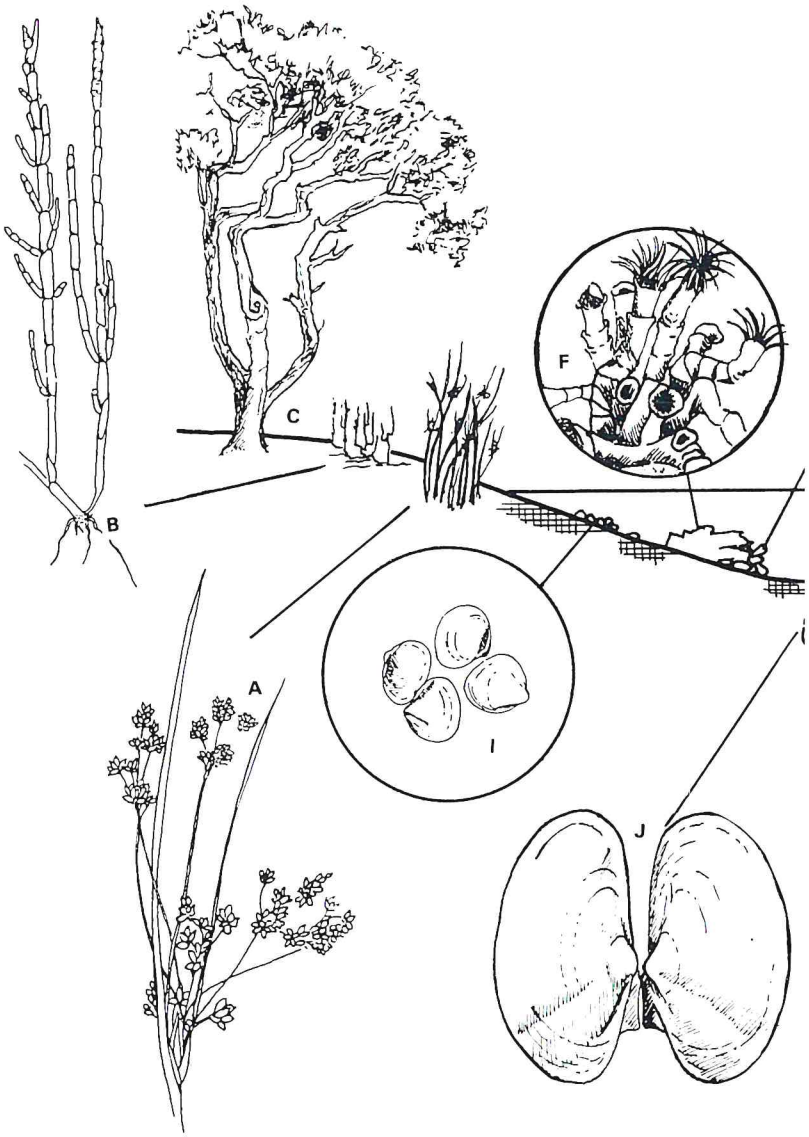
F Tubeworms - *Ficopomatos enigmaticus* 20

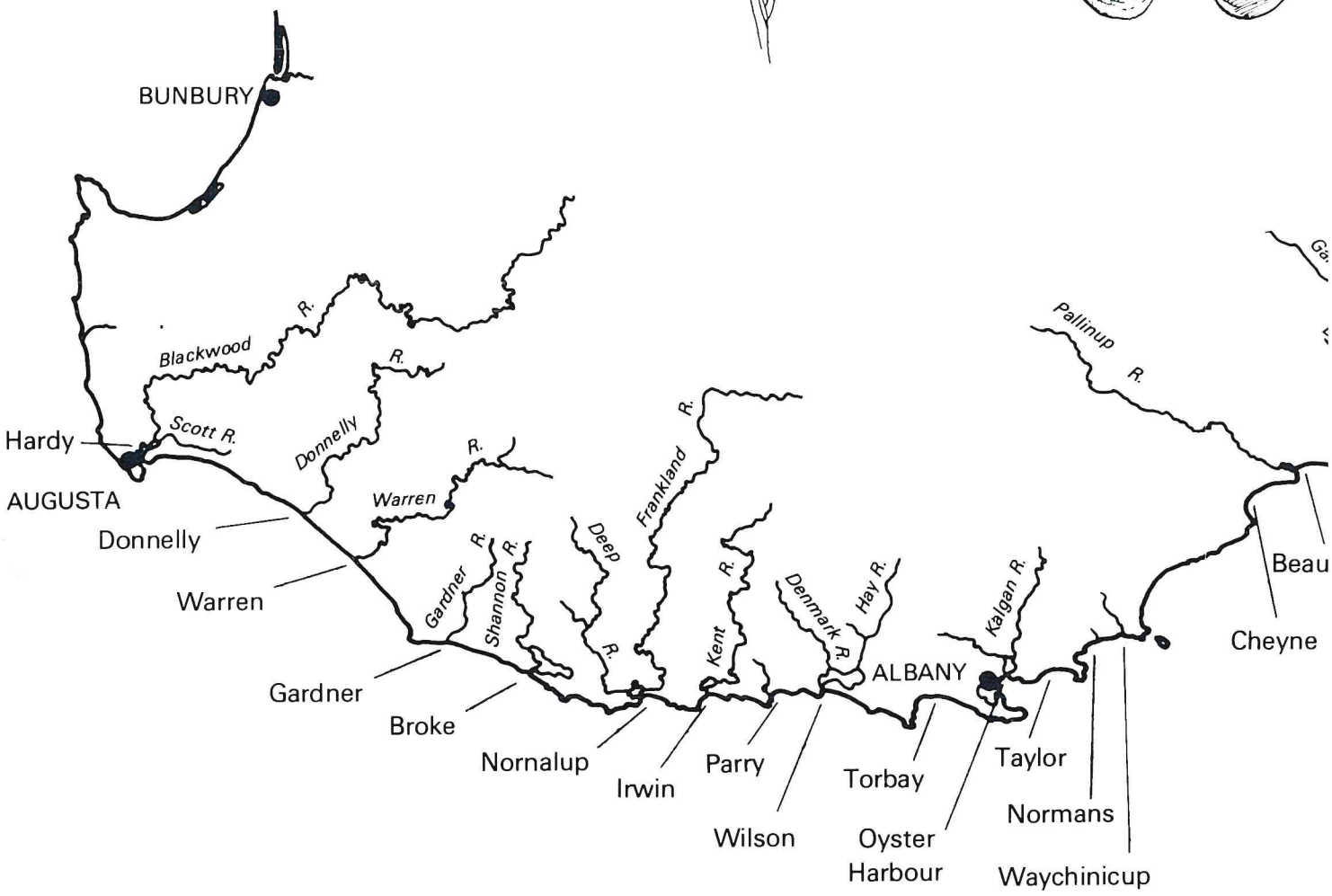
Bivalve molluscs
- G Estuarine mussel - *Xenostrobus securis* 30
- H Edible mussel - *Mytilus edulis* 100
- I *Arthritica semen* 3
- J *Sanguinolaria biradiata* 50
- K Cockle - *Katelysia* 3 spp. 40
- L *Spisula trigonella* 20

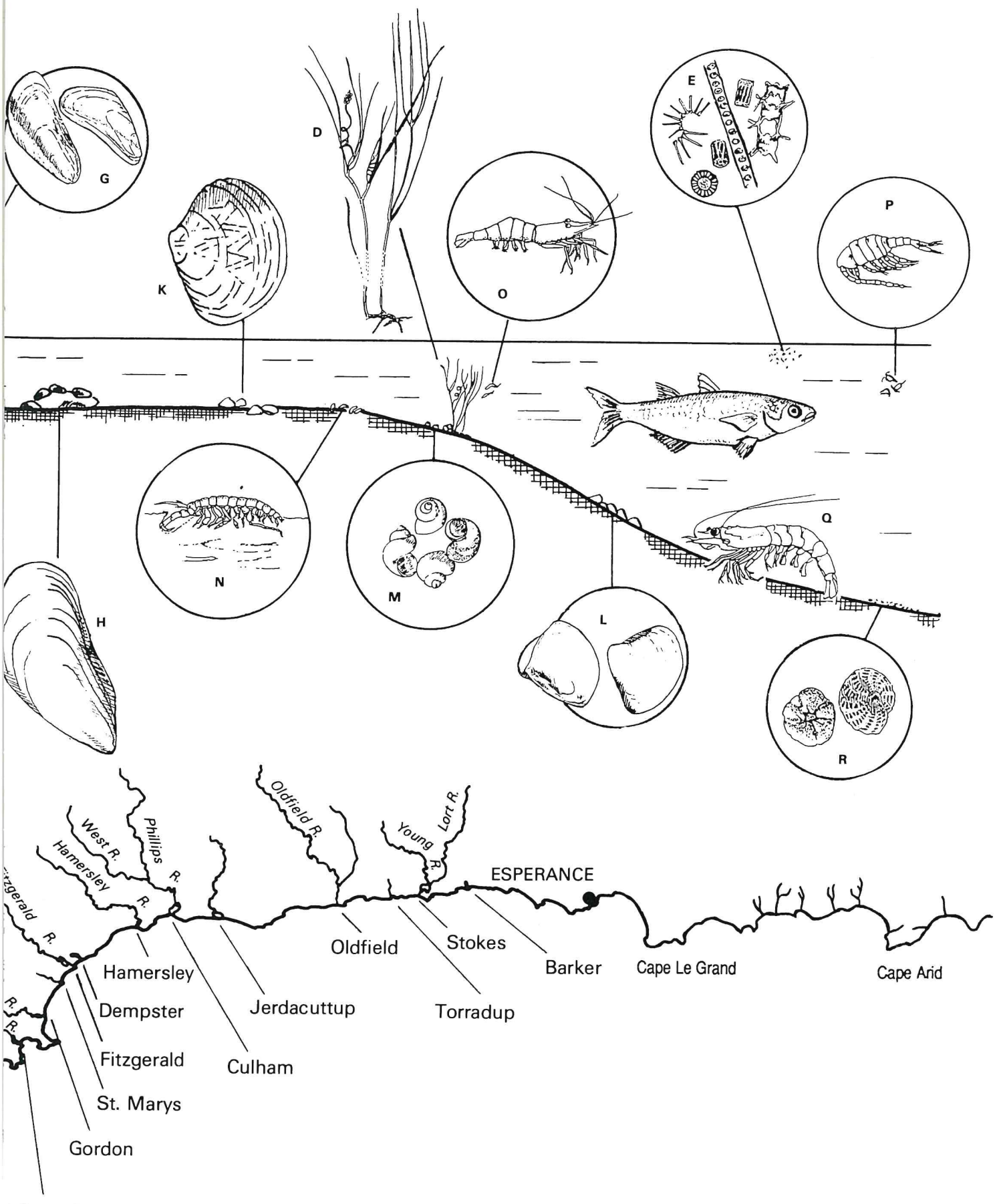
Gastropod molluscs
- M Snail - *Hydrococcus brazieri* 4

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

Hon. R.J. Pearce, M.L.A.
Minister for the Environment

FOREWORD

This series of studies of the estuaries of the south west is part of the State Conservation Strategy initiated by the Government in 1987. As such the studies aim to provide information for organisations concerned with the welfare of the estuaries, especially for local authorities, planners and conservation groups and any Government bodies concerned with management, but also for individuals interested in the estuaries for recreation and for further study of them.

The attraction of estuaries for recreation and for residential and industrial development has placed them under increasing pressure. The varied interests of those who use them often present authorities with difficult conflicts to resolve. I hope that the data provided here and its interpretation will help towards the resolution of such problems.

This fifth study moves east to the estuaries of the Shire of Esperance where Stokes Inlet is a popular resort in the Stokes National Park and where a number of smaller estuaries increasingly attract visits from tourists, campers and fishermen. They are strung out along 250 km of coastline from the Oldfield River to Cape Arid, a coast of great beauty with sandy beaches and rocky headlands, almost all of it now reserved land and much of it in National Parks.

These estuaries are in an area of low rainfall and high evaporation and all except Stokes Inlet are already very shallow. As a result, the water in them is more salt than the sea in summer or may dry up altogether leaving the fish and other fauna die. Although there has been little direct pressure on them, clearing and cultivation in the catchments has already had an impact, as is evident from the accelerated rate at which sediment is settling in Stokes Inlet and shallowing it.

Valuable work is being done by the Land Conservation Districts Committees to prevent soil loss from the catchments by tree planting and other measures and I commend them for the excellent work they are doing. However, much more still needs to be done to reduce the loss and halt the degradation of the estuaries and their tributary rivers.

Clearly an overall approach is needed toward land use in these areas. Sensible catchment and waterway management will only occur when local residents know and care about existing and potential degradation problems. I welcome the interest being shown by local people and local authorities and hope that this report will assist in achieving better planning and management.

CONTENTS

1 INTRODUCTION

Three of the four estuaries considered here lie in the Shire of Esperance: Stokes Inlet, the estuary of the Young and Lort rivers; Barker Inlet; and the estuary of the Torradup River. They are in the Stokes National Park and the adjoining Nature Reserve. The fourth, Oldfield Estuary, is on the western boundary of the Esperance Shire; it is in the Ravensthorpe Shire but is only readily accessible from the Esperance side. It is also locally known as Munglinup Inlet. Also within the Shire of Esperance, there are a number of small estuaries between Cape Le Grand and Cape Arid. As yet there have been no detailed studies of these, but a brief account of them is included here in Chapter 11.

All the estuaries open onto an east - west coastline with small sandy bays and rocky headlands (Figure 1). All are alike in having sand bars that cut them off from the sea for several months to years at a time, greatly restricting exchange with the sea, but they differ greatly in size and in other respects.

Stokes Inlet is the largest, 14 km^2 in area, and it is unique among south coast estuaries (except Oyster Harbour) in having deep water. It has a high sea bar that only breaks for a few weeks at intervals of several years, and in consequence water level and salinity vary greatly with river flow and evaporation. Nevertheless it is a productive estuary and is popular with amateur and professional fishermen. Two rivers, the Young and Lort, flow to the Inlet through riverine reaches which are cut off from the lagoon by a massive river delta when the water level is low in summer. The position of the mouth is unusual, it is in the middle of a small bay without the protection of a nearby western headland. However there are high limestone dunes on either side of the mouth and limestone reefs in the nearshore zone. The catchment is large but rainfall is low, the greater part with less than 400 mm a year.

Oldfield Estuary has a 5 km long, winding riverine stretch that empties into the 3 km long lagoon. The mouth is closed by a high bar on an open sandy beach. The water is 5 m deep when the lagoon is full, but when the bar breaks little water may remain by the end of summer. The estuary is fished by amateurs and professionals. As at Stokes Inlet there is no protecting rocky headland, but again there are nearshore limestone reefs opposite the mouth, which appears to have been further west in the recent past. The Oldfield River and its eastern tributary the Munglinup River have a relatively large catchment, much larger than those of the Torradup River and Barker Inlet.

The **Torradup River** has a narrow, 3.5 km long stretch of shallow, estuarine water which snakes through low dunes to the sea bar. The mouth is about 1 km from a sheltering rocky headland to the west. Salinity is probably never extreme. The catchment is small and a small swampy area surrounds the head of the estuary.

Barker Inlet has a small lagoon (1.8 km^2) which is so shallow that it is often dry in summer, except for a narrow channel near the coast. The mouth opens at the western end of a 7 km long bay against a protecting rocky headland. The catchment is small and has a large swampy area with small salt lakes close to the Inlet.

It is only in very recent times that land in the catchments of the estuaries has been developed for agriculture and in 1950 the road from Esperance to Ravensthorpe was still only a bush track. In 1863 Charles and William Dempster took up a 41 000 acre pastoral lease west of Esperance which included land on either side of Stokes Inlet and in 1873 Alexander and John Moir were granted a lease of 14 000 acres around Stokes Inlet, extended by 57 000 acres in 1888. The Moirs established a homestead near the eastern shore of the Inlet and grazed sheep through the coastal bush, which they burned in patterns to provide fresh feed and so kept it open. They shipped the wool from Fanny Cove together with sandalwood from the surrounding country, and in the 1890s the Cove was a port for miners going to the Dundas and Norseman goldfields. A small area was cleared near the homestead and first barley and then other grain crops were grown as feed for the stock. The limestone walls of the Moir homestead still stand, though roofless, in a small reserve (32601, Preservation of Historical Buildings) within the National Park.

There had been little further development of the Stokes Inlet area when Noel White, a pastoralist from the goldfields, established Young River Station at the head of the Inlet in 1950 with a 70 000 acre pastoral lease. In the 1960s a smaller area south of the road was cleared for sheep and cattle pasture. Most land in the catchments of the four estuaries was only released for farming progressively from the late 1950s to the late 1960s, first near the coast. The upper parts of the Stokes and Oldfield catchments were only released in the 1970s and 1980s. By 1968 2350 km^2 of the Stokes catchment had been cleared for agriculture and 2730 km^2 by 1987.

The four estuaries lie in a region of low rainfall and high evaporation. The average annual rainfall decreases from about 550 mm near the coast to 350 mm inland. This is mainly winter rain, but infrequent unseasonal heavy rains produce 100 mm or more, and floods can be as important to the future of the estuaries as the winter rainfall because of the erosion they cause and the sediment they carry. The present rate of sediment accumulation in Stokes Inlet is excessive, the sediment comes mainly from cleared land in the catchment. Half a metre of soft sediment has collected in the lagoon in the last 30 years (see Section 3.4).

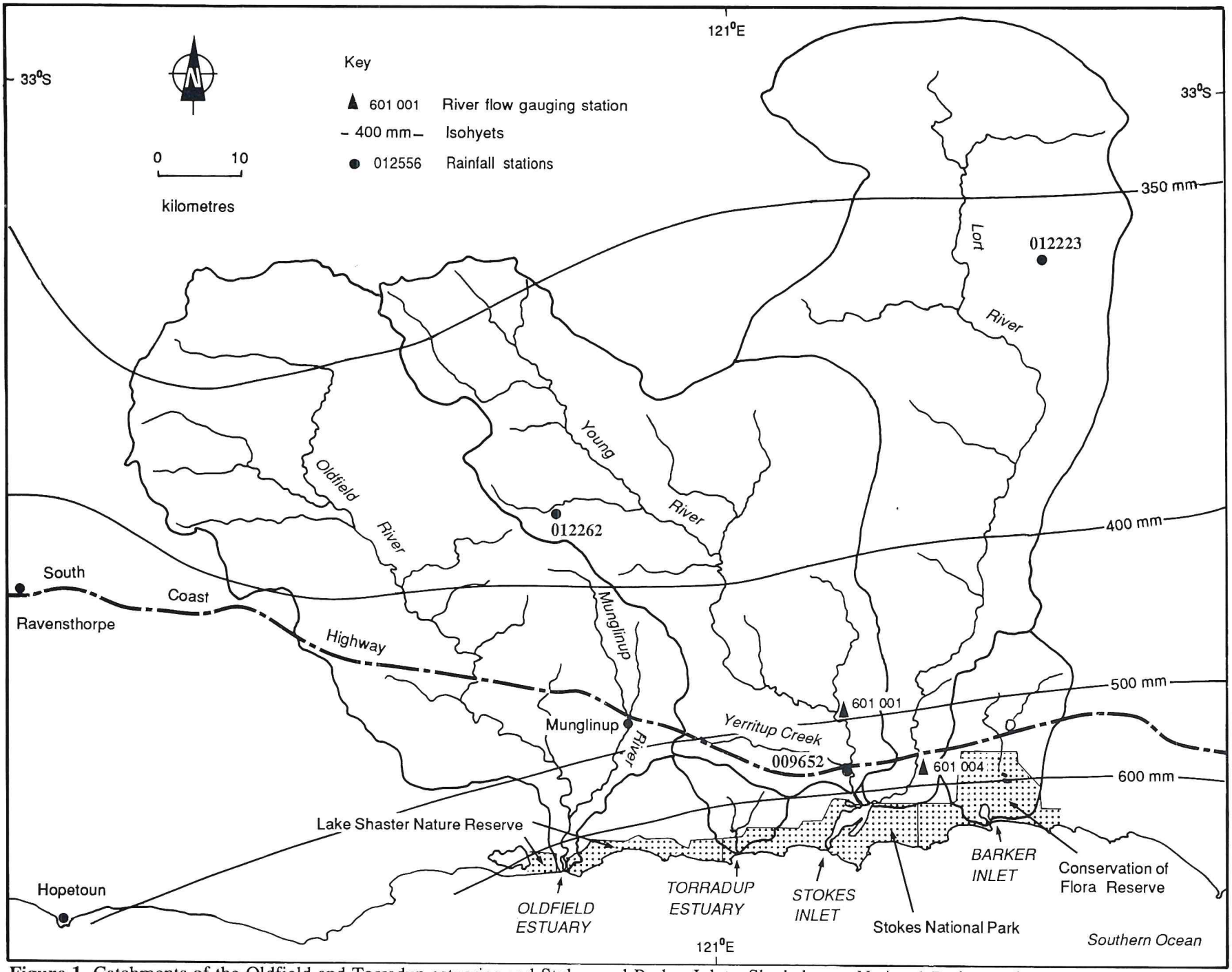


Figure 1 Catchments of the Oldfield and Torradup estuaries and Stokes and Barker Inlets. Shaded area: National Parks and reserves.

The often prolonged closure of the bars, the shallow water and extreme salinities experienced in the estuaries limit their potential as fish habitats. Even in Stokes Inlet the observed salinity ranges from 28 to 86 parts per thousand, from slightly less than sea water salinity (35 ppt) to more than twice. Barker Inlet and Oldfield Estuary are now so shallow that the water becomes brine or dries up altogether in summer. Nevertheless when they hold water, after the bars break, juvenile fish enter and a few species flourish in the rich waters until the salinity becomes too extreme. Black bream are washed down from the Young and Oldfield river pools into the estuaries and are very plentiful at times, particularly in Stokes Inlet.

The four estuaries are surrounded by uncleared bushland; Stokes and Torradup in Stokes National Park, Barker in a Nature Reserve, and Oldfield in a Recreation Reserve. There is a resident Park Ranger at Stokes Inlet and there are two camping grounds on the western shore. The estuary is scenically attractive with its permanent water between high dunes with dense vegetation almost to the water's edge.

1.1 LOCATION AND ACCESS

Access to the four estuaries is from South Coast Highway. Barker Inlet is 67 km, Stokes Inlet 84 km, Torradup estuary 98 km and Oldfield Estuary 124 km west of Esperance. Oldfield Estuary is 70 km east of Hopetoun on Springdale Road. Grid references are to maps 3130 Stokes Inlet and 3030 Oldfield on the 1:100 000 topographic map series published by Natmap.

Stokes Inlet is located between 121°08' and 121°11' East and 33°48' and 33°52' South. The mouth is at grid reference 273524. Stokes Inlet Road is a 6 km long gravel road that leaves South Coast Highway 2 km west of the Young River crossing. It leads to camping areas on the western shore of the Inlet. Access to the eastern shore is by boat or by a sand track off Farrells Road, leading to the old Moir homestead and Fanny Cove. Access to the northern shore and riverine reaches of the Young River is by a sand track from Stokes Inlet Road at the entrance to the Park.

Oldfield Estuary lies at 120° 47' East and between 33° 51' and 33° 53' South. The mouth is at grid reference 954481. Access to the estuary is by bush tracks from Munglinup Beach Road, which leaves Springdale Road close to where it crosses the Oldfield River. It is proposed to upgrade some of these tracks, close others and provide facilities near the estuary. There is a camping and caravan area at Munglinup Beach with toilets and cold showers. The estuary is in a small Recreation Reserve (32337 and 32338) and the Lake Shaster Nature Reserve extends along the coast on either side of this. The riverine reaches of the estuary are in a narrow Park reserve with farm land on either side.

