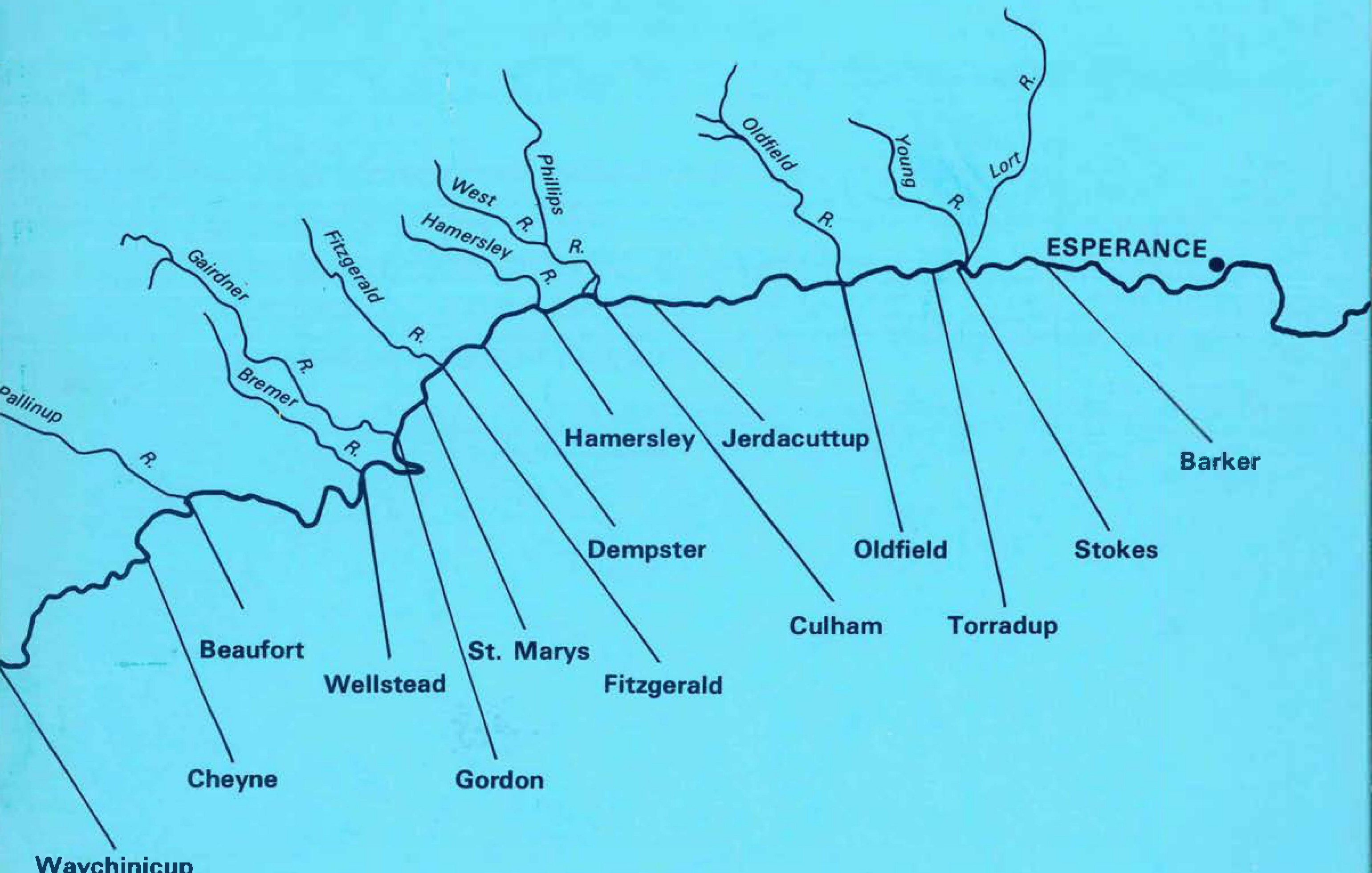
ESTUARIES AND COASTAL LAGOONS OF SOUTH WESTERN AUSTRALIA

AN INVENTORY

NUMBER ONE

WELLSTEAD ESTUARY

THE ESTUARY OF THE BREMER RIVER



Environmental Protection Authority
Perth, Western Australia

Estuarine Studies Series No. 1.