The **Torradup River** estuary is located at 121°01' East and between 33°50' and 33°52' South. The mouth is at grid reference 162514. Access to the estuary is from South Coast Highway along Springdale Road (Torradup Road), thence south along a bush track following a fence line and then through the dunes to near the mouth on the eastern shore. The estuary is within Stokes National Park.

Barker Inlet is located between 121°20' and 121°21' East and 33°48' and 33°49' South. The mouth is at grid reference 472566. Access is from South Coast Highway south along Farrells Road and thence along a bush track to the western shore and the mouth. The Inlet is surrounded by Reserves 27888 and 26885 (Conservation of Flora).

1.2 GEOLOGICAL HISTORY OF THE ESTUARIES

The estuaries are of very recent origin geologically. During the last major glaciation of the Pleistocene period (the last 2 million years), and only 20,000 years ago, sea level was more than 100 m lower than it is now. For some kilometres beyond the present coastline there was dry land, across which the rivers flowed to the sea through river valleys, the location of which is indicated by submarine canyons along the edge of the continental shelf (Von der Borch, 1968). With the melting of the ice caps the sea rose to its present level about 6000 years ago flooding the estuaries, and for some time after sea level may have been about 2 m higher than it is now.

The coastal dunes formed during previous interglacial periods, when sea level was about the same as at present, and subsequently hardened to rock (Coastal Limestone). The ocean beaches formed during and following the rise in sea level from sand eroded from the seabed. Finer sand was blown up into dunes, or added to the Pleistocene dunes, and was stabilised by vegetation. Wave action moved sand onshore - offshore and alongshore, gradually narrowing the entrances to the estuaries. Wind and waves built the sea bars and formed major barriers to water flow. For a time the channels continued to be open to the sea, but the mouths closed progressively, reducing exchange with the sea, and neither the seasonal river floods nor the small tides of the south coast could prevent the bars closing, probably at first seasonally and then in many cases for prolonged periods. The extensive deposits of sub-fossil marine shells in Stokes Inlet indicate that the bar probably closed the estuary off from the sea about 4000 years ago (see Section 3.4).

A considerable depth of river sediment has accumulated in the estuaries in the last 6000 years and sand has spilled into them from encroaching dunes. Tidal currents and waves have carried sand into the mouths of the estuaries to form flood tide and washover deltas. These sediments, and organic material produced in the estuaries, have been redistributed to make the shallow, relatively flat

bottoms of most south coast estuaries (but not yet Stokes Inlet). The marginal shoals and adjacent beach ridges have been formed by erosion and redistribution of sand from the shores and stabilised by salt tolerant plants. The area of open water has shrunk and the entrance channels of many estuaries have been obstructed.

These natural processes of erosion and sedimentation continue at the present time; the estuarine environments are not static, the estuaries are filling from both ends and changing in form. Clearing in the catchments has increased the river sediment and accelerated the shallowing process (Section 3.4).

Stokes Inlet is in a deep valley between the high Pleistocene limestone dunes, through which the rivers maintained a channel. It is located along a probable fault structure, which may explain the deep incision of the river valley. At first the mouth was wide open to the sea, the estuary was deep throughout and the swamps and Lake Cobinup would have been part of the estuary. It was tidal and the salinity of the water was little different from that of the sea until about 4000 years ago. It was a highly productive, sheltered marine embayment similar to Princess Royal Harbour (Albany) today, as shown by the abundant and diverse mollusc shells.

During the last 6000 years much river sediment has collected in the estuary and has formed the wide river deltas, the swamps and Lake Cobinup, and has shallowed the upper part of the estuary. The lower part of the estuary is still relatively deep, except close to the bar where waves have washed beach sand in over the bar and sand has blown in from the beach and dunes. The shore rock of the lower estuary appears to have been formed by lime cementation of beach and dune sand in the last 6000 years. The mouth of the estuary is now only 200 m wide; it has narrowed from both east and west, from the east by a tongue of dune that has probably only recently been stabilised by vegetation, and is subject to erosion, and from the west by a still mobile dune. The presence of two lines of nearshore reefs parallel to the ocean beach suggests that the beach and bar were initially further seawards.

Oldfield Estuary is in many ways a smaller edition of Stokes Inlet, being the estuary of a relatively large river system. However in the absence of shell deposits and high Pleistocene dunes its history is more difficult to interpret. It is unlikely ever to have had any great depth, but was clearly of greater extent when first flooded; river sediment has filled a considerable area on either side of the present winding riverine channel. The narrow lagoon has been filled from both ends with river sediment and beach sand. The mouth is 200 m wide and until recently may have been much wider. It is bordered on both sides by low dunes which have probably only recently been stabilised by vegetation. As at Stokes Inlet, there is a nearshore reef across the mouth of the estuary suggesting that the shoreline has retreated relatively recently.

Torradup estuary appears to be little more than a stream channel that persists through the encroaching swamps and coastal dunes. A small lagoon in the upper part has shrunk with the growth of a series of beach ridges.

Barker Inlet is the remnant of a considerably larger lagoon that was trapped behind the rocky headland and stable dunes when it was first flooded 6000 years ago. The multiple beach ridges all round the Inlet and the two small lakes to the west indicate its former extent, and some of the swampy area to the north may also have been part of it. It is unlikely ever to have been deep, and when first flooded was probably a shallow bay which has been progressively filled with sediment from the land and the sea.

2 CATCHMENT CHARACTERISTICS

Stokes Inlet and Oldfield Estuary both have large catchments which extend 100 km inland from the coast to the southern edge of the plateau, into an area of internal drainage and salt lakes where the northern watersheds are poorly defined, especially that of the Lort River (Figure 1). Torradup estuary and Barker Inlet catchments are much smaller and lie within 15 km of the coast. There was little clearing in any of the catchments until the 1950s, but since then extensive areas of all have been cleared (Table 2).

All along the coast, from Esperance to Hopetoun there are considerable areas of internal drainage to salt lakes behind the coastal dunes, such as Lake Shaster west of Oldfield Estuary. Barker Inlet would probably also be a salt lake but for the position of the mouth close to a western headland which protects it and allows the water to flow to the sea.

The greater part of the Stokes Inlet catchment is in the Shire of Esperance, but the catchment of the Lort River extends into the Shire of Dundas and that of the Young River into the Ravensthorpe Shire. The greater part of the Oldfield catchment is in the Raventhorpe Shire, the eastern boundary of which follows the Munglinup River and Oldfield River to the coast.

2.1 LANDFORMS, GEOLOGY AND SOILS

The Stokes and Oldfield catchments rise gradually from behind the coastal dunes to 250 m to 300 m at their northern watersheds on the southern edge of the plateau, north of which there is a large area of internal drainage to salt lakes. The topography is principally one of low rounded hills and shallow valleys in the northern part and deeper valleys in the southern part. At the coast the chain of rocky headlands is linked by dunes.

The greater part of the catchments lies within the Albany-Fraser geological Province, off the south eastern edge of the ancient Yilgarn Block. The basement rocks are Proterozoic granitic rocks

Table 2 Catchments of Stokes, Oldfield, Torradup and Barker estuaries. Total and cleared areas. Estimated annual average discharge and runoff to the estuaries.

	Stokes			Oldfield	Torradup	Barker
	Young	Lort	Total			
Area of catchment (km^2)	2073	2502	4575	2479	87	259
Area cleared to January 1987 (km^2)	1220	1510	2730	860	62	207
Percentage cleared	59%	60%		35%	71%	80%
Annual average discharge to estuary ($X10^6m^3$)			5	2.3	0.4	1.3
Runoff (mm)			0.9	0.9	5	5

(migmatites, more than 1200 million years old), but near the coast these are covered by the Eocene Pallinup Siltstone (40 million years old). This 'spongolite' rock consists of flat bedded marine sediments with many sponge spicules; it is relatively soft and is sometimes cut into blocks for building house walls. Over most of the catchment these older rocks are overlain by Pleistocene (the last 2 million years) deposits; sandplain on the higher land and colluvial and alluvial deposits (the results of erosion) in the valleys. In places the hard Proterozoic rock is exposed along the river channels and again in the rocky headlands of the coast. The spongolite surfaces within 25 km of the coast, with scarps and steep slopes in the valleys. At the coast the higher dunes have a core of Pleistocene dune limestone that is generally covered by more recent Holocene (the last 10, 000 years) dune sand which may be bound by vegetation or be mobile in blowouts. A belt of dune sand extends up to 5 km inland from the coastal dunes. The geology of the catchments is described and figured by Thom et al. (1977).

Shallow loamy soils overlie yellow clayey subsoils in the upper part of the catchment and there is clay to the surface in the northern part of the Lort River catchment. The soils are saline. In the southern part the soils are sandy with gravel in the west and in the east duplex soils with sand overlying clay subsoil. Along the coast there are poorly developed sandy soils.

Stokes Inlet. The river channels of the Young and Lort rivers are incised into the sandplain exposing the hard granitic rock at intervals along their length. Spongolite rock outcrops in the valleys within 20 km of the coast. Elsewhere colluvial and alluvial deposits fill the valley bottoms. South of the Highway the sandplain gives way to the belt of dune sands about 5 km wide. These are low lying where they border the upper part of the estuary, and there are patches of granitic rock. Closer to the coast and bordering the lower estuary the dunes rise 60 to 80 m and are cut into steep gullies on both sides of the estuary. Under the surface sand the dunes are cemented to various degrees to limestone, and hard travertine layers are exposed on the coast west of the mouth.

Oldfield Estuary. The upper part of the Oldfield River catchment drains an area of Archean granites. Nearer the coast the Oldfield River and its tributary the Munglinup River have cut shallow valleys through the sandplain, with colluvial deposits in the valley bottoms. South of South Coast Highway the valleys have steeper sides, with breakaways where they cut through spongolite rock. Granite is also exposed in the valleys and outcrops in the belt of low lying coastal sand south of Springdale Road. This is less than 20 m above sea level except on the tops of the coastal dunes.

Torradup River estuary. The catchment of the small Torradup River lies south of South Coast Highway in undulating land with sandy, colluvial deposits and granitic outcrops in the valley, rising to sandplain 100 m above sea level. A large farm dam holds water in the valley north of Springdale Road. The estuary is bordered by a 3 km wide dune belt.

Barker Inlet. Almost all of the Barker Inlet catchment also lies within the 100 m contour. Most is sandplain except south of the Highway where the stream has cut a valley in the spongolite to the swampy alluvial area within the Nature Reserve.

2.2 RIVERS

The Young and the Lort rivers enter Stokes Inlet from the north. The Young is about 120 km long from the north west and the Lort rises in salt lake country 100 km north of the estuary. Yerritup Creek enters the Young River from the west just north of the Highway and another tributary enters from the north about 8km

north of the Highway, between the two rivers. There are several pools up to 1km long in the Young River. Both rivers are saline and there are salt lakes in the upper part of the Lort catchment. There are no dams on the rivers.

The Oldfield River flows from the north west with its headwaters among eroded granite hills north of the Ravensthorpe Range. It is about 95 km long. There are a number of permanent pools up to 500 m long in the river south of the Highway: they are reported to be fed from springs from the spongolite. The Munglinup River joins the Oldfield River 8 km from the coast, it flows from sandplain north of the Highway and passes through the town of Munglinup.

The small rivers that flow to Torradup and Barker estuaries drain coastal catchments that are now largely cleared for grazing. Coomalbidgup Creek flows to Barker Inlet through a large swamp where there is no discrete flow channel.

RUNOFF AND RIVER FLOW The only available data are from WA Water Authority gauging stations 601001 on the Young River and 601004 on the Lort River for 12 and 10 years respectively. It is clear from these that runoff from the catchments is small, an average of 0.9 mm or less than 1% of rainfall. Runoff is probably similar to Oldfield Estuary, but considerably higher to Torradup estuary and Barker Inlet because their small catchments are close to the coast, with heavier and more reliable rain.

The estimated average annual discharge to Stokes Inlet is 5 x 10^6 m^3, with a range from 0 to 16 x 10^6 m^3. Extrapolating from the Stokes Inlet data, the estimated average annual flow to Oldfield Estuary is 2.3 x 10^6 m^3. However river flow is erratic; there was no flow in the Young River and negligible flow in the Lort River in 1981 and 1982, and the runoff therefore nil, but in 1975, 9 x 10^6 m^3 flowed down the Lort of which nearly 80% was in November. A storm in March 1976 produced over 2 x 10^6 m^3 which was two thirds of the year's flow in both rivers. Apart from these storm flows the main river flow is from July to October. Yearly and monthly averages clearly do not give a true picture of the flow characteristics of the rivers, or of the effect river flow has on the estuaries.

SEDIMENT TRANSPORT This probably largely results from major floods. At such times fine sediment is washed by sheet erosion from cleared land, coarser material is eroded by gullying and from river beds and trees may be torn up and dropped in the estuaries. Evidence of increased sediment transport following clearing is recorded below (Section 3.4).

WATER CHEMISTRY Both the Young and the Lort rivers are saline at about 6 ppt and 16 ppt* respectively (WA Water Resources Branch, PWD, 1984), but with a great range in salinity. The figures in Table 2.2 indicate the great range of salinity observed in the river water. They are fresher following heavy rain in the catchments, but can be much more saline even while the water is still flowing freely. Oldfield River water is also saline, about 5 ppt in the few samples taken, and river pools have shown salinities of up to 15 ppt. The Torradup River is slightly saline. Barker is probably also saline, but there are no data.

NUTRIENTS The limited available data are recorded below in Sections 3.5 and 4.5.

2.3 COASTAL FEATURES

The coastline from Esperance to the East Mount Barren massif just west of Hopetoun has a series of shallow bays that face south between rocky headlands (Figure 1). The headlands are of hard granitic rocks and the sandy shores of the bays are backed by dunes of predominantly calcareous sand, which in many places are hardened to the relatively soft coastal limestone. The dunes have trapped a series of saline, coastal lakes that have no connection with the sea: the Esperance lakes, Lake Gore, Lake Shaster, the Jerdacuttup Lakes and a number of smaller lakes and swamps.

In many places the calcareous beach sand has been hardened into rock in the shores, forming onshore and nearshore reefs of a hard limestone rock that protects the shores from erosion and appears also to protect the mouths of the estuaries which, unlike most further west, lack the protection of nearby

* parts per thousand, sea water is 35 ppt.

Table 2.2 Young and Lort rivers, records of salinity (ppt) at South Coast Highway. (WA Fisheries Department)

Date	Young	Lort	Date	Young	Lort
7/8/71	4	27	4/10/78	10	27
8/12/71	3	20	13/10/78	6	20
1/9/74	8	38	20/10/78	5	20
18/2/75	18	33	26/7/79	1	3
2/5/77	15	26	22/7/83	12	10
28/8/78	23	26	20/6/84	11	25
31/8/78	-	15	3/10/88	11	41

headlands. Of the four discussed here Barker Inlet alone has such protection.

The mouth of Stokes Inlet is in the middle of the shallow south-facing Dunster Castle Bay, with projecting rocky headlands 4 to 5 km away on either side. The shoreline of the bay and the mouth of the estuary are protected by two lines of limestone reef that break the force of waves and swell on this otherwise exposed coast. There is also limestone in the beach at the mouth. The mouth of Oldfield Estuary opens onto Munglinup Beach 2 km west of a rocky headland. It is protected by an offshore limestone reef, with breaks in it. Torradup estuary opens into the middle of the bay east of Margaret Cove and gains limited shelter from the western headland. Barker Inlet faces south east at the western end of a bay, against a rocky headland where the mouth is sheltered from the prevailing south westerly winds and swells. Limestone beach rock is exposed intermittently along the bay shore.

The dune patterns reflect the prevailing south westerly to westerly winds. At Stokes Inlet there are blowouts in the dunes on both sides of the mouth. A travertine cap overlies exposed soft rock and sand for some distance west of the mouth. There are active blowouts in the dunes at Oldfield Estuary. At Torradup estuary there is a large blowout on the eastern side of the mouth. At Barker Inlet there is a small blowout west of the headland, but none to the east.

TIDES These are mainly of the daily type and small range typical of the south west, with a maximum daily range of 0.75 m. Seasonal and meteorological factors may result in an overall range of 1.75 m and storm events may cause an extreme range of about 2 m (Esperance). The estuaries are only tidal when the bars are open and the tides are greatly attenuated by the narrow, shallow entrances.

2.4 RAINFALL

Rainfall is highest near the coast, with an annual average of 541 mm at Young River Station, and decreases to about 350 mm in the upper Oldfield and Lort River catchments (Figure 2.4). This is mainly winter-spring rain, but it should be noted that the records are for less than 20 years, except for the Young River station (32 years), and that occasional summer storms with over 100 mm distort the monthly means. Such storms include 145 mm in February 1955, 103 mm in January 1966 and 105 mm in February 1970 at Young River rainfall station; and further inland, 117 mm at Lort River rainfall station in February 1976 and 128 mm in February 1970 in the Oldfield catchment. Annual rainfall extremes are listed in Table 2.4.

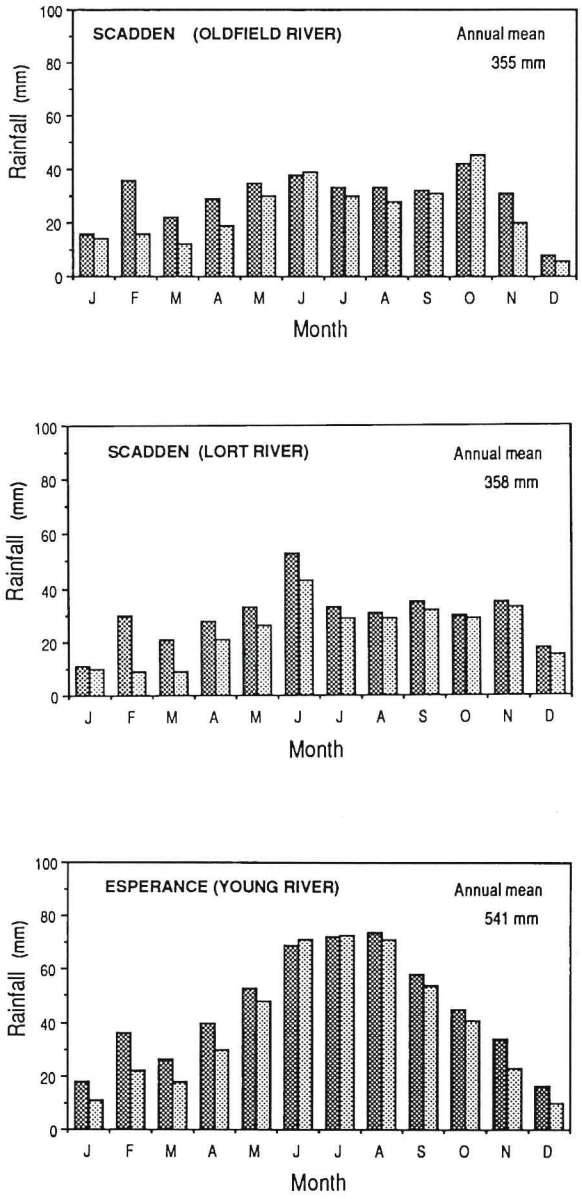


Figure 2.4 Monthly rainfall (mm) in the upper Oldfield and Lort river catchments and at Young River Station (Figure 1). Means ▩ , medians ▨ . (Commonwealth Bureau of Meteorology)

2.5 LAND OWNERSHIP AND USE

Stokes Inlet. By 1987 60% of the catchment had been cleared for agriculture, mainly for cereal production and sheep grazing, with some beef production near the coast (Table 2). The area immediately south of the Highway is cleared for cattle grazing and grazing land comes close to the water's edge along the riverine reaches of the estuary.

The Inlet and Lake Cobinup are surrounded by Stokes National Park which is 3 to 5 km wide along the coast and has an area of 10 667 ha. This is all virgin coastal bush with high dunes which are densely vegetated. The Park is maintained by a

Table 2.4 **Highest and lowest, monthly and annual rainfalls at three rainfall stations: Esperance (Young River), 009652, Scadden (Oldfield River), 012262, and Scadden (Lort River), 012223, rainfall stations. (Commonwealth Bureau of Meteorology)**

	TORRADUP ESTUARY YOUNG RIVER 1954-1986	OLDFIELD ESTUARY YOUNG RIVER 1969-1984	LORT RIVER 1969-1984
Average annual	541 mm	355 mm	360 mm
Highest annual	735 mm (1971)	460 mm (1975)	461 mm (1975)
Lowest annual	397 mm (1963)	233 mm (1972)	243 mm (1972)
Highest monthly	163 mm My (1971)	128 mm Fb (1970)	216 mm Jn (1980)
Highest two monthly	243 mm Ap/My (1971)	144 mm Oct/Nv (1971)	244 mm Jn/Jly (1980)

resident Ranger. There are camping areas near the western shore of the Inlet with barbecues, bench tables and borehole toilets. Many bush tracks in the Park were badly eroded by the heavy 1986 rains and have been closed. The Young and Lort rivers are both in narrow reserves (Parks and Protection of River and Foreshore).

Oldfield Estuary. The upper half of the Oldfield River catchment is in the eroded bush country of mining reserves subject to severe fires with consequent rapid rainfall runoff. The Cheadanup Nature Reserve (65 km^2) is adjacent to this and the small Munglinup Nature Reserve covers the head of a tributary. There are reserves 500 m to 4 km wide bordering both the Oldfield and Munglinup rivers along most of their length, although these are subject to grazing at times. The Lake Shaster Nature Reserve extends along the coast on either side of the Recreation reserves that border the estuary itself. Much of the lower half of the catchment has been cleared for agriculture, but only 35% of the total catchment has been cleared.

Torradup estuary. The greater part (71%) of the Torradup River catchment is cleared, though the estuary itself is in the Stokes National Park.

Barker Inlet. The catchment of the Inlet is also largely cleared (80%) except where the river flows into the swampy area in the Nature Reserve.

2.6 VEGETATION

A mosaic of dense scrubland and sand heath dominates the coastal dune system and coastal plain of the four estuaries. The dense scrub to 3 m high is characterised by the upper canopy of *Eucalyptus angulosa*, *E. falcata* and *Acacia cyclops* with an understorey of *Spyridium globulosum* and *Leucopogon obovatus*. The shallow limestone ridges are characterised by *Eucalyptus preissiana*. The sand heath on the coastal plain is dominated by *Banksia speciosa* and *Lambertia inermis* and a diverse mix of large proteaceous species. The sand heath, up to 1 m high, east of the Torradup estuary is characterised by *Adenanthos cuneatus*, *Melaleuca striata* and *Hakea corymbosa*.

The valleys in the lower Oldfield River catchment are very similar to the lower Lort and Young rivers and are mallee of *Eucalyptus floctoniae*, *E. leptocalyx*, *E. uncinata* over a *Melaleuca* dominated understorey characterised by *Calothamnus quadrifidus* , *Melaleuca uncinata* and *Melaleuca* sp. (unnamed).

Most of the northern Oldfield catchment is uncleared with mainly shallow coarse sands over granite with *Melaleuca uncinata* and *Eucalyptus tetragona*. On the domed clay is mallee, *E. eremophila*. Large patches of broombush thickets are scattered over the catchment consisting of *Casuarina campestris*, *Calothamnus* and *Melaleuca*. There are a few stands of *E. platypus* (Moort).

The Torradup River catchment is almost all cleared north of the Stokes National Park except in the river valleys. The eastern tributary is a mallee-heath with *E. tetragona*.

Generally the Lort and Young river catchments are similar. South of Rollond Road large scale clearing has occurred except in the valleys and small tributary catchments. Inland 25 km from the Inlet the valleys are entirely mallees characterised by *Eucalyptus* sp. affin. *redunca* and *E. uncinata*. The valley north of here to Rollond Road is mallee on domed clay soil, with *E. eremophila* dominant. The spongolite along the Yerritup Creek and slightly north is characterised by *Calothamnus quadrifidus*, *E. floctoniae*, *E. falcata* and *Melaleuca uncinata* and north of Mills Road on a tributary of Young River there are 'gilgai'plains, mostly mallee of *E. eremophila - E. forrestiana* with occasional patches of *E. platypus* (Moort).

North of Rollond Road the catchments of the Young and the Lort rivers are virtually uncleared. It is a mosaic inland sandplain, characterised by *Banksia media* and *Melaleuca striata*, and *Eucalyptus floctoniae*/*E. eremophila* dominated mallee over *Melaleuca* such as *Melaleuca eleuterostrachya*. The domed clay soils of Young River carried *E. eremophila* with patches of mallee-heath *E. tetragona*.

The catchment of Barker Inlet is almost entirely cleared north of the Nature Reserve. A mallee-heath is present along the south valley of Coomalbidgup Creek. Surrounding Lake Coomalbidgup there is a pure stand of *E. occidentalis* (Yate).

3 STOKES INLET - PHYSICAL FEATURES

Stokes Inlet is one of the most attractive and interesting estuaries of the south coast; it has a large area of water set in a deep valley through high dunes with dense bush and shady paperbark trees to the beaches. The estuary has deep permanent water, unlike most others east of Bremer Bay. It is elongate, perpendicular to the coast and the Young and Lort rivers flow in at its northern end. Both rivers have estuarine reaches several kilometres long, the Young carved into a steep-sided valley in hard rock, clear evidence of the great age of the river system, and the Lort in flat land along the southern edge of the high ground (Figure 3.11). A sketch map of the estuary drawn by Surveyor General J.S. Roe in December 1848 is reproduced in Figure 3.12. Figure 3.13 (page 16) shows the main landform features of the estuary and the adjacent coastline.

The sea bar is closed most of the time, only opening briefly at intervals of years. In consequence the salinity of the water varies considerably making it an unfavourable environment for all except a few estuarine species of animals and plants, and one to which marine recruits only have infrequent access. The bar is high and water level in the estuary varies about 3 m with river flow and evaporation. The shallow northern part of the Inlet with the wide river deltas often dries in summer separating the river water from that in the lagoon. The wide salt flats to the north east are dry much of the time. Lake Cobinup, north of the estuary, floods in winter and overflows into the Inlet, but holds little or no water in summer.

Stokes Inlet is located along a probable fault structure, as evidenced by clay deposits (deeply weathered basement) transected by ferruginous veinlets. This may explain the deep incision of the river valley.

3.1 LANDFORMS

RIVERS The Young River has a rocky estuarine reach for about 6 km, with samphire swamps along the wide lower part. It discharges onto the wide deltaic flats which isolate it from the lagoon when water level is low in summer. The river is reported to have shallowed greatly following clearing in the catchment, but major floods will no doubt scour much sediment from the river bed. The Lort River is also estuarine for about 3 km through alluvial sand flats with dense tree cover and salt marshes. It discharges onto the north eastern salt flats. Both rivers hold permanent water even when cut off from the lagoon basin.

SALT FLATS The wide salt flats on the northern and eastern shores of the Inlet are flooded following heavy rain but may be dry for extended periods and paperbark seedlings establish themselves. The southern part is separated from the lagoon by a high, well vegetated sand ridge.

INLET This is elongate in a NE-SW direction, approximately 10 km long and 2 km wide in the northern part, and an area of about 14 km^2 when full. The northern part is very shallow and scattered outcrops of granitic rocks are exposed near the western shore when water level is low, but are submerged when the estuary is flooded. The Inlet deepens progressively towards the mouth. The beaches are a shelly sand with extensive deposits of cockle shells and in the southern part limestone outcrops along the shore. Much of the shoreline is bordered by paperbark thickets and dense scrub.

INLET CHANNEL and MOUTH The Inlet narrows to a channel 2 km long and 500 m wide that winds between the steep, well vegetated dunes, where much of the shoreline is beach limestone, with embedded shells. Then on the eastern shore a valley and wide bay have a sandy shore while on the west a steep active dune face is cascading sand into the estuary. The water deepens to over 5 m opposite this dune then shallows again to the bar, where a washover delta extends 300 m into the estuary along the eastern shore. Deeper water generally persists along the eastern shore.

3.2 THE BAR

The mouth of the estuary is closed by a sand bar about 200 m long and 1.5 to 2 m above sea level. At the eastern end a well vegetated dune 7-10 m high extends onto the bar and at times extends westwards, only to be carried away with a major flood. The western shore of the bar is bare hummocky sand with scattered stabilising dune plants and wattle shrubs on the higher ground. The bar is built of pale grey, poorly sorted, medium to fine grained sand, mainly quartz with 25% calcareous shell material (Figure 3.21).

The bar may break across its full width, cutting a channel along the eastern shore and eroding the dune on its Inlet face, but as flow decreases the channel swings across to the western shore. There is reported to be reef rock under the bar which prevents the channel scouring to any depth when the bar breaks. Offshore, two lines of limestone reefs protect the shoreline and bar from waves and swell, but waves wash over the bar carrying sand into the Inlet and sea water seeps through the bar into the estuary when water level is below that of the sea.

The bar breaks infrequently and only remains open briefly, from a couple of weeks to 6 weeks (Figure 3.22). It is reported to have opened in 1919, 1927 (or 1932) and then not until 1967. The thirty year gap (and the 3 months it was open in 1927) was before the extensive clearing in the catchment and since then the bar has broken more frequently, although still with one period when it remained closed for nearly seven years. The general pattern appears to be of spring breaks following wet winters and late heavy rains in October-November. The occasional heavy cyclonic rains of January-February

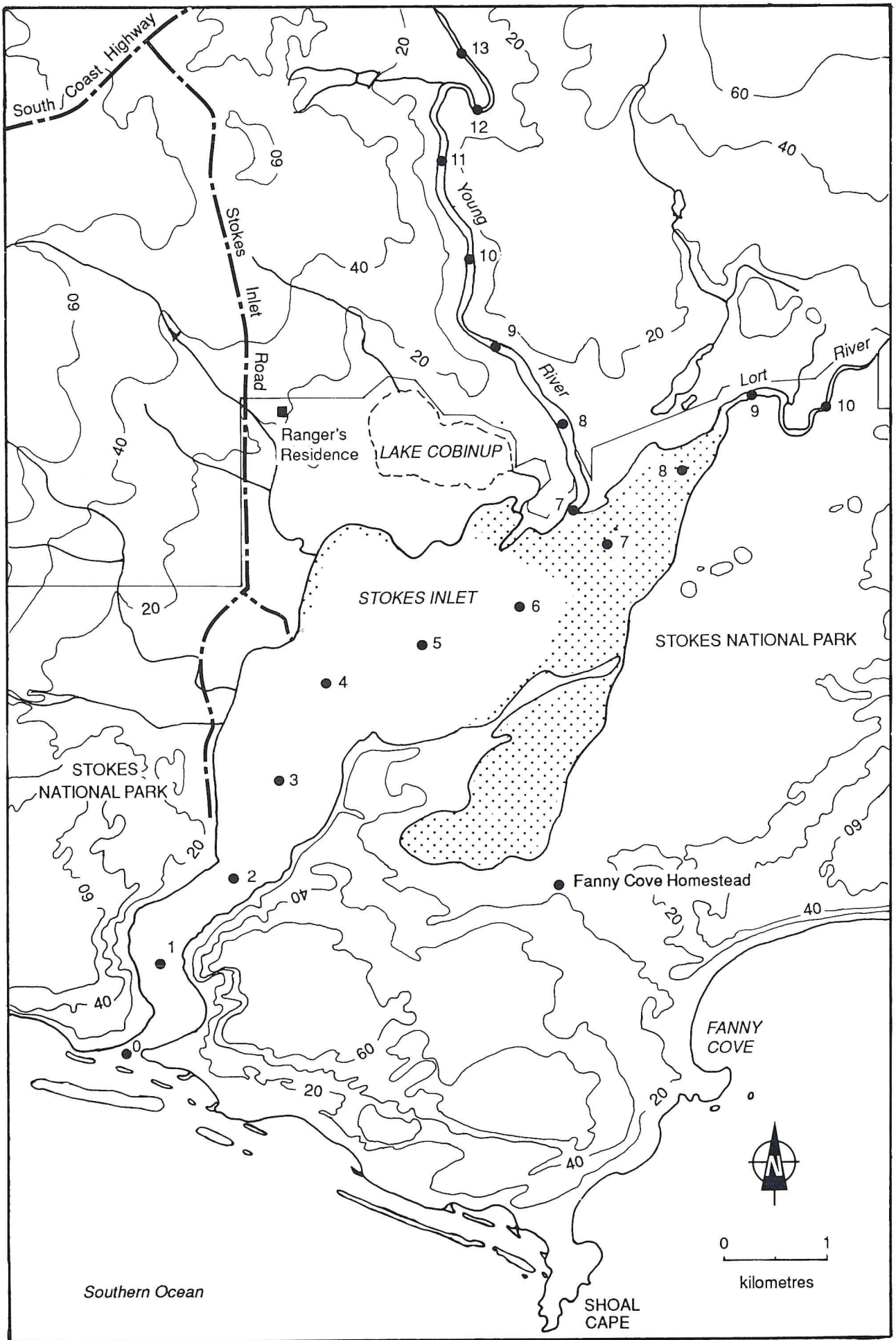


Figure 3.11 Stokes Inlet. Topography of the surrounding area. Contours in metres. Distance in kilometres from the mouth.

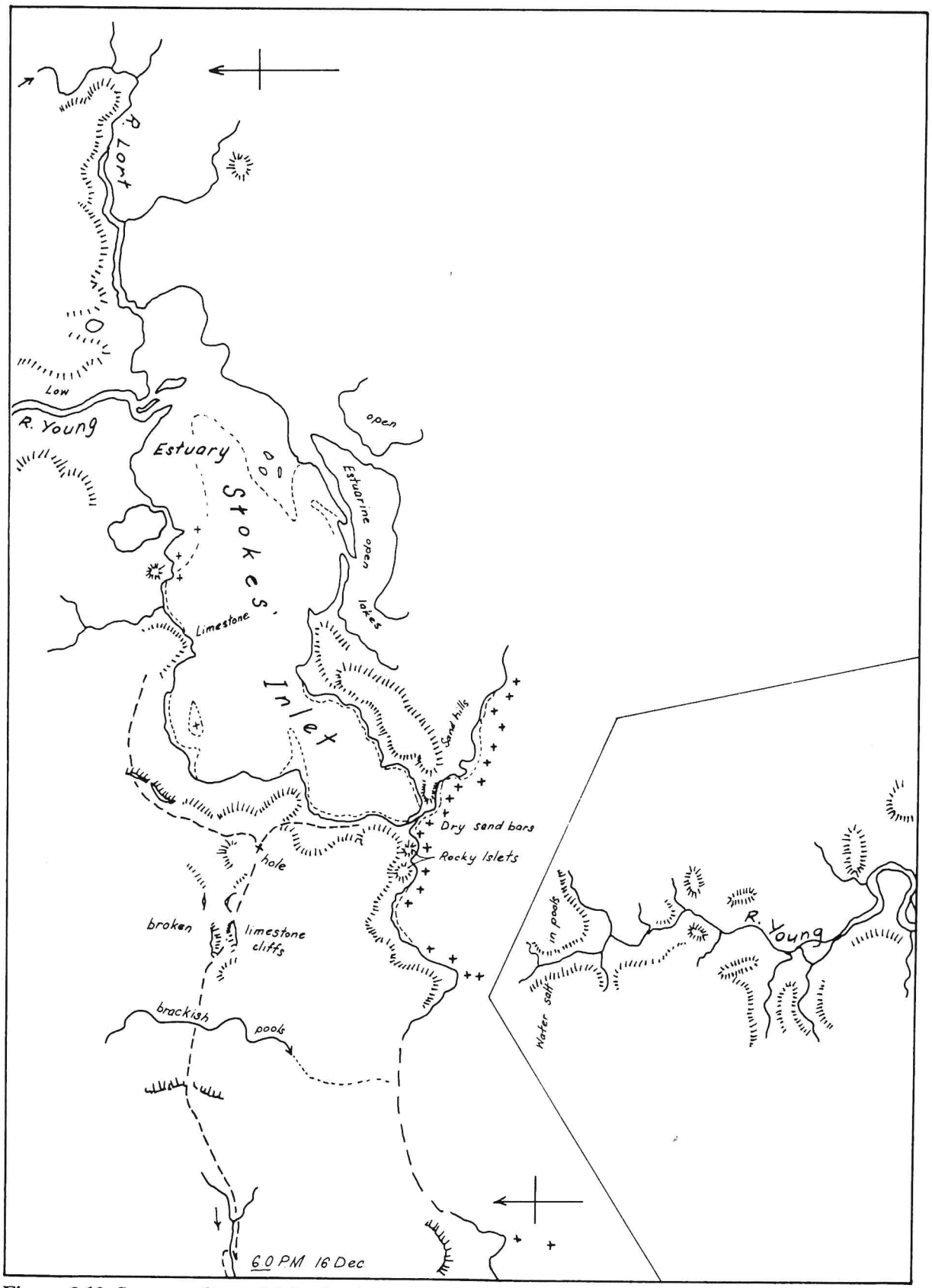


Figure 3.12 Surveyor General John Septimus Roe's sketch map of the Stokes Inlet area in 1848.

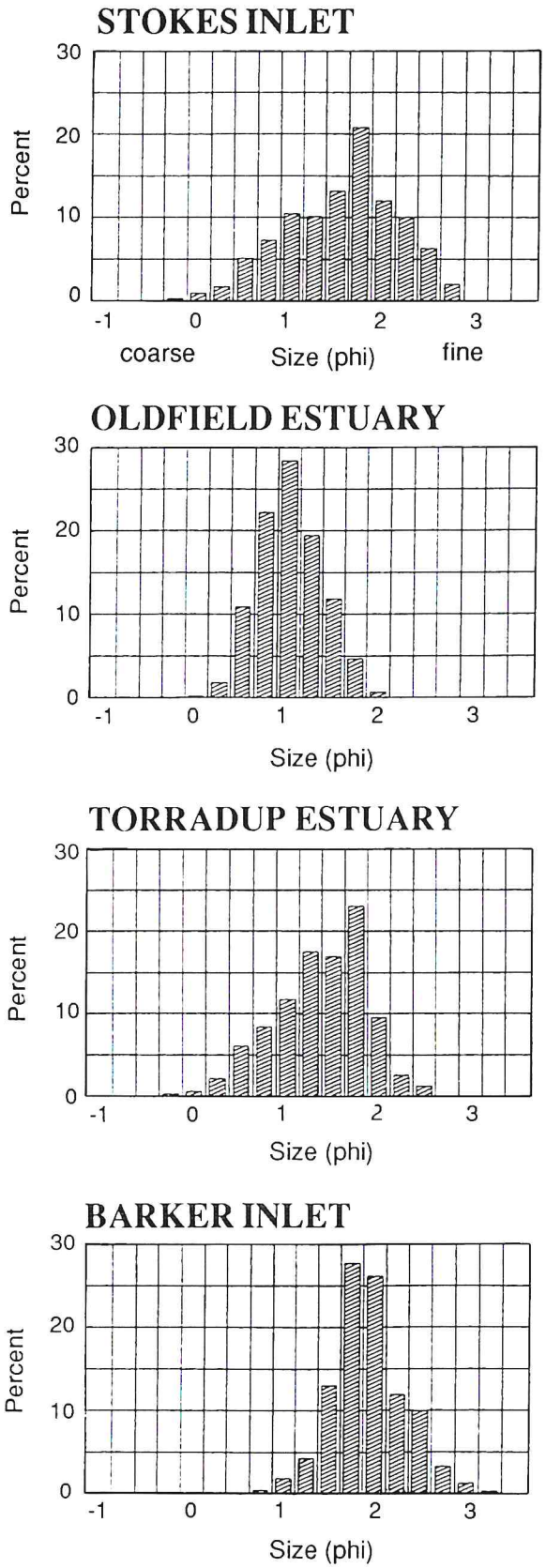


Figure 3.21 Sand size distributions from the bar crests at Stokes, Oldfield, Torradup and Barker estuaries. Sizes are in phi units: -1 phi = 2 mm, 3 phi = 0.125 mm.(Bill Wilson)

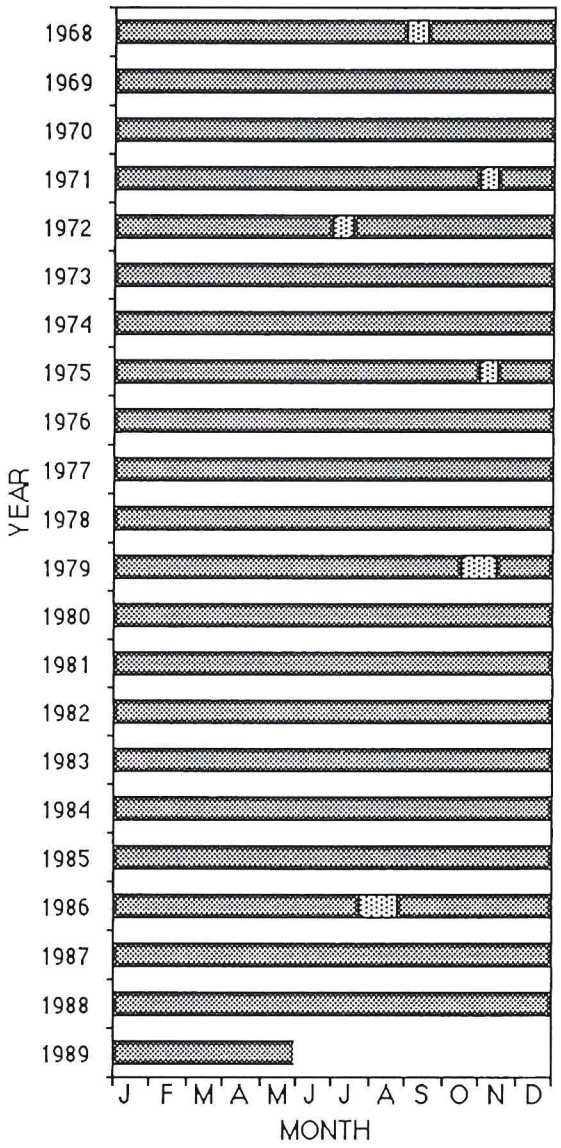


Figure 3.22 Reported openings of the Stokes Inlet. Bar closed , open .

(about 100 mm) never appear to have produced sufficient flow to break the bar. It was broken artificially in July 1972 when the water nearly topped the bar.

High river flow is required to break the bar and keep it open on this high energy coast. Reliable local rainfall records are only for a relatively short time and records from three Water Authority river flow gauging stations for an even shorter period (1973 to 1982). On the basis of this data it is concluded that a flow of at least 10 x 10^6 m^3 is required to break the bar naturally (Table 3.2). Such a flow is expected to result from rainfall of 100 mm inland and about 200 mm near the coast in 1 or 2 months in winter.

In 1971, above average autumn rain was followed by heavy rain in October (96 mm) and November (105 mm) at Young River Station. The pattern was similar

in 1975: 106 mm in April, 95 mm in October and 138 mm in November. Nearly 12 x $10^6 m^3$ of water flowed to the estuary in November and the total for the year was 15 x $10^6 m^3$; runoff was 2.5 mm; and the maximum instantaneous flow in the Young River was 64 m^3/s. In September 1978 the water level was extremely high due to a fairly wet year, and the year's inflow was estimated to be 6.5 x $10^6 m^3$, but the bar did not break. In 1979 heavy winter rain (500 mm May to September) caused extensive flooding throughout the catchment, a total of 10 x $10^6 m^3$ flowed to the estuary during the year, and the bar broke on the 13th October across the western side when strong northerly winds drove water to the top of the bar. The bar did not break again until 1986 when it is reported to have opened twice, briefly in May and on the 26th July 1986 when it stayed open for 6 weeks; there was heavy rain in May (97 mm), July (164 mm) and August (128 mm).

Table 3.2 Total river flow volumes from the catchment to Stokes Inlet estimated from the Water Authority gauging stations 601 001 and 601 004 between 1975 and 1983. (Water Resources Branch, PWD, 1984)

Year	Total volume to estuary (X 10^6 m^3)	Bar (open/ closed)
1975	16.0	OPENED (natural)
1976	7.8	CLOSED
1977	0.5	CLOSED
1978	6.5	CLOSED
1979	10.8	OPENED (natural)
1980	0.6	CLOSED
1981	0.8	CLOSED
1982	2.8	CLOSED
1983	1.9	CLOSED

The following interesting record is from PWD files: In 1961 Ernie Smith said the bar needed opening as it had not been breached for 25 years but there would be no local opposition to opening it. In the adjoining areas and in the hinterland great development had taken place and the runoff was much greater than it had been. Once the bar was breached it would continue to open through the years. There were vegetated sandhills across the bar but as there was a valley through them he thought a bulldozer could open a channel without a great deal of trouble. There is no record of the bar having been opened.

3.3 WATER DEPTHS

Water level varies by nearly 3 m from 1.5 m above to 1.5 m below sea level. The level rises rapidly following heavy rain and river flow and falls slowly with evaporation, or rapidly at first if the bar breaks. At flood levels the roots and lower trunks of the paperbark trees are submerged, while at low water levels there are wide sandy beaches exposed, as are the wide northern and eastern shallows of muddy sand. Figure 3.3 shows water depths below sea level as determined from echo sounding traverses. The Inlet deepens progressively from the northern shallows to over 4 m within a kilometre of the bar. One sounding of 10 m was earlier found opposite the mobile dune on the western shore. Near the bar the water is generally deepest near the eastern shore.

Seepage of low salinity water from the coastal dunes and seepage of sea water through the bar contribute a small but unknown input, however these are unlikely to make much contribution to the volume of estuary water.

3.4 BOTTOM SEDIMENTS

The beaches are a firm shelly sand above normal water level, with accumulations of shells in many places, both at the top of the beaches and along the water line. The sediment becomes more muddy below water and in deep water it is a fine mud with a high water content.

Cores taken from the bottom sediment in deep water in 1987, and tested by the ^{137}Caesium technique, show that 50 to 60 cm of wet sediment (20-25 cm dry) has accumulated in the last 30 years following clearing in the catchment (B. Campbell and K. Heinz-Wyrwoll pers. comm.). It must be supposed that a considerably greater depth of river sediment has accumulated, less rapidly, since the estuary was first flooded, but proof of that must await deep coring. Dune sand is pouring in from the western shore and beach sand washes in from the bar.

The shells are principally those of species of cockle (*Katelysia*) a sample of which has been dated by the 14Carbon technique at 4380 ± 355 years old, showing that the estuary was permanently open to the sea until that time. Another interesting date is from the wood of a *Melaleuca* stump found rooted about 1 m below the present level of living paperbark trees; this was 7300 ± 200 years old suggesting that the trees were growing there while the sea was still rising to its present level (G. Kendrick pers. comm.).

With the growth of the bar and its closure the character of the estuary changed from that of a marine bay to the present condition where it is only intermittently open to the sea for brief periods, where water level and salinity vary seasonally over a wide range and there is a very restricted flora and fauna.