June 1987

ERRATA

Page 8 Caption: **Figure 3.12** Wellstead Estuary. Geomorphology of the estuary. (R. Colman, I. Eliot)

Page 16, Section 5.2: *Polypogon monspeliensis*

Page 17, Table 5.2: *Polypogon monspeliensis*

Section 5.4: *Cakile, Acacia, Exocarpos, variifolia*
for 'asociation' read 'community'

Table 5.41: *Angianthus cunninghamii*
Billardiera variifolia
Exocarpos sparteus
delete second *Euphorbia paralias*

Page 18, Table 5.42: *Westringia dampieri*

Page 19, Table 6.22: *Fulvia tenuicostata*

An Inventory of Information on the

ESTUARIES AND COASTAL LAGOONS OF SOUTH WESTERN AUSTRALIA

WELLSTEAD ESTUARY

Wellstead Estuary May 1987 Photo Stuart Chape

By

Ernest P. Hodgkin and Ruth Clark

Environmental Protection Authority
Perth, Western Australia

Estuarine Studies Series - No. 1
June 1987

INVENTORIES OF THE ESTUARIES AND COASTAL LAGOONS
OF SOUTH WESTERN AUSTRALIA

Earlier this year on behalf of the State Government I released the State Conservation Strategy.

This inventory of the Wellstead estuary is one of the steps towards implementation of the strategy. It is the first in a series being prepared to summarise and interpret available data on the estuaries of the south-west Western Australia.

Estuaries attract residential development for permanent and holiday - type accommodation such as camping grounds and caravan parks and as a result, they are coming under increasing pressure. Even some of those in National Parks are affected by clearing in the catchments of their tributary rivers, so altering the pattern of river flow and sediment transport.

The data in the inventory are gleaned from a great variety of sources - published reports, unpublished records of Government departments, the records and recollections of fishermen and others with local knowledge, and the results of a few specially contracted studies. I would appreciate it if anyone with further relevant information on this and any other estuary could contact the Estuarine Studies Branch of the Environmental Protection Authority so that the data base is maintained and updated.

The principal author and co-ordinator of this work - Dr Ernest Hodgkin is a much respected scientist who has dedicated himself over the past 13 years in particular, to studying estuarine and marine areas subject to environmental stress. His work on Hardy Inlet at Augusta, and more recently on the Peel-Harvey estuary, has lead to a better understanding of these sensitive environments and how they function, as well as providing management solutions to environmental problems. It is fortunate that his talents have now been directed to developing these inventories of information on the South-west estuaries with the assistance of his co-author Ruth Clark.

Few estuaries of the South-West conform to the usual definition of an estuary - the mouth of a tidal river where there is a mixing of salt water and fresh water. Most, if not all, were flooded 6000 to 8000 years ago after the last Ice Age. But sand bars now block the entrances and the estuaries are only briefly and irregularly open to the sea, the tributary rivers flow intermitently and for much of the time there is no mixing of sea water and water from the land, which in many cases is saline.

In consequence our estuaries are different in many respects from those in most other parts of the world, and present unusual problems for management, and for the plant and animal life. These and other aspects of the estuaries and coastal lagoons of the south coast - their geological history, coastal features, climate, riverflow and sedimentation - will be discussed in a comparative account that is being prepared as part of this Estuarine Studies Series and will stress the similarities and differences between them.

I am certain this inventory of the Wellstead Estuary will be an invaluable source of information to organisations such as local authorities, planners and conservation groups, as well as individuals, such as students, interested in the management or further study of our estuaries and coastal lagoons.

Hon Barry Hodge, MLA
Minister for the Environment

1. INTRODUCTION

Wellstead Estuary is the estuary of the Bremer River. It is about 180 km north east of Albany in the shire of Jerramungup at the small town of Bremer Bay. The catchment is relatively small and lies in the coastal belt with low (400 to 600 mm) rainfall, but heavy rains in winter or summer can cause flash floods of considerable volume. The mouth of the estuary is at the extreme southern end of Bremer Bay against a headland of hard Archaean rock which shelters it from south westerly winds and swell. In this situation the bar is low and breaches more frequently than those of other estuaries east of Albany and may stay open considerably longer. The greater part of the estuary is incised into the relatively soft, flat-bedded Pallinup Siltstone rock and is bordered by steep slopes and cliffs. Although the basin part of the estuary is shallow the upper, riverine part is scoured to depths of 5 m in places.