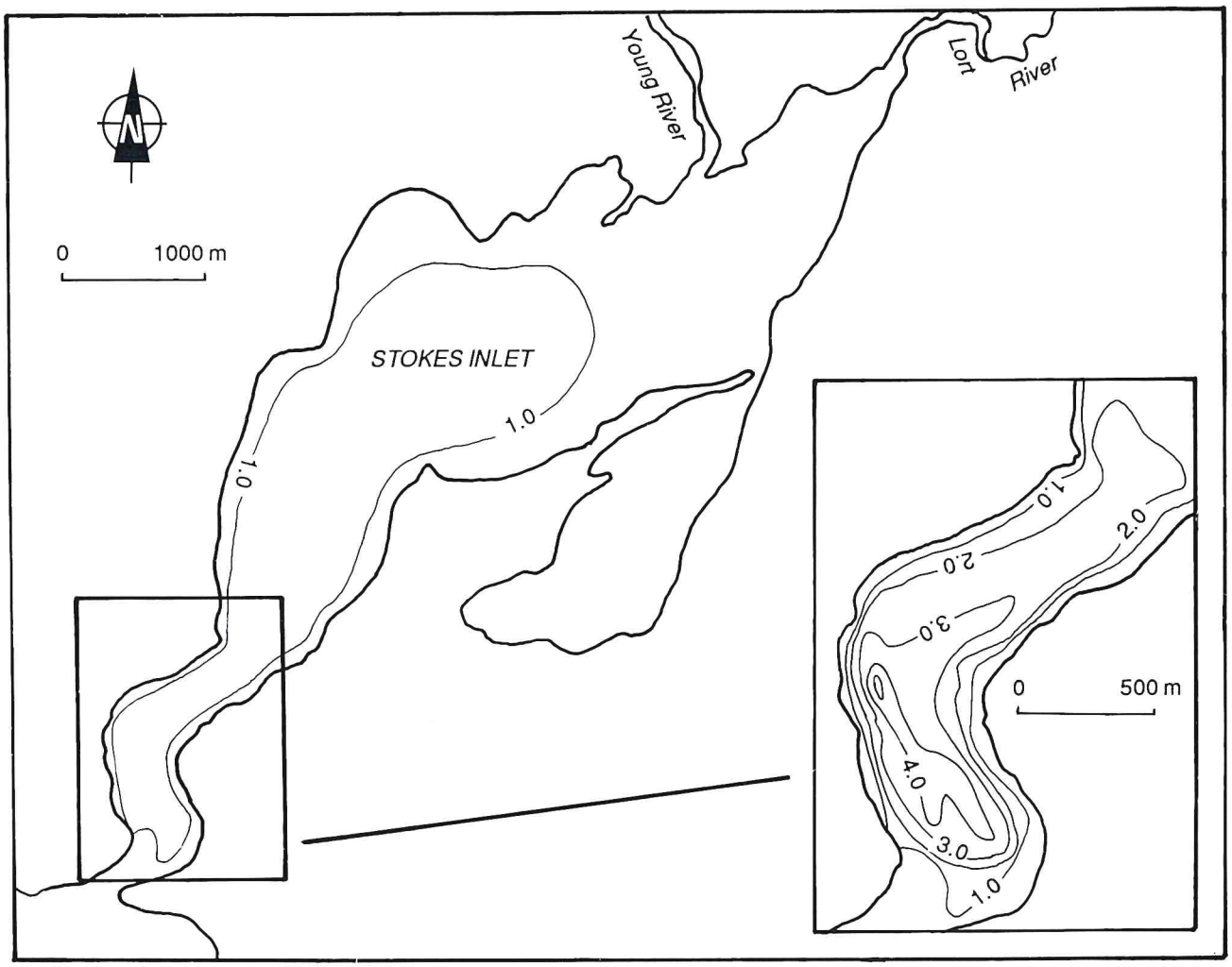


Figure 3.3 Stokes Inlet. Bathymetry. Depths in metres below mean sea level. (J. Bowyer, 7 March 1987)

3.5 WATER CHARACTERISTICS

SALINITY Table 3.51 summarises known salinity data and Figure 3.5 relates observed salinities to rainfall during 1972 (the bar broke at the end of June). Salinity is seldom less than that of sea water (35 parts per thousand), but may be more than twice that at the end of summer. Flood water briefly depresses surface salinity to the salinity of river water and stratification may be quite abrupt until wind and waves mix the water body. The 1979 floods brought surface salinity down from 42 ppt to 4 ppt, but two weeks after the rains had stopped it had risen to 30 ppt as the result of wind mixing, with the deep water at 36 ppt. The stratified condition does not appear to continue for long even in the deepest part of the estuary. The salt content of estuary water derives from sea water flowing in during the brief periods while the bar is open, from water seeping through the bar, and from saline river water.

Table 3.51 Stokes Inlet. Records of salinities (ppt), S - surface, B- bottom, O - open, C - closed.

Date	S/B	Km from the bar At bar	1	2	5	O/C
8/12/71	S	36	34			C
	B		36			C
1972		See Fig. 3.5				
1/9/74	S/B	>40				C
18/2/75	S/B	>40				C
2/5/77	S			42		C
19/7/78	S	32	33	34		C
5/4/79	S/B	42				C
26/7/79	S				4	C
27/10/79	S	30				O
	B	36				O
9/8/82	S		62			C
21/10/83	S/B	67	68		67	C
25/4/84	S/B		86	86	86	C
20/8/84	S	54	50	38	36	C
	B	62	78	68	36	C
8/4/85	S		60	61	61	C
	B		78	60		C
28/4/87	S	41	45			C
3/10/88	S/B	35				C

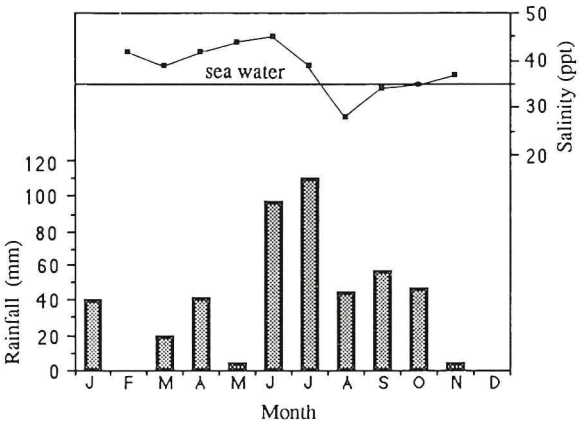


Figure 3.5 Salinity and rainfall at Stokes Inlet in 1972. (WA Fisheries Department, Commonwealth Bureau of Meteorology)

TEMPERATURE There are few temperature records. They range from 22.4°C (Feb.1972) to 14.5°C (Sept. 1975) at the surface, but a temperature of about 12°C must be expected in winter to 25°C in summer. Temperature may also change with depth, especially under stratified conditions.

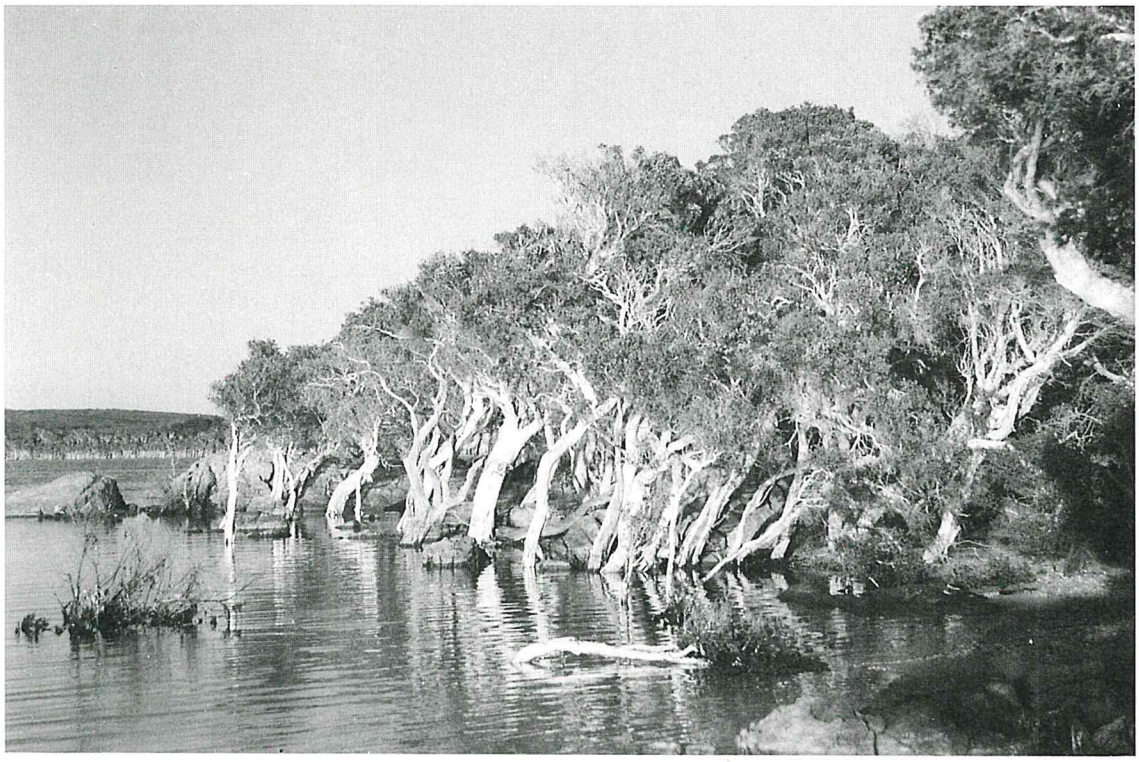
OXYGEN Surface water can be expected to be saturated or supersaturated with oxygen, but there is likely to be some deoxygenation of deeper water when it is stratified.

NUTRIENTS The only detailed nutrient data are listed in Table 3.52. Two subsequent samples showed similar levels of Total P (20 and 30 µg/L). The Young and the Lort rivers were not flowing when sampled so that the figures give little indication of the nutrient content of water flowing into the estuary. Estuary water levels were low at the time of the February sampling. The figures suggest a minor degree of nutrient enrichment and the presence of blue-green algae in the water on some occasions would support this. Nutrient levels may be higher in the riverine reaches of the estuary when cut off from the lagoon.

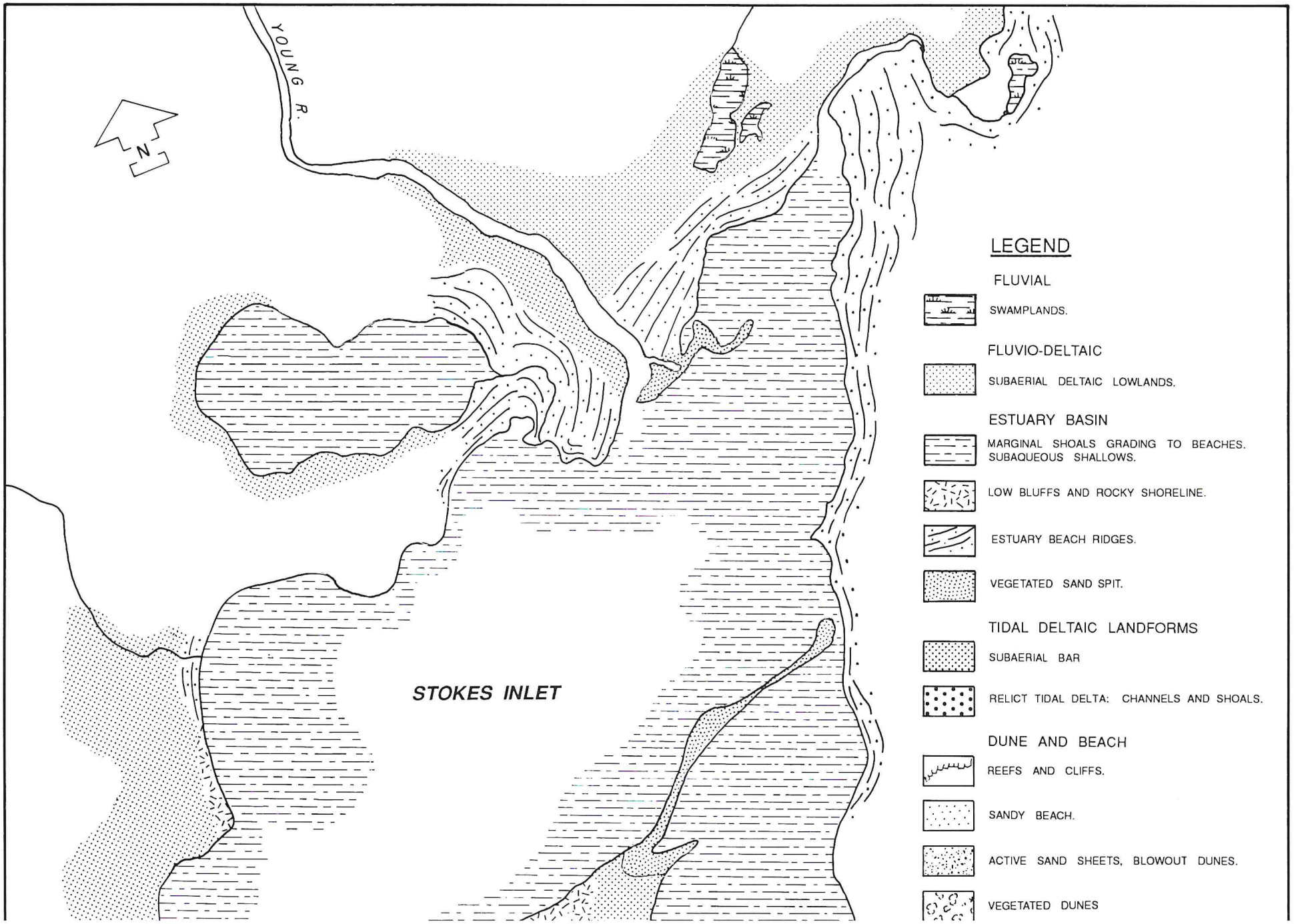
POLLUTION There is no evidence of pollution.

Table 3.52 Nutrient values (µg/L) in Stokes Inlet and in Young and Lort river water at South Coast Highway, 1 September 1974, and 18 February 1975. (Lenanton and Edmonds pers. comm.)

		Phosphorus		Nitrogen	
Year	S/B	PO_4-P	Total P	NH_4-N	Total N
STOKES INLET					
1974	S	10	20	20	570
	B	10	30	20	580
1975	S	10	30	20	1500
	B	10	30	20	1400
YOUNG RIVER					
1974	S	10	50	20	990
1975	S	130	500	20	3300
LORT RIVER					
1974	S	10	10	50	270
	B	10	110	20	1700
1975	S	10	30	20	2200
	B	10	30	20	1100



Stokes Inlet rocky shore with *Melaleuca cuticularis*.


YOUNG R.
N
STOKES INLET
LEGEND
FLUVIAL
SWAMPLANDS.
FLUVIO-DELTAIC
SUBAERIAL DELTAIC LOWLANDS.
ESTUARY BASIN
MARGINAL SHOALS GRADING TO BEACHES. SUBAQUEOUS SHALLOWS.
LOW BLUFFS AND ROCKY SHORELINE.
ESTUARY BEACH RIDGES.
VEGETATED SAND SPIT.
TIDAL DELTAIC LANDFORMS
SUBAERIAL BAR
RELICT TIDAL DELTA: CHANNELS AND SHOALS.
DUNE AND BEACH
REEFS AND CLIFFS.
SANDY BEACH.
ACTIVE SAND SHEETS, BLOWOUT DUNES.
VEGETATED DUNES

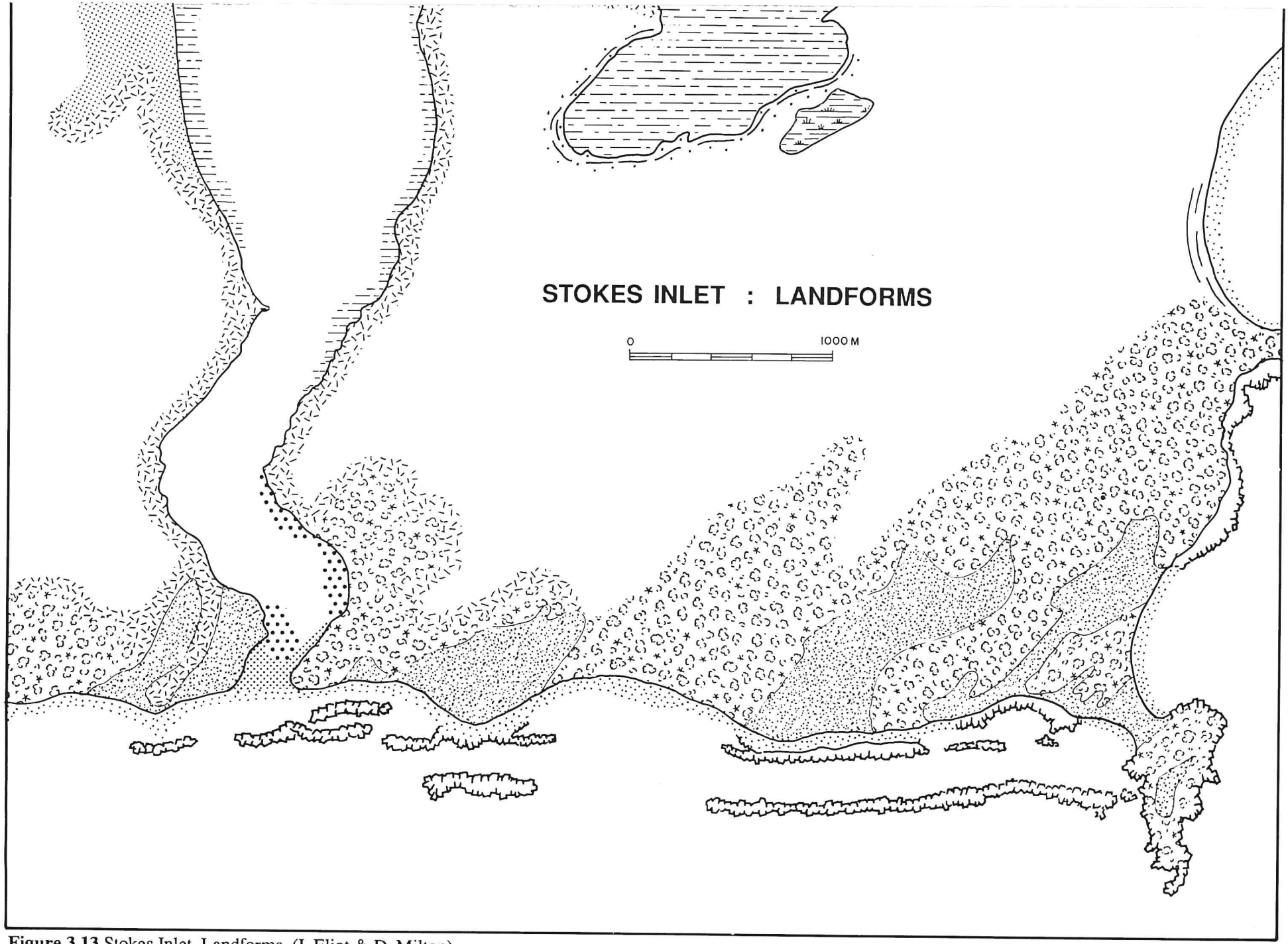


Figure 3.13 Stokes Inlet. Landforms. (I. Eliot & D. Milton)

4 OLDFIELD ESTUARY - PHYSICAL FEATURES

The Oldfield River is estuarine for 8 km from the coast almost to Springdale Road. It lies north-south perpendicular to the coast, where the mouth is closed by a high bar. The upper part of the estuary is a winding, riverine channel through a sandy plain, it then widens where there is higher ground and rock on the eastern shore and finally opens to a 3 km long meandering basin that is nowhere more than about 500 m wide (Figure 4.11). Figure 4.12 shows the main landform features of the estuary and the adjacent coastline. Because of the high bar there may be over 4 m of water in the estuary when it is full, but the water level can fall below that of the sea by autumn leaving only a little shallow water in the deeper parts. The bar breaks infrequently, every 3 to 4 years, and only stays open briefly. After breaking it is fished successfully for two or three years while the water level stays high and salinity is favourable, but with poor rains the remaining water becomes too saline for fish. At such times the small salt lake snail *Coxiella* is very abundant on mud in the shallow water.

4.1 LANDFORMS

The RIVER is only 10 to 20 m wide where it winds through the sandy estuarine floodplain, with steep cut banks up to 2 m in places. Between 4.5 km and 3 km from the bar it widens to about 100 m with a higher bank and rock (granite) on the eastern shore. It is shallow where it widens and this may dry out in summer separating the riverine part from the basin.

The BASIN is 3 km long and narrow, nowhere more than 600 m wide, and about 1 km^2 in area. It winds between a high bank cut in the eastern dune sands and low estuarine sediments on the western shore. There is little evidence of active fluvial deposition. The river delta is small with an elongate silt jetty extending well into the basin. Beach ridges are prominent on the north western shore and on the

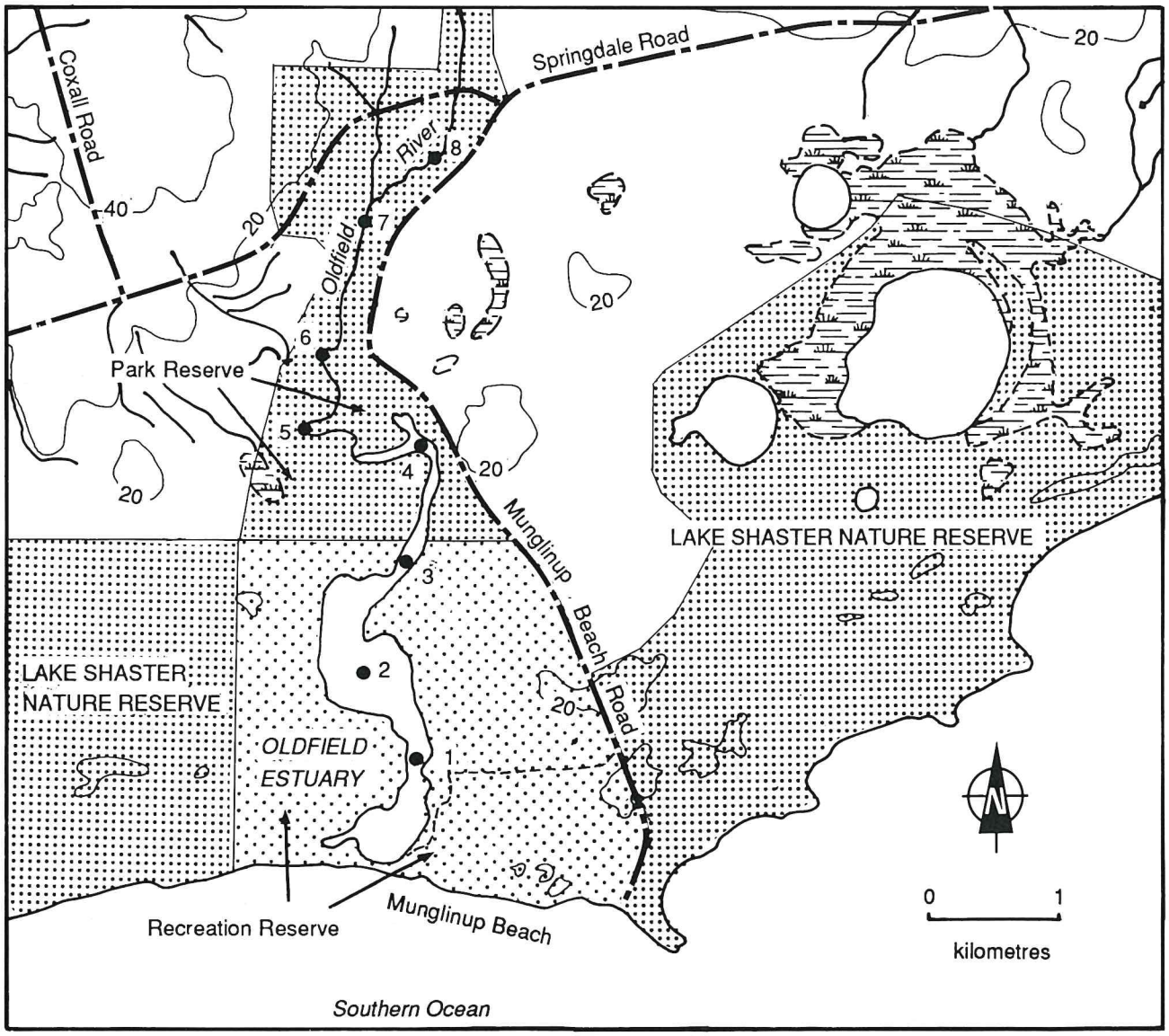


Figure 4.11 Oldfield Estuary. Topography of the surrounding area. Contours in metres. Distance in kilometres from mouth.