The salinity of estuarine water varies greatly with rainfall and evaporation and opening and closing of the bar; from almost fresh following heavy rain in the catchment to more than twice sea water salinity when the bar has been closed for a long period in hot dry weather. In consequence there is a very limited variety of plants and animals that now live within it permanently, though at times there is recruitment to it of a more diverse fauna when the bar is open. However, it is evident from the extensive shell beds that before about 4000 years ago the estuary was wide open to the sea and then had the much richer fauna characteristic of a sheltered marine bay such as Princess Royal Harbour has today.

With a good road to it, a sheltered beach of fine white sand, a small town and a caravan park Bremer Bay has become a popular holiday resort. The sealing of Bremer Bay Road in 1977 has contributed to an 80% increase in traffic to the town. However there are intractable problems with the estuary itself. With the low river flow from the small catchment and high evaporation from the shallow water of the basin the salinity of the water can become extreme in years of low rainfall, the water level falls exposing areas of rotting weed adjacent to the town and making it difficult to launch boats into the estuary. The bar is low and the almost unlimited supply of fine beach sand continues to build the massive tidal delta, through which it would be costly to maintain a channel to keep the estuary flushed with sea water. Premature opening of the bar, before there is a sufficient head of water to scour a natural channel, probably enhances the rate of accumulation of delta sand, further shallowing the estuary and making it more difficult to maintain a channel through the delta.

1.1 LOCATION AND ACCESS

Between 119°20' and 119°25' East and 34°20' and 34°25' South. Map reference: 2729 Bremer 200915.

The estuary is approached by a bitumen road from South Coast Highway to Bremer Bay township (60 km). Small boats can be launched opposite the caravan park and at the end of a track through the town, though with difficulty when the bar is closed and the water level is low. Four-wheel drive tracks give access to the estuary shoreline at several points.

2. CATCHMENT CHARACTERISTICS

The Bremer River is the only river flowing to the estuary, it has a relatively narrow catchment aligned in a generally NW-SE direction parallel to the Pallinup and Gairdner rivers. Much of the coastal sandplain to the west has only internal drainage to numerous small swamps and in the absence of clearly defined drainage channels the area of the catchment can only be estimated approximately at 695 km^2.

2.1 GEOMORPHOLOGY, GEOLOGY AND SOILS

The upper reaches of the Bremer River (north of Devils Creek Road) flow through a dissected plateau of hard Archaean granitic rock, capped by sandplain that rises from 20 to 100 m above sea level (Figure 2.1). The sandplain soils are generally sands with some lateritic gravels overlying dense mottled clays, waterlogged in the wetter winters and with little or only sluggish runoff. In its lower reaches the river meanders in a narrow, deeply dissected valley with steep

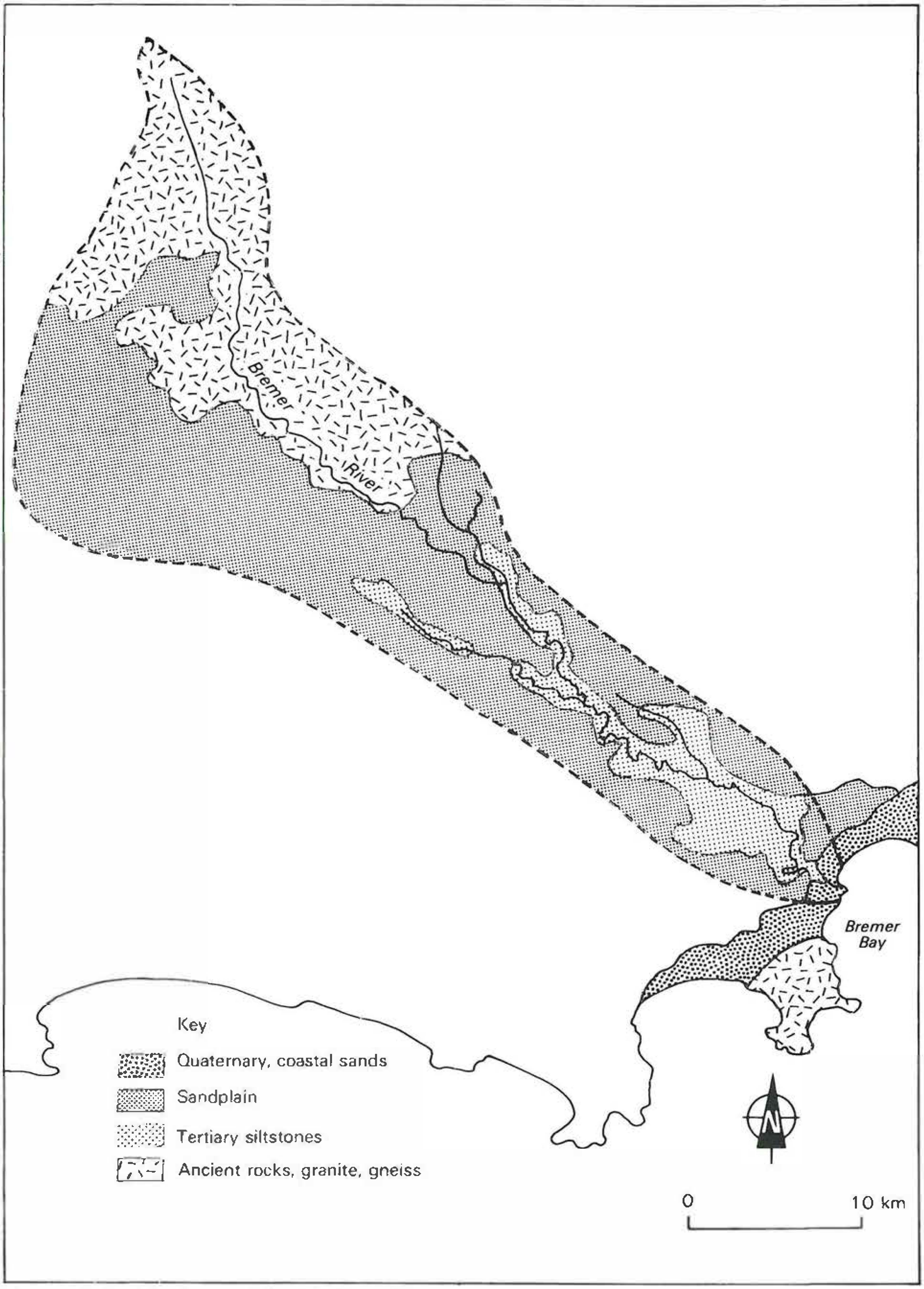


Figure 2.1 Geology of the Wellstead Estuary catchment. Simplified from Thom & Chin (1984)

escarpments exposing the weathered country rocks, mostly the softer, flat-bedded Pallinup Siltstone (Tertiary marine sediments of the Plantagenet Group). These and the clayey slopes below them would provide the main source of fine textured sediments within the catchment. Low, unconsolidated coastal dunes border the mouth of the estuary on its northern side and overlie shell beds which outcrop along the margins of the estuary. Water bores sunk behind the dunes have gone through 1.5 to 2 m thick beds of shell material. The south side of the mouth is bordered by a headland of Archaean rock.

2.2 COASTAL FEATURES

The mouth of the estuary lies at the southern end of Bremer Beach, deep within Bremer Bay, sheltered by granite headlands to the south and east (Figure 2.2). The beach is thus only exposed to winds and waves from the SE, winds that are strong mainly on summer afternoons. Swell is mainly from the south west.

The beach sand is mainly a fine siliceous sand that packs hard allowing vehicles to drive on it. At times waves overtop the bar, carrying beach sand and drift weed into the estuary to contribute sand to the large tidal delta and organic matter to the water.