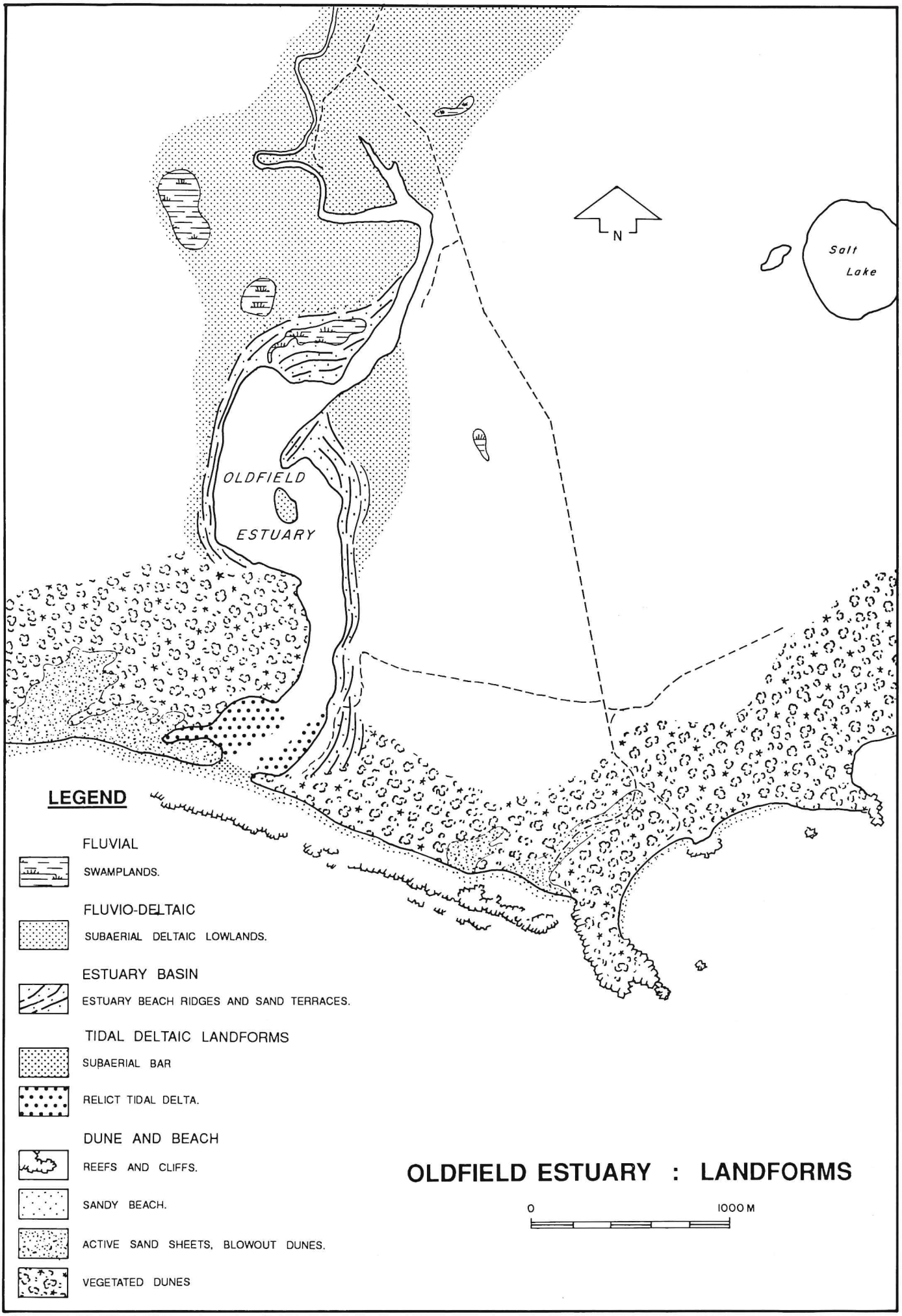


Figure 4.12 Oldfield Estuary. Landforms. (I. Eliot & D. Milton)

eastern shore 2 km from the bar. Opposite this there is a small island. Near the mouth the eastern dunes rise to 10-15 m, with a core of coastal limestone which outcrops on the estuary shore about 200 m from the mouth. A narrow tongue of dune extends westwards separating the basin from the beach; it is stabilised by dense vegetation on the steep basin side, but only sparsely on the seaward side. The western dunes are low and only sparsely vegetated for some distance from the mouth.

At its seaward end the basin is closed by the bar from which a small flood tide delta protrudes into the estuary overlying a more extensive storm tide delta. A shallow arm of the basin extends westwards behind the foredunes.

4.2 THE BAR

The bar is high and narrow, a part of the steep ocean beach, only 100 m across and 200 m east-west. It rises to about 3.5 m above sea level and is built of off-white, well sorted medium to coarse grained quartz sand with 20% calcareous skeletal remains (Figure 3.21).

We have no record of bar openings until it broke in August 1986, before which it is reported not to have opened for 7 years. It opened again in 1987 and in May 1978 following very heavy rain. Earlier it was said to have broken every 3-4 years. With such an exposed coastline and high beach it is unlikely to stay open for long. On two occasions up to six detrital and vegetation strandlines have been seen along the estuary shore, possibly indicating that the bar had opened and closed several times before finally closing.

4.3 WATER DEPTHS

The depth of water varies greatly with river flow and evaporation, the basin can be almost dry at the end of summer but the water level rises abruptly with floods and the water may be 4 - 5 m deep. The basin deepens towards a central area about 1 m below sea level and a maximum channel depth of 2.5 m. This channel may be kept active by river floods when the bar is breached. The northern part of the basin also has a 1 m deep channel, with marginal sand flats that are exposed at low water. The wider part of the riverine estuary is also about 1 m deep and the narrow northern part is reported to have deep pools, possibly the result of scouring by floods.

4.4 BOTTOM SEDIMENTS

The sediments of the marginal shoals are sandy, changing to muddy sand in the deeper part of the basin.

4.5 WATER CHARACTERISTICS

SALINITY Table 4.51 lists salinity records from the estuary. Following river flow, water in the estuary may be nearly fresh (less than 5 ppt). When the bar breaks some sea water enters while the bar remains open and as it mixes with the river water the salinity increases. In the absence of further river input the bar closes and the salinity rises as the result of evaporation, and water level drops. The few high salinities recorded (about 60 ppt) were when little water remained in the basin at the end of summer. Apart from such times the water is probably seldom much more saline than sea water (35 ppt). The few salinities from the upper estuary are all low, even when high in the basin, suggesting that there may be groundwater seepage to this part of the estuary.

Table 4.51 Oldfield Estuary. Records of surface salinity (ppt) at the bar, 1, 4 and 5 km and in river pool at 9 km. (Figure 4.11)

	kilometres from bar				
	Bar	1	4	5	9
8.12.71					6
1.9.74		14		9	
18.2.75		>40		11	
30.4.77		58	16		12
19.7.78		5			6
20.10.78	10				
5.4.79	31			14	
26.7.79		3			
27.10.79	13			5	4
24.5.82		62	46		
22.7.83	21	21			20
19.1.87	7	7	7	7	7
29.4.87	9	9			
4.10.88	7				

TEMPERATURE The only available temperature records are: 13.8°C on 1.9.74 and 22.8°C on 18.2.1975; the temperature was uniform throughout the estuary and surface to deep (Lenanton and Edmonds, pers. comm.). A temperature of about 12°C may be expected in winter to 25°C in summer, or more in shallow water.

OXYGEN Surface water can be expected to be saturated or supersaturated with oxygen, but there may be some deoxygenation of deeper water if it is stratified.

POLLUTION There is no evidence of pollution of the estuary.

NUTRIENTS The only records are those of Lenanton and Edmonds: total phosphorus in the 'river' was 0.03 mg/L and in the estuary 0.06 and 0.11 mg/L surface and bottom respectively on 1.9.1974; and in the 'river' 0.04 mg/L and in the estuary 0.02 and 0.03 mg/L surface and bottom respectively on 18.2.1975. (Table 4.52)

Table 4.52 Nutrient values (µg/L) in Oldfield Estuary and in Oldfield River at South Coast Highway, 1 September 1974, and 18 February 1975. (Lenanton and Edmonds pers. comm.)

Year	S/B	Phosphorus PO_4-P	Phosphorus Total P	Nitrogen NH_4-N	Nitrogen Total N
OLDFIELD ESTUARY					
1974	S	10	60	20	2200
	B	10	110	20	2700
1975	S	10	20	20	2800
	B	10	30	20	3300
OLDFIELD RIVER					
1974	S	10	30	20	830
1975	S	10	40	20	1900

5 TORRADUP ESTUARY - PHYSICAL FEATURES

This is a small, 3.5 km long, stretch of open water nowhere more than about 200 m wide and only 0.4 km^2 in area (Figure 5.11). Figure 5.12 shows the main landform features of the estuary. The mouth opens towards the western end of a 3 km long south facing beach, and the rocky headland at Margaret Cove affords some protection from south west winds and swell. Most of the estuary is shallow and the marginal sand flats are exposed in summer, but the narrower parts are 2 m deep or more. It always holds water, which may be almost fresh when the river flows and is probably seldom much more salt than sea water. The sea bar breaks every year but only stays open briefly, for about a week.

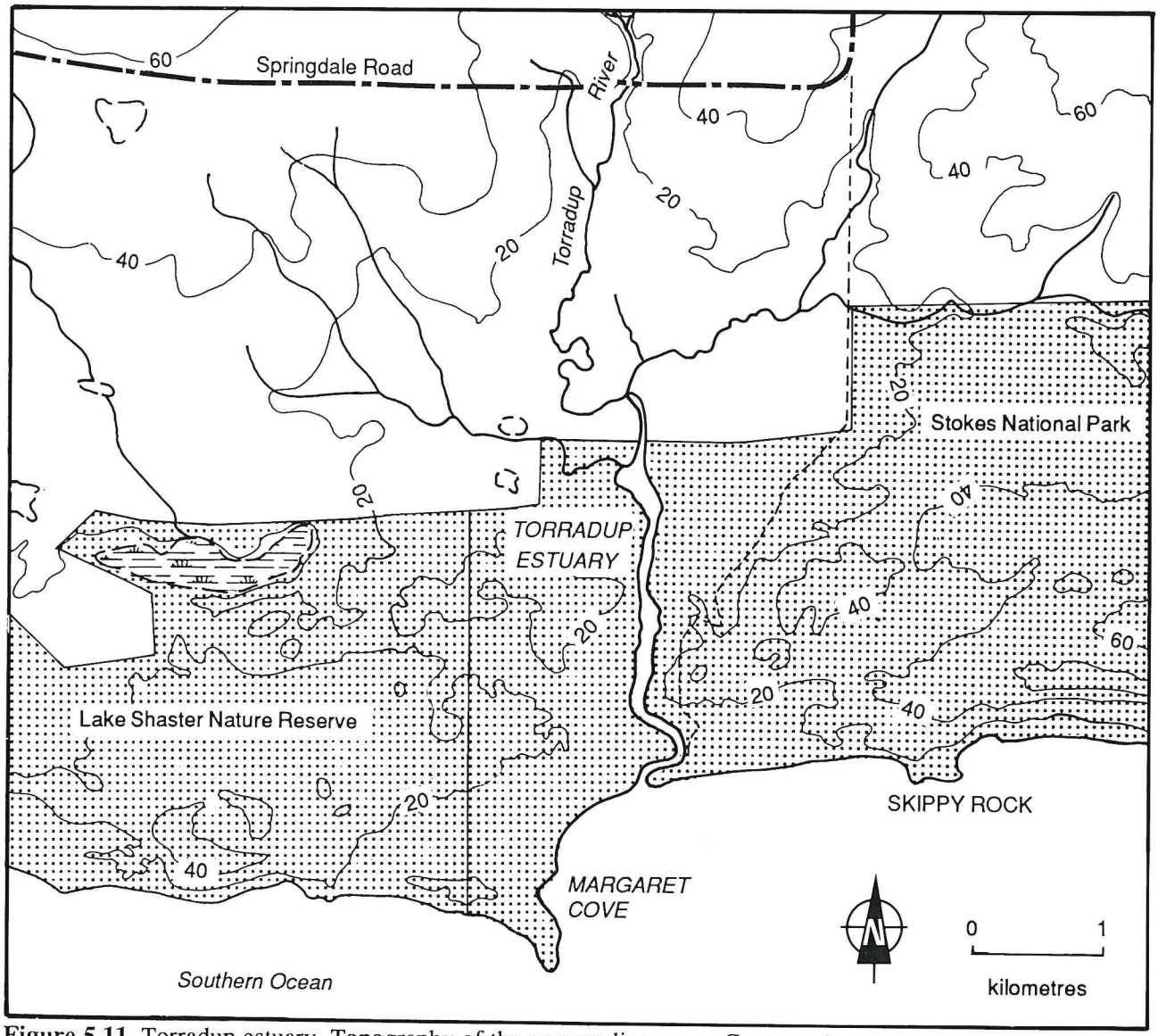


Figure 5.11 Torradup estuary. Topography of the surrounding area. Contours in metres.

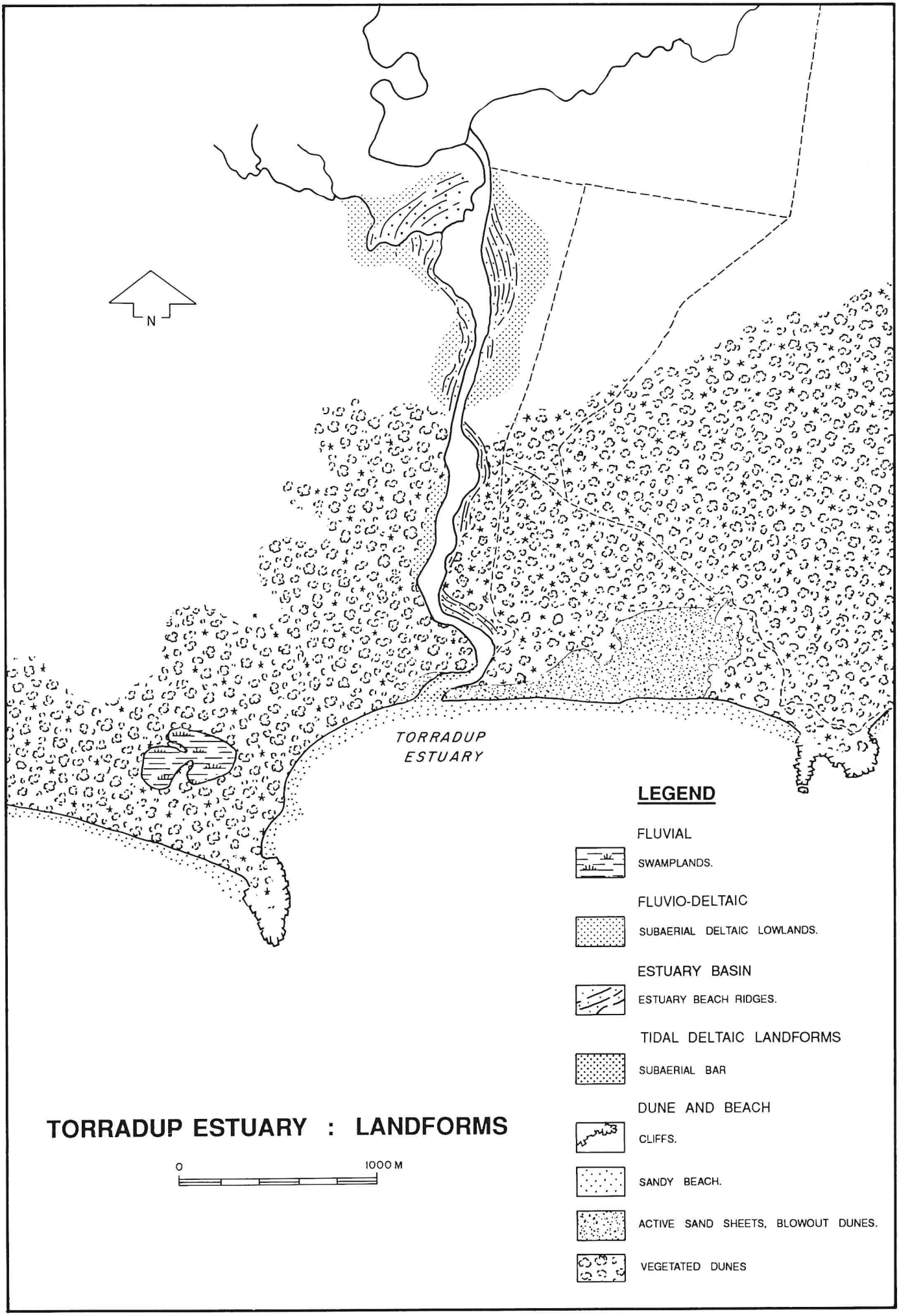


Figure 5.12 Torradup estuary. Landforms. (I. Eliot & D. Milton)

5.1 LANDFORMS

It lies north-south from where the small Torradup River flows into it through an area of lowland swamp south of Springdale Road. From a narrow winding riverine reach it widens at 3 km from the bar to the remnant of a small lagoon which is bordered by beach ridges that are stabilised by rushes and other vegetation. It narrows again to about 50 m and then widens to 150 m before winding through the coastal dunes. It is shallow and sand flats in the wider parts are exposed when water level falls in summer.

The southern end of the estuary narrows to a channel that veers eastwards through steep coastal dunes that have a core of dune limestone, and then west parallel to the bay shore behind a narrow dune barrier to the bar. This dune is sparsely vegetated mobile sand subject to erosion by wind and river flow. The dunes to the west of the mouth are also only sparsely vegetated near the shore. The position of the mouth appears fairly stable, but while the eastern dune barrier is probably growing slowly westwards a major flood or beach erosion could break through at its eastern end and may have done so in the past. East of the estuary a blowout extends inland 0.5 km from the beach.

5.2 THE BAR

The bar is 90-100 m long and 100 m across. It is part of the beach line and 1.5 to 2 m above sea level. It is built of mainly medium grained quartz sand with 25% calcareous skeletal material (Figure 3.21). It opens regularly, especially after heavy rains, but seldom stays open for more than a few days. The absence of a flood tide delta indicates that the bar is well scoured when it breaks. Waves wash sand over the bar into the channel when it is closed making a small washover delta.

5.3 WATER DEPTHS The depth of the water varies 2 m or more with river flow and evaporation. There has been no depth survey of the estuary. The greatest depth is about 2 m below sea level where the channel is scoured in narrow reaches. In the wider parts the sand flats are exposed at sea level.

5.4 BOTTOM SEDIMENTS The marginal shoals and sand banks are of clean, medium grained sand, and in the deeper parts the bottom is a muddy sand.

5.5 WATER CHARACTERISTICS The few observed salinities range from 11 ppt to 40 ppt. River water is almost fresh and brown, tannin stained. The higher salinities result from sea water flowing into the estuary when the bar is open, or waves washing over the bar, followed by mixing and evaporation. The presence of the salt lake snail *Coxiella* suggests that the water may sometimes become highly saline, perhaps only in isolated pools on the sand flats.

6 BARKER INLET - PHYSICAL FEATURES

Barker Inlet is a wide, shallow basin which appears to be the remnant of a former considerably larger area of water of which the beach ridges, swamps and numerous small salt lakes were probably a part. Unlike the three previous estuaries, the mouth is at the extreme western end of a bay hard against a rocky headland which protects it from south west winds and swell. But for this the encroaching dunes might have blocked it off from the sea long ago. The Inlet probably seldom holds water through summer except in a deep, narrow channel to the mouth. Two branches of a small river drain from the northern swamp which is fed by Coomalbidgup Creek. On the western shore two salt lakes join the Inlet when it is full. Figure 6.11 shows the topography of the surrounding area and Figure 6.12 shows the main landform features of the estuary.

6.1 LANDFORMS

RIVER The river is estuarine for about 200 m. It discharges through a small channel over a wide deltaic area.

INLET The Inlet is pear shaped, narrowing towards the mouth, with an area of 1.8 km^2. Marginal shoals grade gradually into the basin which is probably nowhere more than 1 m below mean sea level, except where a narrow gutter extends for about 700 m through the inlet channel to the bar. Extensive estuarine beach ridges border most of the basin, rising steeply from the shoreline and densely vegetated in many places.

INLET CHANNEL AND MOUTH The basin narrows to about 100 m between coastal dunes which have a core of dune limestone. The eastern shore is steep, with rock exposed along the shore, and on the west low unconsolidated dunes are backed by a steep rock slope. The channel is shallow except where the deep gutter is scoured along the eastern shore.

6.2 THE BAR

The bar is about 100 m wide between the dunes and is part of the beach line. It is low, probably 1-1.5 m above sea level and the waves wash over it. The bar sand is a well sorted medium to fine grained mainly quartz sand (Figure 3.21). We have no information on how often the bar breaks or remains open. The absence of vegetation on the bar indicates that it probably breaks across its full width fairly frequently, and the presence of the gutter suggests that tidal scour keeps it open on the eastern side for weeks before it finally closes.

6.3 WATER DEPTHS

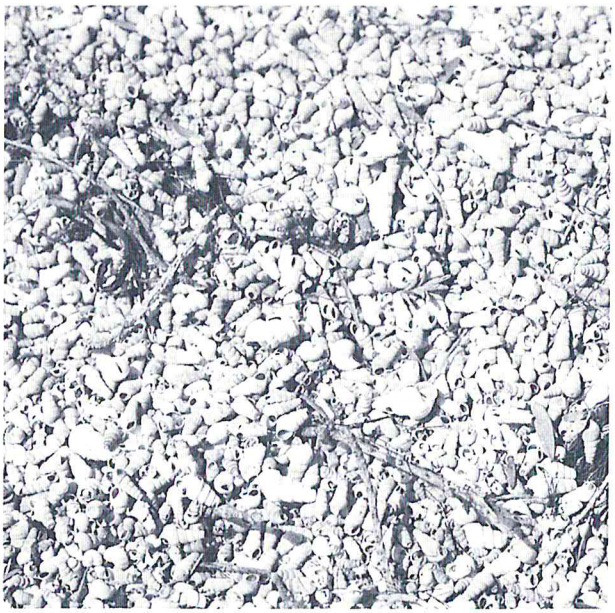
The estuary is shallow, often with no water in the basin during summer. The narrow tidal channel gutter appears to always hold water.

6.4 BOTTOM SEDIMENTS

The marginal shoals and sand banks are of clean, medium grained sand changing to muddy sand and mud. Calcareous rock is exposed in the shallows of the eastern shore.

6.5 WATER CHARACTERISTICS

The salinity of the water must vary from nearly fresh when the basin first fills with river water almost to brine when the basin dries. In October 1988, when the water level was 0.7 m below the crest of the bar, the salinity was 23 ppt. The marginal vegetation includes both salt tolerant plants, samphire and *Melaleuca cuticularis*, and others with only limited salt tolerance. Shells of the salt lake snail *Coxiella* are abundant on the beaches showing that the water is hypersaline at times.



Coxiella shells on the shore at Barker Inlet.

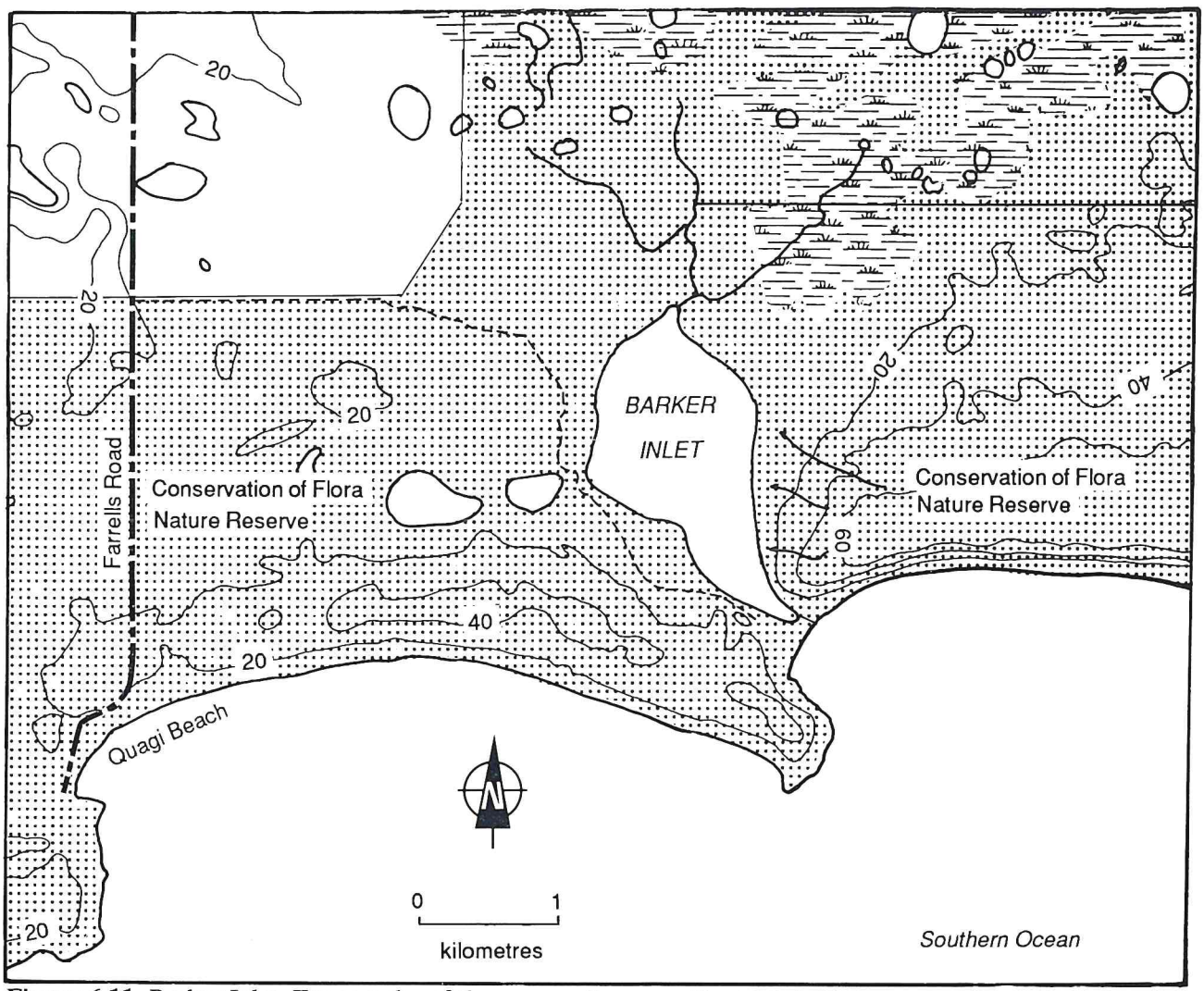


Figure 6.11 Barker Inlet. Topography of the surrounding area. Contours in metres.

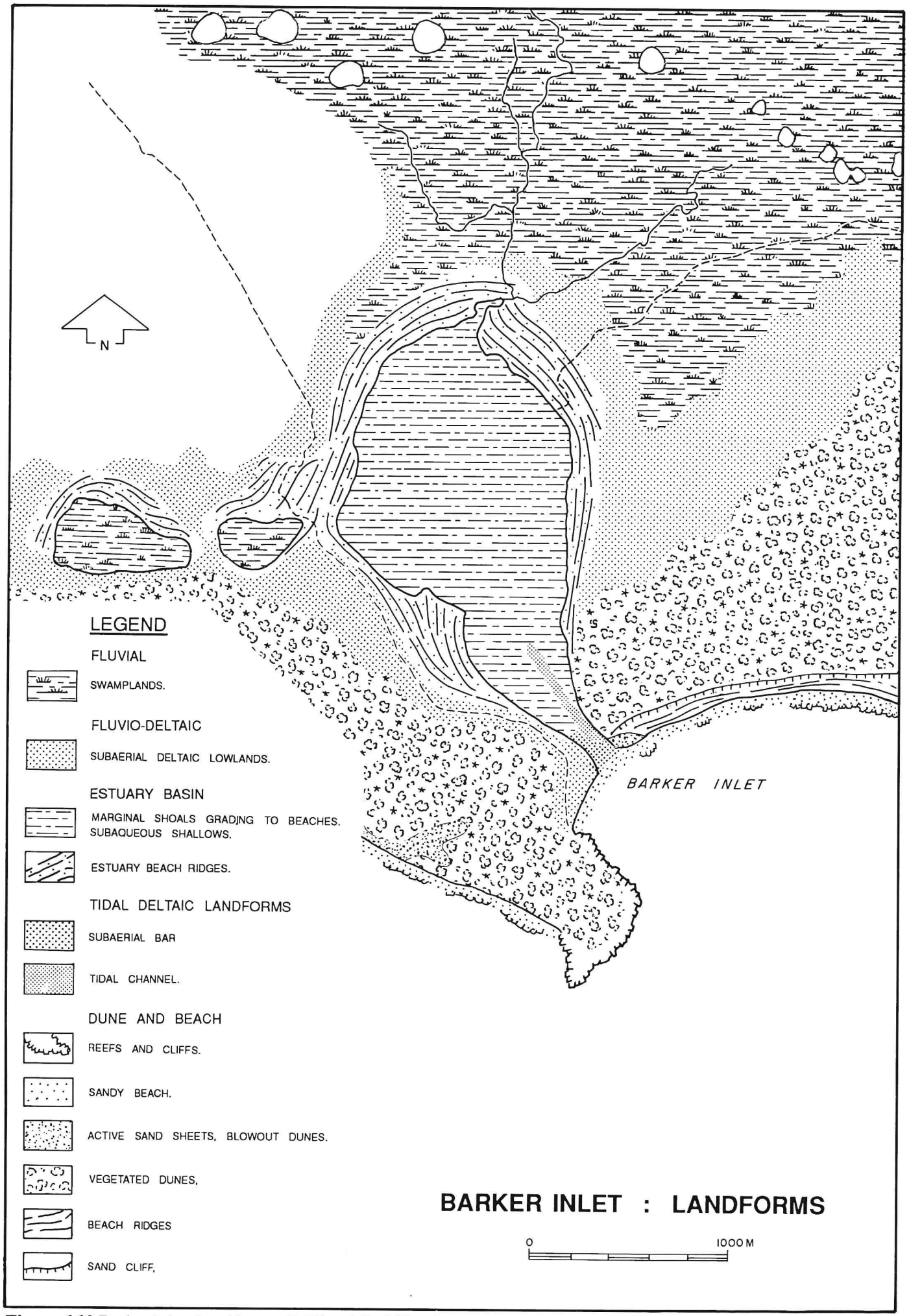


Figure 6.12 Barker Inlet. Landforms. (I. Eliot & D. Milton)

7 ESTUARINE VEGETATION

Surveys of the estuarine vegetation of Stokes Inlet and Oldfield Estuary have been made by M. Cambridge in May 1977 and by J. M. Chambers in January 1987, with collections by the authors on other occasions at the four estuaries.

7.1 AQUATIC PLANTS

The aquatic flora of these estuaries is dominated by three species of salt tolerant, attached plants: the small green alga *Polyphysa peniculus* , the seagrass *Ruppia megacarpa*, and the stonewort *Lamprothamnium papulosum* . *Polyphysa* grows extensively in shallow water throughout Stokes Inlet, sometimes forming a continuous cover both on sand and rock, and may be abundant in shallow water in both Oldfield and Torradup estuaries. *Ruppia* is sometimes abundant, even on the eastern shallows of Stokes Inlet when they are flooded, and it also grows in the riverine reaches of these three estuaries. At times it is heavily grazed by swans. *Lamprothamnium* is also recorded from shallow water in the three estuaries. *Ruppia* was the only species found on the one brief visit to Barker Inlet. The filamentous green alga *Cladophora coelothrix* was found washed up on the shore of Stokes Inlet in 1987.

Tannins and humic acids often stain the water of Oldfield and Torradup estuaries light brown so that light only penetrates to the bottom in shallow water (<0.5 m deep), which would restrict the distribution of aquatic macrophytes. Suspended particulate matter may have the same effect in Stokes Inlet and Barker Inlet.

7.2 FRINGING AND SALTMARSH VEGETATION

The fringing vegetation reflects both the character of the shoreline, slope and sand or rock substrate, and the hydrology of estuary water and variation in water level. The saltwater paperbark (*Melaleuca cuticularis*) commonly forms a fringe along the shoreline, narrow where the ground slopes steeply or wide where it is flat or gently sloping. Elsewhere the sedge *Juncus kraussii* fronts the paperbarks along the water or may clothe low sandy beach ridges, alternating with samphire (*Sarcocornia quinqueflora* and *Halosarcia pergrannulata*). Where the groundwater is less saline the low lying areas are colonised by the sedges *Gahnia trifida* and *Baumea juncea.*

At **Stokes Inlet** *Melaleuca cuticularis* forms a continuous band around the estuary. Along the sandy western shore it forms a woodland strip 20 m wide with a sparse understorey of *Isolepis nodosa.* The band is narrower on the steeper, south eastern shore and shrinks to the width of a single tree, many of which are dead. Some grow even where they are rooted among the rocks. Paperbarks dominate the high sand ridge that separates the eastern sand flats from the rest of the estuary and saplings also invade the flats.

Sarcocornia quinqueflora is common along the northern and north western shores of the Inlet where there are beach ridges and a small swamp near the mouth of a creek. Here it occurs in front of and among the paperbarks and is associated with other common salt tolerant species: *Samolus repens*, *Suaeda australis*, *Carpobrotus* sp. and *Lomandra* sp. Behind these, on slightly higher ground, there are either *Isolepis nodosa* and *Euphorbia paralias* or *Juncus kraussii* and *Baumea juncea.* Samphire also grows in the eastern sand flats, *Sarcocornia* near the shoreline and *Halosarcia* in central areas at higher levels. A blue-green algal mat was found in front of the samphire in a bay near the Young River mouth in 1987.

At **Oldfield Estuary** *Melaleuca cuticularis* forms a continuous fringe along much of the shoreline, narrow where the banks are steep and wide in low lying swampy areas. The presence of the sedge *Baumea juncea* beneath the paperbarks reflects the low salinities experienced when the estuary is flooded. Another sedge *Gahnia trifida* occurs with *Baumea* from 2 km upstream from the mouth. The sheoak *Casuarina obesa* dominates the fringing vegetation along much of the narrow riverine part of the estuary, but sections of the sandy banks have been eroded and there is little or no vegetation cover. At the mouth of the estuary, the western fringe vegetation comprises *Baumea juncea* and couch (*Cynodon dactylon*) with *Euphorbia paralias* behind. At the rock outcrop on the eastern shore terrestrial vegetation extends to the water's edge.

Torradup estuary also has a fringe of *Melaleuca cuticularis* and *Juncus kraussii*, the *Melaleuca* fading out in the flatter sandy areas where there are rushes, sedges and samphire and the herb *Wilsonia humilis* . On the eastern shore, 0.5 km from the mouth, the salt marsh has a wide border of *Juncus* then sparse *Juncus* and samphire under paperbarks and, near higher ground, *Gahnia trifida* and *Acacia eglandulosa.*

Barker Inlet is fringed by *Melaleuca cuticularis*, *Gahnia trifida* and *Lepidosperma* sp. in front of shrubland comprising *Templetonia retusa*, *Olax phyllanthii*, *Pimelea ferruginea*, *Acacia* (aff. *rostellifera*) and *Melaleuca seriata.* On the western shore, salt marsh plants *Halosarcia pergrannulata*, *Suaeda australis*, *Melaleuca cuticularis* and *Juncus kraussii* were found in front of *Euphorbia paralias*, *Acacia eglandulosa* and other established dune species.

7.3 TERRESTRIAL VEGETATION

Dune vegetation is similar at the four estuaries (Table 7.31), with *Spinifex hirsutus* dominating the foredune and *Scaevola crassifolia* common in the

Table 7.31 Dune vegetation present at Stokes, Oldfield, Torradup and Barker estuaries. (J.M. Chambers)

Colonisers:

Spinifex hirsutus	*Arctotheca populifolia*
Isolepis nodosa	*Ammophila arenaria*
Carpobrotus sp.	*Euphorbia paralias*

First dune:

Scaevola crassifolia	*Lepidosperma gladiatum*
Acacia eglandulosa	*Olearia axillaris*
Cakile maritima	*Angianthus cunninghamii*
Pimelea ferruginea	

Established dunes:

Spyridium globulosum	*Acacia rostellifera*
Leucopogon parviflorus	*Rhagodia baccata*
Templetonia retusa	*Guichenotia ledifolia*

dunes further inland. Dune species are also common around the estuaries, together with *Eucalyptus* and other species listed in Tables 7.32 and 7.33. On the steep south eastern shore of Stokes Inlet a stand of *Melaleuca lanceolata* is surrounded by vegetation dominated by *Acacia rostellifera* and *A. eglandulosa*, with *Banksia attenuata* at higher elevations. Table 7.32 lists species collected at the northern end of Torradup estuary and Table 7.33 species collected near the shore at Barker Inlet.

Table 7.32 Dune and terrestrial plant species collected at the northern end of Torradup estuary. (ident. J.M. Chambers)

Melaleuca cuticularis	*Lepidosperma* sp.
Calothamnus lateralis	*Calothamnus* sp.
Hakea trifurcata	*Hakea* sp.
Adenanthos obovatus	*Dryandra sessilis*

Table 7.33 Dune and terrestrial plant species collected near the shore at Barker Inlet. (ident. J.M. Chambers)

Hakea trifurcata	*Allocasuarina humilis*
Dryandra sessilis	*Eucalyptus* sp.
Lysinema ciliatum	*Adenanthos obovatus*
Melaleuca seriata	*Melaleuca* sp.
Isopogon tridens	*Petrophile media*
Jacksonia horrida	

8 ESTUARINE FAUNA

8.1 PLANKTON

Plankton samples have only been taken at Stokes Inlet and Oldfield Estuary. The common estuarine copepod species *Gladioferens imparipes* was present in both and *Acartia clausi* (? *tranteri*) in Stokes Inlet.

8.2 BOTTOM FAUNA

Table 8.2 lists the bottom fauna found at Stokes Inlet and Oldfield Estuary. These are predominantly common estuarine species which tolerate a wide range of salinity. The small salt lake snail *Coxiella* is abundant at times in both estuaries, on the salt flats at Stokes and in the basin at Oldfield.

At Stokes Inlet some more marine species are also found in the estuary following the opening of the bar. Many juvenile prawns (*Penaeus latisulcatus*) and mussels (*Mytilus edulis*) were found in the survey made in May 1987 nine months after the bar had been open, and they had matured by October 1988. A few cockles (*Katelysia scalarina* and *Fulvia tenuicostata*), a blue manna crab *Portunus pelagicus* and a shore prawn *Leander littoreus* have also been found at such times. These species have mainly been found in the southern part of the estuary near the bar while the estuarine species are widely distributed throughout the Inlet. Large numbers of a small, unidentified jellyfish were observed in the estuary in November 1988.

These more marine species have not been found at Oldfield Estuary which appears to have a less diverse fauna, though sampling has not been repeated there.

The only species recorded from Torradup estuary are the bivalves *Arthritica semen* and *Sanguinolaria biradiata*, the snail *Coxiella*, the shrimp *Palaemonetes australis* and an unidentified polychaete worm.

Coxiella is abundant in Barker Inlet and a few recently dead shells of *Fulvia* and *Katelysia* were found.

8.3 FISH

The composition of the fish fauna of the estuaries depends largely on the time and duration of bar openings and the salinity of the water. For example after the Stokes Inlet bar had been closed for about 30 years Black bream was the only commercial fish caught (apart from a few very large, blind Sea mullet). Black bream is an estuarine species that also lives in river pools. A few non-commercial estuarine species, such as the Common minnow and species of hardyheads and gobies, may also survive under these conditions. But when the bars break fertilised eggs, larvae and juveniles of a variety of marine species such as Sea mullet enter and are fished for as long as conditions favour growth and survival. Adults of a

Table 8.2 Bottom fauna at Stokes Inlet (S) and Oldfield Estuary (O). Surveys by J. Wallace (April 1977) and J.L. Shaw (May 1988) with collections by other observers.

		S	O
POLYCHAETA:			
Spionidae:	*Prionospio* sp.	+	-
Capitellidae:	*Capitella* sp.	+++	+
	Ficopomatus enigmatica	-	+
MOLLUSCA:	Gastropoda		
Hydrobiidae:	*Hydrobia buccinoides*	++	+
Hydrococcidae:	*Hydrococcus brazieri*	++	-
Atylidae:	*Liloa brevis*	+	-
Amphibolidae:	*Salinator fragilis*	+	-
Nassariidae:	*Nassarius burchardi*	+	-
	Coxiella sp.	+	+
MOLLUSCA:	Bivalvia		
Mytilidae:	*Mytilus edulis planulatus*	++	-
Leptonidae:	*Arthritica semen*	+	+
Cardidae:	*Fulvia tenuicostata*	+	-
Mactridae:	*Spisula trigonella*	+++	-
Sanguinolariidae:	*Sanguinolaria biradiata*	+	-
Veneridae:	*Katelysia scalarina*	+	-
Tellinidae:	*Tellina deltoidalis*	+	-
CRUSTACEA:			
Mysidacea:	Mysid sp.	++	-
Amphipoda:	*Melita* sp.	+	+
Isopoda:	*Sphaeroma* sp.	+	+
Decapoda:	*Penaeus latisulcatus*	+	-
	Ovalipes australiensis	+	-
	Leptograpsodes octodentatus	+	-
	Palaemonetes australis	-	+
INSECTA:			
Trichoptera larvae		+	-
Chironomidae:	*Pontomyia cottoni*	+++	+

number of these marine species return to the sea to spawn at the next bar opening and continue their growth in coastal waters. Table 8.3 lists the species recorded from the two estuaries.

There are reported to have been mass mortalities of fish in Stokes Inlet in 1932, 1938 and 1983 similar to those experienced in Beaufort and Gordon Inlets. Presumably they also occur in Oldfield Estuary and Barker Inlet when they dry up. Large numbers of Australian salmon, whiting and bream entered Stokes Inlet when the bar opened in 1968. There is reported to have been quite a variety of species of fisn in the estuary before the bar broke in November 1975, but after the opening only Black bream were caught.

Both Stokes Inlet and Oldfield Estuary are fished by commercial fishermen and Stokes Inlet is also popular with amateur (recreational) fishermen who principally target Black bream and Sea mullet. The principal species fished in Oldfield Estuary are Black bream, Sea mullet, Yelloweye mullet, and 'Salmon trout'. Sea mullet, Yelloweye mullet and flathead are fished in Torradup estuary, but apparently not Black bream.

Net fishing is prohibited from 1 December to 30 April inclusive each year in all waters of Stokes Inlet and all rivers and streams flowing into it. There are no restrictions on recreational net fishing in Oldfield Estuary, Torradup and Barker Inlets.

8.4 BIRDS

Table 8.4 lists thirty seven species of waterbirds which have been recorded at the four estuaries, with their observed abundance.

Table 8.3 Commercial and non-commercial estuarine* and marine species of fish caught in Stokes Inlet (S) and Oldfield Estuary (O). (R.C.J. Lenanton, G.M. Cliff & J.L. Shaw - WA Fisheries Department, Lenanton, 1974 & Prince *et al.*, 1982)

Commercial		S	O
Clupeidae:	Pilchard *Sardinops neopilchardus*	+	
Engraulididae:	Australian anchovy *Engraulis australis*	+	
Plotosidae:	Cobbler *Cnidoglanis macrocephalus*	+	
Hemiramphidae:	Southern sea garfish *Hyporhamphus melanochir*	+	
Triglidae:	Red gurnard *Cheilodonichthys kumu*	+	
Platycephalidae:	Southern sand flathead *Platycephalus bassensis*	+	
	Southern blue-spotted flathead *Platycephalus speculator*	+	
Sillaginidae:	Southern school whiting *Sillago bassensis*	+	
Carangidae:	Trevally *Pseudocaranx* sp.	+	
	Samson fish *Seriola hippos*	+	
Arripidae:	Western Australian salmon *Arripis truttaceus*	+	
	Australian herring *Arripis georgianus*	+	
Sparidae:	Black bream* *Acanthopagrus butcheri*	+	+
	Pink snapper *Chrysophrys auratus*	+	
	Tarwhine *Rhabdosargus sarba*	+	
Cheilodactylidae:	Queen snapper *Nemadactylus valenciennesi*	+	
Mugilidae:	Yelloweye mullet *Aldrichetta forsteri*	+	
	Sea mullet *Mugil cephalus*	+	+
Scombridae:	Blue mackerel *Scomber australasicus*	+	
Monacanthidae:	Brown-striped leatherjacket *Meuschenia australis*	+	
	Chinaman leatherjacket *Nelusetta ayraudi*	+	

Non-commercial		S	O
Galaxiidae:	Common minnow *Galaxias maculatus*		+
Gonorynchidae:	Beaked salmon *Gonorhynchus greyi*	+	
Atherinidae:	Elongate hardyhead* *Atherinosoma elongata*	+	+
	Wallace's hardyhead* *Atherinosoma wallacei*		+
Scorpaenidae:	Soldierfish *Gymnapistes marmoratus*	+	
Enoplosidae:	Old wife *Enoplosus armatus*	+	
Cheilodactylidae:	Crested morwong *Cheilodactylus gibbosus*	+	
Labridae:	Brown-spotted wrasse *Pseudolabrus parilus*	+	
Gobiidae:	Blue spot goby* *Pseudogobius olorum*	+	+
Pleuronectidae:	Elongate flounder *Ammotretis elongatus*	+	
Tetraodontidae:	Prickly toadfish *Contusus brevicaudus*	+	
	Banded toadfish *Torquigener pleurogramma*	+	

Table 8.4 Waterbirds found at Stokes (S), Oldfield (O), Torradup (T) and Barker (B) estuaries. (R. Clark, J. Lane, RAOU)

Common name	Scientific name	S	O	T	B
Australasian Grebe	*Podiceps novaehollandiae*	80	#	2	—
Hoary-headed Grebe	*Podiceps poliocephalus*	—	#	—	—
Great -crested Grebe	*Podiceps cristatus*	9	—	—	—
Australian Pelican	*Pelecanus conspicillatus*	28	2	1	—
Little Black Cormorant	*Phalacrocorax sulcirostris*	1000+	—	10	—
Great Cormorant	*Phalacrocorax carbo*	20	#	—	—
Pied Cormorant	*Phalacrocorax varius*	6	—	—	—
Little Pied Cormorant	*Phalacrocorax melanoleucos*	47	—	1	—
White-faced Heron	*Ardea novaehollandiae*	15	#	—	—
Great Egret	*Egretta alba*	#	—	—	—
Black Swan	*Cygnus atratus*	495	54	34	3
Australian Shelduck	*Tadorna tadornoides*	2597	—	75	100
Pacific Black Duck	*Anas superciliosa*	20	170	75	—
Grey Teal	*Anas gibberifrons*	1515	90	18	20
Chestnut Teal	*Anas castanea*	275	18	5	—
Australian Shoveler	*Anas rhynchotis*	—	50	24	—
Maned Duck	*Chenonetta jubata*	—	1	—	—
Musk Duck	*Biziura lobata*	—	10	50	—
Pink-eared Duck	*Malacorhynchus membranaceus*	—	15	280	—
Blue-billed Duck	*Oxyura australis*	—	—	65	—
Eurasian Coot	*Fulica atra*	—	15	600	—
Sooty Oystercatcher	*Haematopus fuliginosus*	5	—	#	2
Pied Oystercatcher	*Haematopus ostralegus*	10	2	—	—
Common Sandpiper	*Tringa hypoleucos**	#	#	—	—
Wood Sandpiper	*Tringa glareola*	#	—	—	—
Silver Gull	*Larus novaehollandiae*	100+	2	1	5
Caspian Tern	*Sterna caspia*	2	—	—	—
Crested Tern	*Sterna bergii*	3	—	—	—
Red-capped Plover	*Charadrius ruficapillus**	4	4	—	—
Red-necked Stint	*Calidris ruficollis**	#	—	—	—
Bar-tailed Godwit	*Limosa lapponica*	#	—	—	1
White-breasted Sea Eagle	*Haliaeetus leucogaster*	2	—	—	—
Osprey	*Pandion haliaetus*	3	—	—	—
Black-winged stilt	*Himantopus himantopus*	100+	—	—	—
Red-necked Avocet	*Recurvirostra novaehollandiae*	#	—	—	—
Pacific Gull	*Larus pacificus*	1	—	—	—
Hooded Plover		—	—	—	5

* denotes migratory bird; present in greater numbers in spring and summer, most depart in autumn. All other birds are sedentary or vagrant. # denotes present but no numbers recorded.

9 MANAGEMENT

Management of the bars is a controversial issue here as with other barred estuaries of the south coast and concerns Stokes Inlet especially. Artificially breaking the bar is often advocated to allow more frequent recruitment to fish populations from larval fish present in the adjoining coastal water. However, if this is done before estuary water level has reached its maximum height and the bar is ready to break naturally there may be insufficient flow to scour a good channel. Without this scouring the premature opening is thought to accelerate the natural rate of infilling of the estuary with marine sand that is washed in while the bar is open.

Conservation of the catchment soil is as important for the estuaries as it is for good agronomic management of the catchments. Clearing in the catchment, and the resulting increased river flow, may have been beneficial to Stokes Inlet by the bar breaking more frequently, so allowing fish stocks to be replenished and preventing mass fish mortalities. However, as reported in Section 3.4, clearing has been followed by greatly increased sediment deposition in the estuary and the basin is shallowing rapidly. Oldfield Estuary and Barker Inlet are already so shallow that the water often becomes seriously hypersaline or dries up altogether. Stokes Inlet is still relatively deep and always holds water that is seldom so saline that the fish die. It will be a tragedy if it too becomes so shallow that it dries up.

The blowout on the western shore of Stokes Inlet channel is a spectacular feature. However sand cascading from it is a third source of the sediment that is progressively filling the Inlet, here at its deepest part. There is no measure of the quantity of dune sand contributing to shallowing the Inlet. Nevertheless it should be prevented by establishing appropriate vegetation to stabilise the blowing sand.

The estuaries are surrounded by bush in National Park and Shire reserves, containing a wealth of native plants and animals. It is important to preserve the bush, for the benefit of the estuaries themselves and for the pleasure it gives to those who use them. Visitors must be encouraged to show more concern for the environment, and for other users, than has sometimes been shown in the past. For example campers have already seriously damaged paperbark trees and other vegetation on the shores of these estuaries.

As yet there is no management plan for Stokes National Park, but the initiation of a fauna and flora survey is welcomed. The Esperance Shire proposes to provide camping and other facilities on the eastern shore of Oldfield Estuary, to upgrade tracks to these and close other tracks. If greater use is made of the estuary and its environs care will have to be taken to ensure protection of the vegetation along the high eastern shore and the dunes.

10 FURTHER INVESTIGATION

The information reported in this Study is based largely on the recollections of local residents and fishermen and limited observations made by the authors and other scientists on sporadic visits to the estuaries. There have been no continuing, coordinated studies such as are essential to a proper understanding of the ecology and problems for management. It is obvious that there are still many gaps in our knowledge of these estuarine environments.

The most important gaps at the present time relate to river flow to the estuaries, the input of sediment, the behaviour of the bars in relation to the retention of water, and the resulting viability of the estuarine habitats for fish and other fauna. The urgent need is to determine the present rate of sediment accumulation, as has been done by the preliminary study of Stokes Inlet sediments (Section 3.4). It would also be valuable to establish the long term history of the estuaries, as has been done by deep coring in many estuaries of New South Wales (Roy, 1984). Sediment input to estuaries represents sediment lost from catchments, much of it soil the agricultural land can ill afford to lose. Catchment management investigations now being made in higher rainfall areas west of Albany will provide valuable information about both soil and nutrient loss there, but the limited evidence available from our studies suggests that soil loss, and the unwanted gain to the estuaries, is much greater in the lower rainfall areas east of Albany. Valuable efforts are being made to conserve the soil by farmers and others in the Soil Conservation Districts Advisory Committees, in the present instance especially the Esperance SCDAC, but much more still needs to be done.

Accurate estimates of the long term behaviour of the catchments, rivers and estuaries can only be made on the basis of statistical analysis of continuous river flow records. It is essential that the Water Authority streamflow gauging stations east of Albany be maintained and if possible extended so that quantitative estimates of flow, salt, nutrient and sediment loads can be made. There are only limited records for the Young and Lort rivers and none for the Oldfield River. The rivers are too saline to be a source of potable water, but the dynamics of the estuaries depends greatly on the volume and pattern of flow in the tributary rivers.

There is little evidence of eutrophication in the four estuaries from excessive nutrient input; nevertheless experience in other estuaries of the south coast with cultivated catchments (Wilson Inlet and Beaufort Inlet especially) indicates the likelihood of increased nutrient input and consequent excessive algal growth. It would be wise to sample estuary water for nutrients on a regular basis, also river water when it is flowing.

As noted above, there is much controversy on the subject of bar opening, with little factual information on which to base rational decisions for management. Premature breaching may be followed by a shorter open time than if the bars are allowed to open naturally, less effective scouring of the channels, and less flushing of estuary water to sea. Prolonged opening of the bars, without continued strong river flow, may allow an increased net input of beach sand and further shallowing the estuaries. At present there is no basis for judging what the long term effect of premature breaching of the bars will be on the estuaries. The estuaries differ in form and dynamics and what may be wise management for one may be inappropriate for another. It would be valuable to have records of dates of the opening and closing of the bars in relation to river flow and beach dynamics.

Barker Inlet is no longer an estuary in the usual sense of the word. The other three are nearing the end of their lives, as estuaries, through normal environmental processes, now accelerated by human activities. They can continue to be healthy systems for many years to come if properly managed, but rational management decisions can only be made on the basis of reliable information. This is to advocate a study of the dynamics of the estuarine systems. Data relevant to such a study include: records of river flow, water level changes in the estuaries relative to sea level (especially when the bars are closed), salinity of the estuary water, plant nutrients in estuary and river water, and the condition of the aquatic plants. These records and samples should be taken regularly, preferably over a number of years. It would also be valuable to have accurate bathymetric surveys of Stokes and Oldfield estuaries.

The four estuaries are a most interesting series biologically and geomorphologically, with significant individual features. They offer a fascinating field for study both into the response of the flora and fauna to the changing hydrological environment and into the evolution of the physical features of the estuaries. With the exception of Barker Inlet they are highly productive in spite of the extreme hydrological conditions, even though the fisheries to a large extent depend on recruitment from external sources, the sea and pools in the rivers. They warrant the further study suggested, to provide information which will help to secure their future as attractive environments both for the plants and animals that inhabit them and the humans that visit them.

11 ESTUARIES EAST OF ESPERANCE

East of Esperance the coastline of the Shire is similar to that to the west (Section 2.3) as far as Cape Arid. It lies east-west, with a series of shallow bays between rocky headlands. However the bays are generally smaller, the headlands more numerous, and offshore there are the many islands of the Recherche Archipelago. East of Cape Arid, from Cape Paisley, the coast veers north east and is of a totally different character, devoid of water courses.

Rainfall is relatively high, about 600 mm, along the coastal strip between Esperance and the Cape Arid peninsula, but falls off rapidly inland. There are many small creeks and rivers, only a few of which have estuaries. One creek opens to the shore close to the western face of the Cape Le Grand massif and another forms a small lake at Thistle Cove on the Cape. Jenamullup Creek flows to the beach against a rocky headland on the west side of Cape Arid. The flow from Lake Boolenup (just west of Thomas River) and many other creeks disappears in the coastal dunes and rarely reaches the sea.

Immediately east of Esperance, Bandy Creek was an estuary until the small boat harbour was constructed in 1982 and a dam wall built preventing sea water entering it. Eastwards to Cape Le Grand a series of creeks drain through the wide belt of Quaternary dune sands behind the long, high energy, west facing beach.

East of Cape Le Grand the land rises steeply from the coast to the sandplain of the plateau at about 80 m above sea level. Here the creeks and rivers have cut narrow valleys in the soft spongolite (Pallinup Siltstone) rock that borders the coast and overlies the harder granite bedrock. The coastal headlands are granite, as are the islands of the Archipelago and outcrops in the sandplain inland. There is a narrow band of dune sands along the coast, bound by vegetation or interrupted by blowouts, and some stabilised as a soft dune rock. The carbonate content is low and decreases eastwards, the dunes near Cape Arid being a fine white silica sand. The geology of the area is described and figured by Morgan and Peers (1973) and Lowry and Doepel (1974).

Between Cape Le Grand and Duke of Orleans Bay the creeks are short and probably only hold water following winter rains. East from Duke of Orleans Bay there are again many short creeks, but here several rivers have excavated deep valleys in the spongolite rock and discharge to narrow, riverine estuaries 1 to 2 km long (Figure 11). The heads of the creeks are only about 10 km from the coast on the edge of the plateau. These are: the Dailey River, Mungliginup Creek, Alexander River, Blackboy Creek, and Thomas River. The estuaries are all (or shortly will be vested) within reserves; the first four in small reserves managed by the Shire and Thomas River in Cape Arid National Park. Other vacant

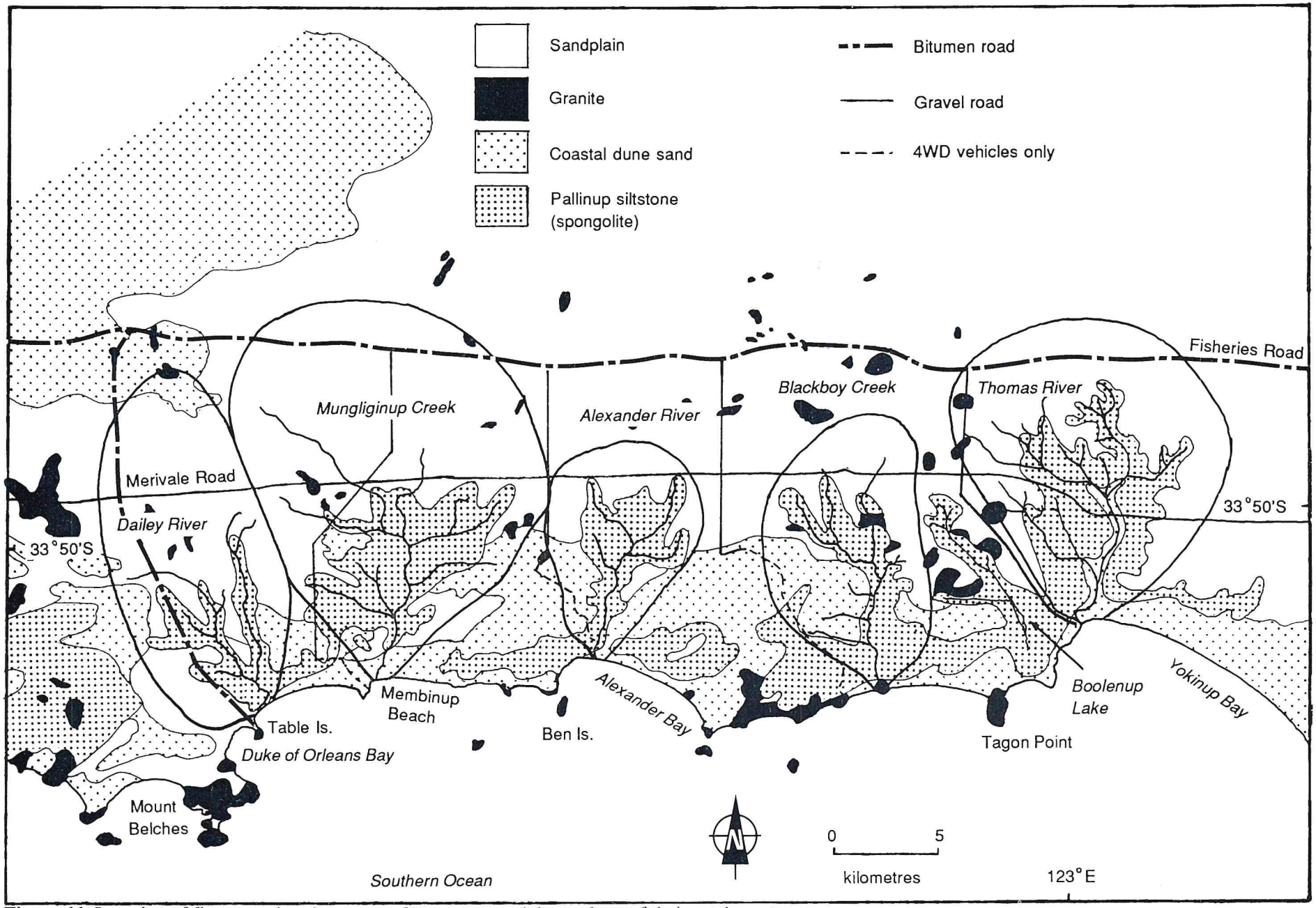


Figure 11 Location of five estuarine rivers east of Esperance and the geology of their catchments.

Crown Land from Mungliginup Creek to Cape Arid National Park will be incorporated in a proposed Nature Reserve. The estuaries are in uncleared coastal bush but the tributaries extend into cleared farm land on the plateau though the deep tributary gullies are still largely uncleared. Small dams have been constructed in a number of them. Most of the clearing was done in the late 1950s and the 1960s.

Further east, in the Cape Arid National Park, creeks have carved valleys in the granite. Two of these discharge to small estuaries on the eastern shore of the peninsula: Jorndee Creek and Poison Creek (names that appear on few maps).

Small though these seven estuaries are they are of great natural beauty and it is to be hoped that care will be taken in their management. They are of considerable interest and there should be further study of them. They differ from most estuaries further west being in narrow valleys cut deep through the spongolite and dune sands or, at Cape Arid, in granite. In form they resemble the riverine estuaries of the Donnelly, Warren and Gardner rivers, in the Shire of Manjimup, which cut through Pleistocene dunes in the high rainfall south west. But hydrologically and biologically they are totally different. In contrast to the mainly fresh water of the three western estuaries the water is brackish to more salt than the sea.

Table 11 lists fish netted in the estuaries by Fisheries Department staff in May 1977. Recreational fishing is mainly in the Dailey River, Munglinup Creek and the Thomas River. The principal species caught are Black bream, Sea mullet and Yelloweye mullet. Thomas River is reported to be a good Mullet nursery.

The estuaries have only been visited once briefly by one of us (EPH) in company with Fisheries Department staff in May 1977, and the accounts given here derive mainly from that trip and from air photographs (principally WA 1778(C) Bunbury - Israelite Bay, Job No. 770049 of 22.11.78).

Access to the estuaries is from Merivale Road (gravel) or from Fisheries Road, bitumen to Tagon Road. An account of the natural resources of the coastline from Cape Le Grand eastwards to the Thomas River, with recommendations for management, will be found in Craig and Oma (1984).

11.1 BANDY CREEK

This Creek is no longer estuarine, having been dammed close to the mouth to make the small boat harbour. However before 1982 it was estuarine for perhaps 3 km, winding in a channel less than 10 m wide between steep banks through the coastal dune sands. It widened to about 200 m at the mouth and was closed by the beach, here 100 m wide and of fine white sand. The beach was low and waves washed over it into the estuary.

Bandy Creek flows 30 km from salt lake country on the sandplain, at 160 m above sea level, and through the swamp and lake system of the Lake Mullet Nature Reserve north east of Esperance.

Salinities recorded in the estuary: 12.4.1971 - 11.5 ppt; 3.5.1977 - 30 ppt.

11.2 DAILEY RIVER

Dailey River and Duke Creek flow in narrow, parallel valleys cut into the spongolite rock which join 1 km from the coast. At the coast the river turns abruptly south west behind the beach for 2 km. It is only this coastal reach that is estuarine, with perhaps a short length of the valley (Figure 11.2). The greater part of the catchment is in cleared land with only the valley bottoms remaining in bush.

The northern part of the estuary lies between the high, densely vegetated foredune and rising land with low coastal scrub. The dune narrows southwards and becomes little more than a beach ridge with scattered vegetation, and on the landward side the estuary is separated from a small swamp by dune. Rushes (*Juncus*) and paperbark trees (*Melaleuca*) fringe part of the estuary and windclipped *Banksia speciosa* is dense along the dunes.

The estuary is 7 to 10 m wide and 2 m deep. It discharges across the beach at the end of the tombolo

Table 11 Fish species caught in Bandy Creek (BA), Dailey River (DR), Mungliginup Creek (MG), Alexander River (AL), Jorndee Creek (JN) and Poison Creek (PO). (R.C.J. Lenanton & G.M. Cliff - WA Fisheries Department)

		BA	DR	MG	AL	JN	PO
Atherinidae:	Elongate hardyhead *Atherinosoma elongata*	+	+	+	+		
Atherinidae:	Swan River hardyhead *Atherinosoma presbyteroides*	+	+	+	+	+	
Arripidae:	Western Australian salmon *Arripis truttaceus*	+		+		+	
Sparidae:	Black bream *Acanthopagrus butcheri*	+					+
Mugilidae:	Yelloweye mullet *Aldrichetta forsteri*	+	+	+	+	+	+
Mugilidae:	Sea mullet *Mugil cephalus*		+	+	+	+	+
Gobiidae:	Long-finned goby *Favonigobius lateralis*	+					
Gobiidae:	Blue spot goby *Pseudogobius olorum*	+		+	+		

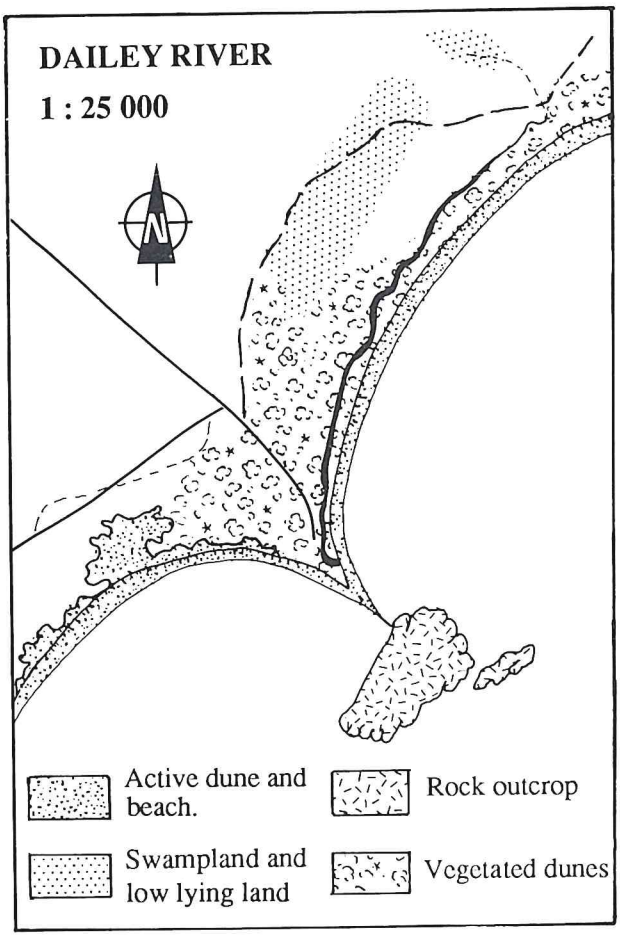


Figure 11.2 The estuary of the Dailey River.

which connects Table Island to the shore. It is reported to break through the beach frequently. The sparsity of vegetation along the southern part of the shore dune suggests that estuary water may break through further north during floods. The beach faces east and the mouth is in the shelter of Table Island and the tombolo and by Mount Belches.

Salinity of estuary water was from 8 ppt to 10 ppt near the mouth on 4.5.1977. The presence of shells of the small gastropod *Coxiella* sp. suggests that the water is sometimes hypersaline. Much decaying seagrass is washed across the beach into the estuary, probably providing a rich food source for the fauna. Fishing is reported to be good in the estuary.

Access to the estuary is from Orleans Bay Road (bitumen) off Merivale Road 65 km east of Esperance. The road continues to Duke of Orleans Bay where there is a Caravan Park, general store and camping area at Wharton townsite in the shelter of Mount Belches. The Duke of Orleans Regional Reserve extends from the Cape Le Grand National Park to Mungliginup Creek.

11.3 MUNGLIGINUP CREEK

Mungliginup Creek flows in a narrow valley close to the coast and branches into cleared land on the plateau, only the steep slopes and valley bottoms of

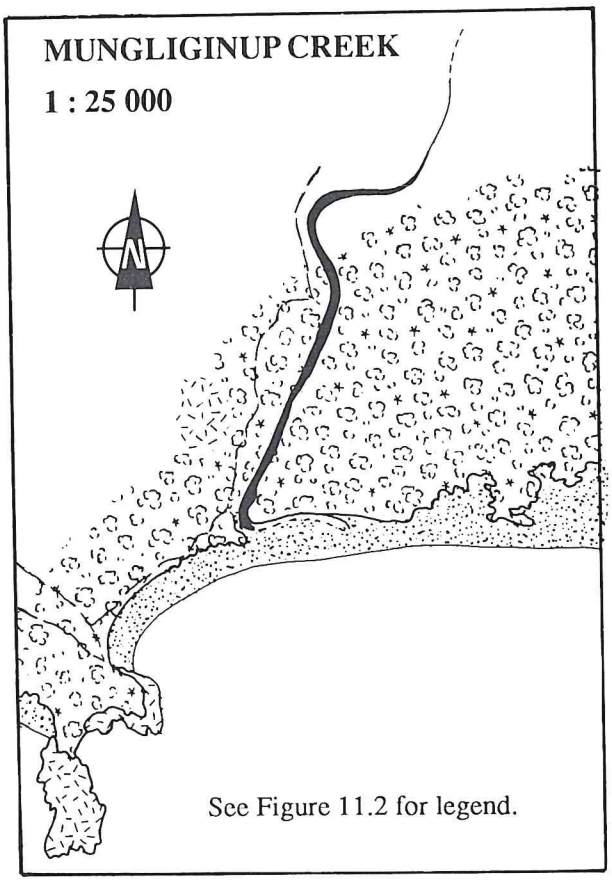


Figure 11.3 The estuary of Mungliginup Creek.

the tributaries are still in bush. The estuary lies perpendicular to the coast in a narrow riverine reach 2 km long between steep banks (Figure 11.3). There is spongolite rock along much of the high east bank, but on the west and near the coast the banks are well vegetated coastal dune sands. Near the coast the estuary is 20 m wide and over 2 m deep, but narrows to less than 10 m towards its head.

The mouth is within 500 m of the western end of the 4 km long, south facing Membinup Beach and is sheltered from south westerly winds and swell by the rocky headland of Membinup Point. The estuary opens onto a 200 m wide beach of fine white silica sand across which it may flow in flood. But from that position it cuts a shallow channel eastwards behind the beach and against the dunes for about 300 m, at which point it is closed by beach sand.

The estuary always holds water, but the bar is reported to break infrequently, at intervals of several years. When visited on 6.5.1977 the bar was closed and the salinity of the water was 46 ppt at the mouth and 42 ppt 1.2 km up the estuary. River water is always salty and flowing water in a tributary creek had a salinity of 26 ppt. *Ruppia* and the alga *Polyphysa* were growing in the estuary and the small bivalve mollusc *Spisula trigonella* was abundant.

Access to the estuary is from Daniels Road off Merivale Road 77 km east of Esperance, thence by a bush track to the beach at Membinup Point. There is a small camping area with a borehole toilet close to the estuary.

11.4 ALEXANDER RIVER

The Alexander River and its small tributaries have cut deep, narrow valleys in the spongolite rock. In the cleared land of the upper tributaries the steep slopes only carry a sparse cover, with a narrow ribbon of bush in the valley floors. About 1 km of the river is estuarine and this also is in the spongolite except close to the mouth (Figure 11.4). There, on the west, a narrow foredune lies between the beach and the shallow sandy soil covering the rock. On the east a blowout has piled beach sand over the rock in a small dune. Spongolite rock outcrops in the beach 200-300 m on either side of the estuary mouth.

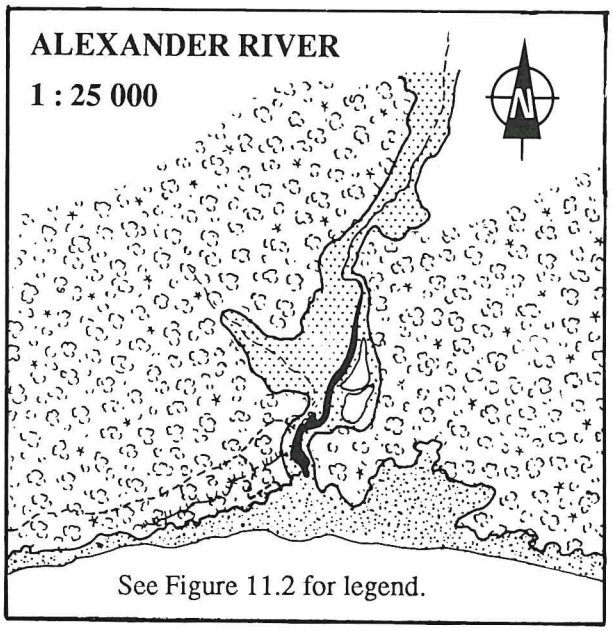


Figure 11.4 The estuary of the Alexander River.

The valley widens near the coast and rushes, samphire and dense paperbark scrub border the estuary which is only 10 m wide. The estuary opens into the deep curve of Alexander Bay, 3 km from the western rocky headland. The headland and Ben Island give it limited shelter from south west winds and swell. The fine white silica sand of the beach fills the mouth of the estuary which is set back 200 m from the line of the otherwise narrow beach.

When visited on 6 May 1977 salinity of the water was 26 ppt, it was brown and dirty, with floating mats of blue-green algae.

Access is to the western side of the estuary from Alexander Road off Merivale Road 85 km from Esperance, thence for 4 km of eroded bush track to the beach and behind the dunes or along the beach to the mouth. There is a small camping area with a borehole toilet.

11.5 BLACKBOY CREEK

The topography of the catchment of Blackboy Creek is similar to that of the three previous estuaries, being cut into a deep, north-south valley in spongolite rock. The greater part of catchment is in bush, only the higher ground of the upper tributaries being cleared. The estuarine part, 1 km long, is bordered by dune sands in which there is a blowout on the western side (Figure 11.5). It is only about 10 m wide. There is dense vegetation to the east of the mouth against the rock outcrop in the beach. The estuary discharges across a 250 m wide, south facing beach, a similar distance west of the rock outcrop. The bar is reported to only break infrequently. We have not visited the estuary and have no information on the condition of the estuary water.

Access is by a bush track from Exchange Road off Merivale Road 93 km east of Esperance. This leads to a rock outcrop on the beach 1.5 km west of the mouth. The Esperance Surfcasters Club has a hut at the Creek to which there is public access.

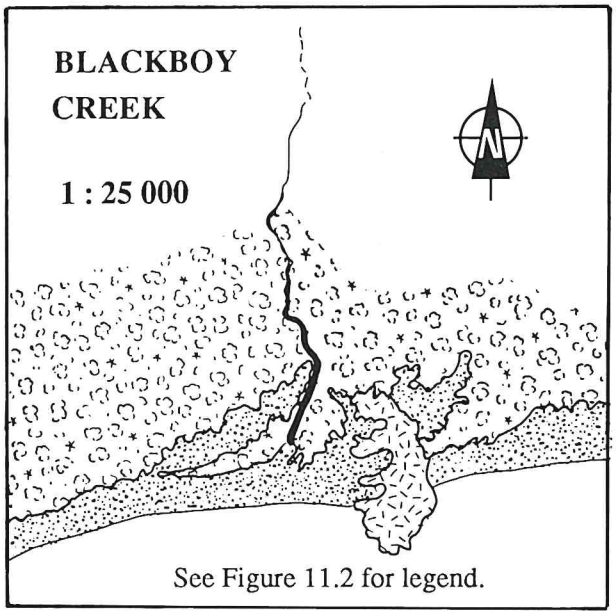


Figure 11.5 The estuary of Blackboy Creek.

11.6 THOMAS RIVER

The estuary of the Thomas River opens at the extreme western end of the 18 km long, south west facing beach of Yokinup Bay to Cape Arid (Figure 11.6). The river has cut deeper into the spongolite rock of the catchment than have the rivers discussed above and the narrow valley bottom is filled with river sediment for 7 km from the mouth. The main valley of the river is in the National Park, but the tributaries extend into cleared land on the plateau with the gullies still in bush.

At the beach the estuary is 600 m from the sheltering western, granite headland. Here the channel turns abruptly west behind a lightly vegetated beach ridge and against the foredune. A pool persists in the

beach when the water ceases to flow. The estuary is narrow (20 m) and shallow near the mouth where sand falls into it from a small blowout on the eastern bank. It then widens to about 20 m for 500 m before narrowing to 10 m or less. A small tributary creek flows into the estuary from behind the western dunes near the mouth. Observed salinities: October 1971- 22.5 ppt, 7.5. 1977- 26 ppt.

The beach is a fine white silica sand, but rhizomorphs (calcification around old roots) in the blowout indicate a proportion of carbonate sand. Eastwards the dune field widens greatly and there is an extensive blowout in the predominantly siliceous dunes.

The estuary is in the Cape Arid National Park, with a small Shire Reserve on the west bank of the river. Access to the estuary and to the Park Ranger's residence is by Tagon Road (gravel) from Merivale Road 105 km east of Esperance. There is a campsite near the mouth of the river with borehole toilets, but no drinking water.

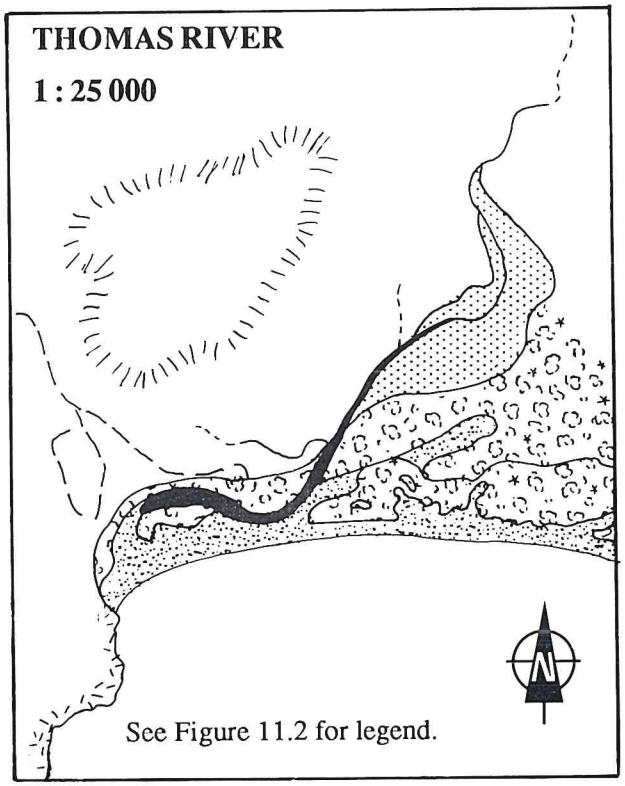


Figure 11.6 The estuary of the Thomas River.

11.7 JORNDEE CREEK

Jorndee Creek is cut into the granite rock of the eastern face of Cape Arid, with sandy alluvial soils in the valley bottom. The small estuary at the mouth of the Creek is of particular interest because it is the only estuary east of Albany (except the Waychinicup gorge) that is permanently open to the sea. It opens eastwards onto a low granite shore that bars the mouth at the south end of a small sandy bay and foredune (Figure 11.7). Tidal flow washes sea

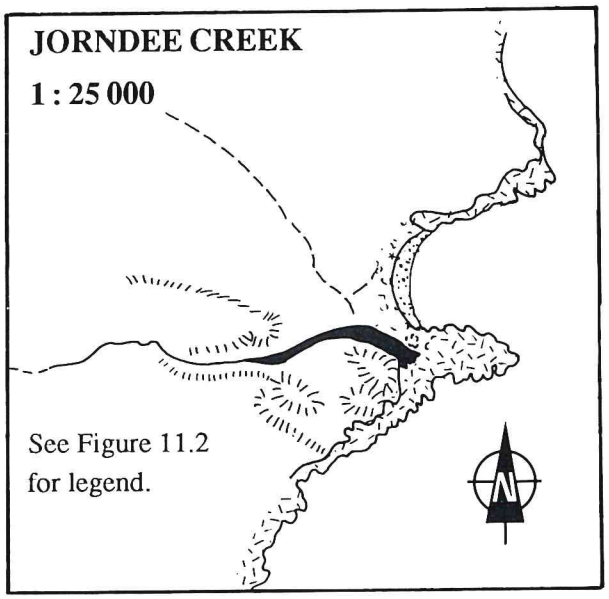


Figure 11.7 The estuary of Jorndee Creek.

water in and out over the rock bar and carries sand in from the beach and up the estuary so that the water is very shallow. The estuary empties at low tide.

The estuary is 500 m long and 5 -7 m wide between steep banks with a dense cover of paperbarks and banksia (*Banksia speciosa*), which block the channel at the head. It widens to about 50 m near the mouth with rushes and samphire along the shore and a wide flat with *Suaeda*.

Water in the estuary was of sea water salinity when visited on 5.5.1977 and on 11.4.1971; this is presumably the normal situation except when the creek is flowing.

The estuary is in the Cape Arid National Park. Access is by a bush track (2 km) off Poison Creek Road. There is a camping area with borehole toilets at the end of the track on the north side of the estuary.

11.8 POISON CREEK

Poison Creek flows off the granite of Cape Arid, through a sandy alluvial plain, and discharges to the small estuary between low granite hills (Figure 11.8). The estuary opens across a low sand bar close to a granite headland at the southern end of the 1 km long beach of a small bay. Fern Creek ends against the granite headland at the east end of the bay but does not break through the dune to the sea. A narrow channel winds from Fern Creek behind the foredune and against the granite to connect with Poison Creek through which it discharges. There are dune rock bars between pools in the connecting channel.

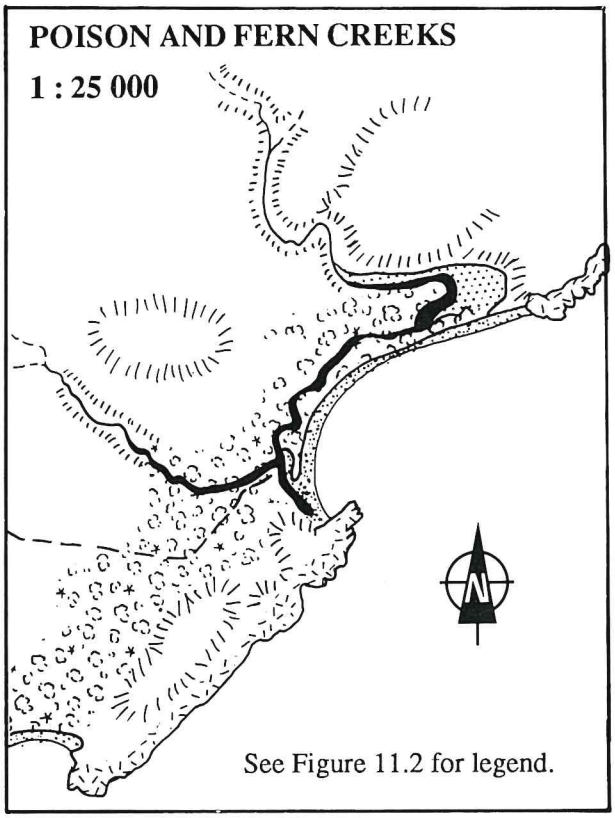


Figure 11.8 The estuary of Poison and Fern creeks.

The estuary is 700 m long, about 15 m wide and shallow near the mouth, it narrows to a few metres at the head. Dense paperbark thickets clothed the banks near the mouth, but these have been badly degraded by campers. This area has now been closed and will be rehabilitated. There is only sparse vegetation further upstream, possibly following severe burns.

Beach sand closes the mouth of the estuary. Salinity of the estuary water was 46 ppt when visited on 5.5.1977 and 20 ppt in a pool near the head of the estuary. A salinity of 51 ppt was found near the bar on 11.4.1971.

The estuary is in the Cape Arid National Park. Access is by Baring Road and Poison Creek Road (gravel) off Fisheries Road. The camping area has been relocated 2 km west to Seal Creek, but camping is still permitted on the beach. The location of Jorndee Creek and Poison and Fern creeks is shown in Figure 11.9.

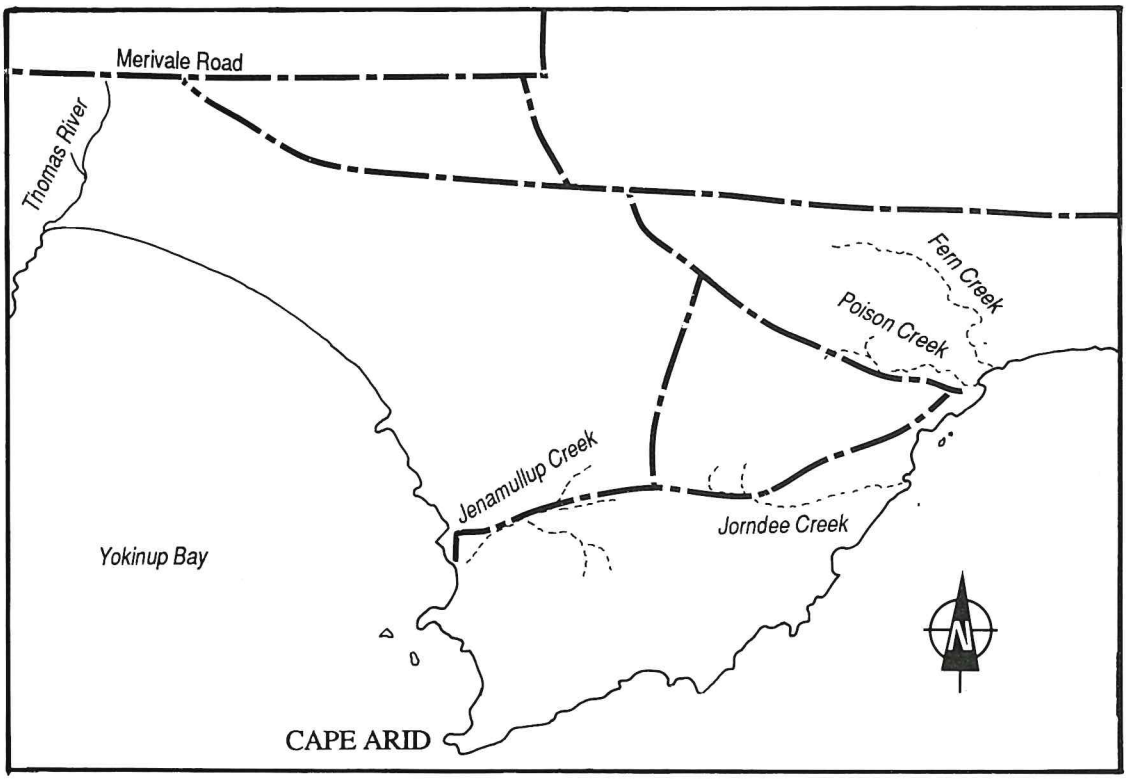


Figure 11.9 Location of Thomas River, Jenamullup, Jorndee, Poison and Fern creeks.

12 ACKNOWLEDGEMENTS

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The data in this series of studies have been gleaned from a variety of sources - published reports, unpublished records of government departments and the personal observations of the authors. However it will be obvious that there are still many gaps in our knowledge of these estuaries and the authors will greatly appreciate the continued assistance of those who have contributed in any way to the study and of anyone else who has relevant information on any estuaries of the south coast.

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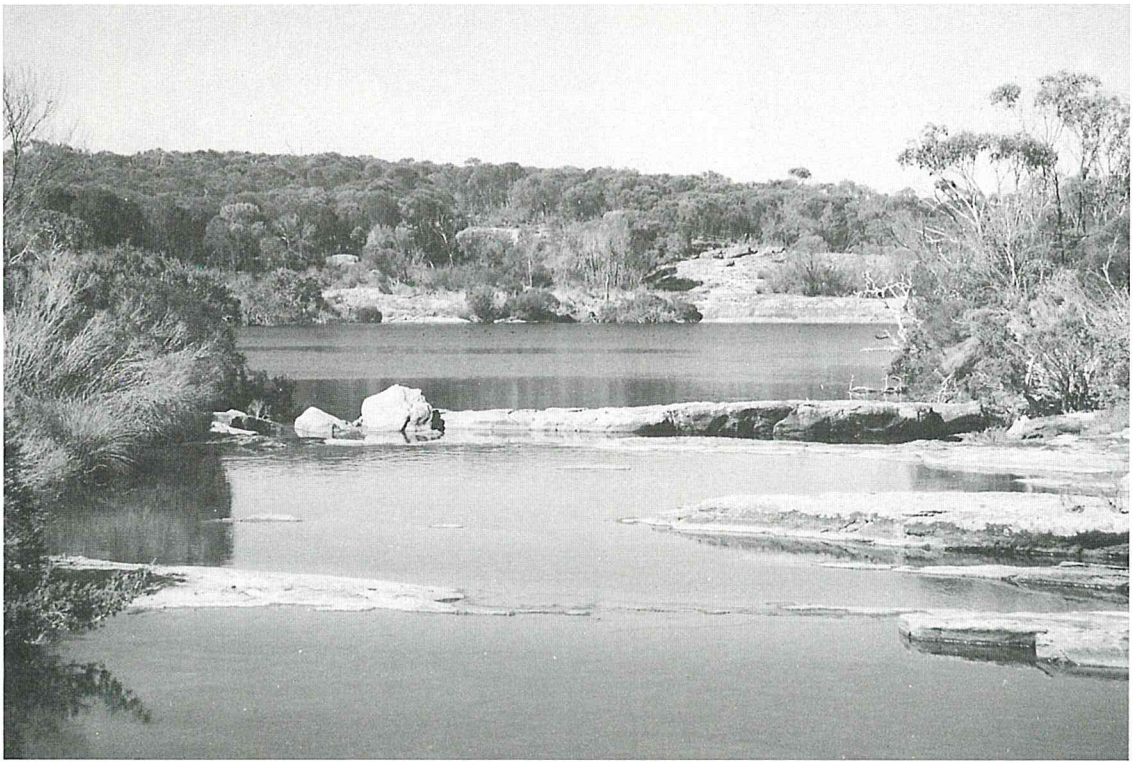
Polyphysa peniculus, a common aquatic plant.

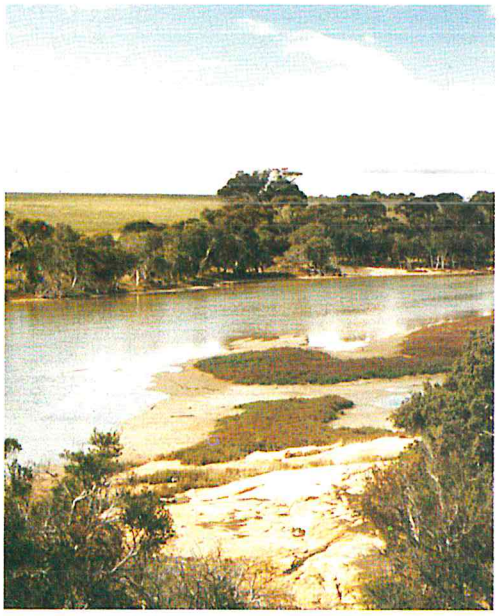


A pool in the Young River at the Jonegatup Road crossing.

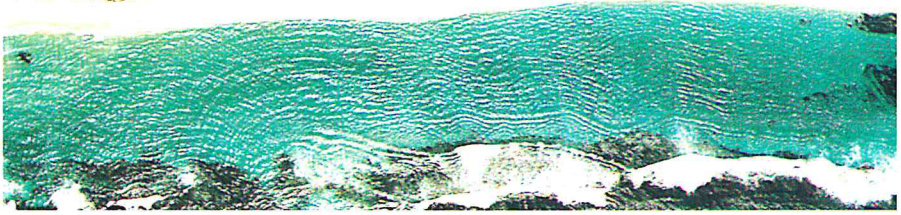
Torradup estuary, view upstream from the mouth.

Above: TORRADUP estuary
Land Administration
December 1988.

Top Right: BARKER INLET
Land Administration
December 1988.



Above: An estuarine stretch of
YOUNG RIVER.



Bottom right: OLDFIELD ESTUARY
Land Administration
December 1988