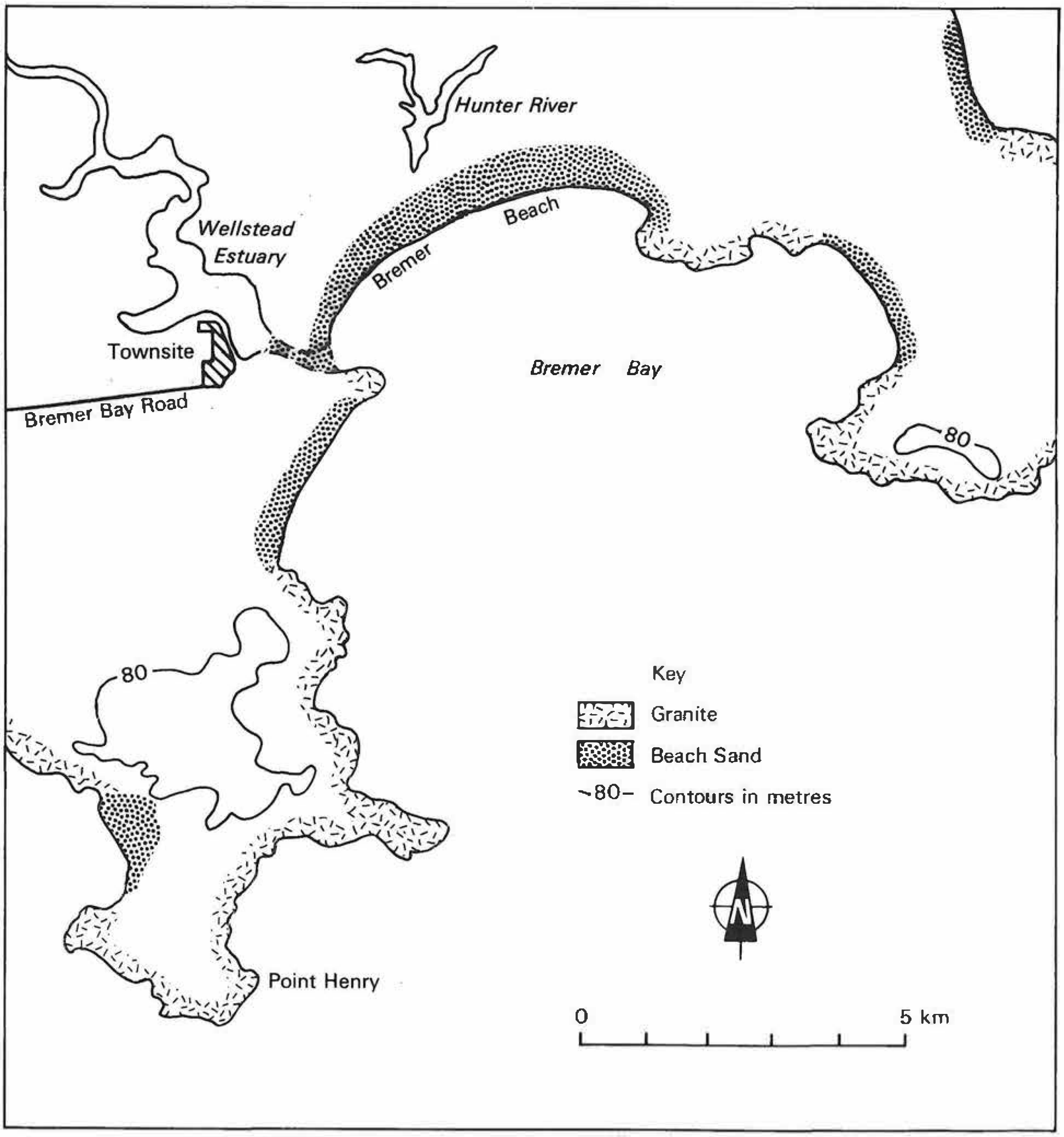


Figure 2.2 Wellstead Estuary. Geomorphology of the coastline.

Tides are mainly of the daily type and small range typical of the south west, with a mean spring range of 0.5 m. Seasonal and meteorological factors result in an overall range of about 1.2 m and storm events may cause an extreme range of 1.8 m (Albany).

2.3 RAINFALL

Mean annual rainfall in the upper catchment is 450 mm, increasing to 600 mm to 700 mm at the coast (Figure 2.3), but with extremes from 959 mm to 442 mm at Bremer Bay (Table 2.3). This is mainly winter rain, but summer cyclonic storms may precipitate 200 mm or more in a couple of days (252 mm in February 1955 at Bremer Bay) and over 150 mm at Jerramungup. An early winter storm in May 1921 produced 401 mm at Bremer Bay.

2.4 RIVERS

The Bremer River is about 70 km in length. Devil Creek is the only major tributary, entering the river on its south side about 20 km from the bar. A number of pools in the river bed, some up to a kilometre long, retain water throughout the year, but apart from these the channel is dry much of the time. Congdon and McComb (1986) record a rich growth of the aquatic plants *Ruppia megacarpa* and *Nitella gloeostachys* in a pool near Gordon Inlet Road.

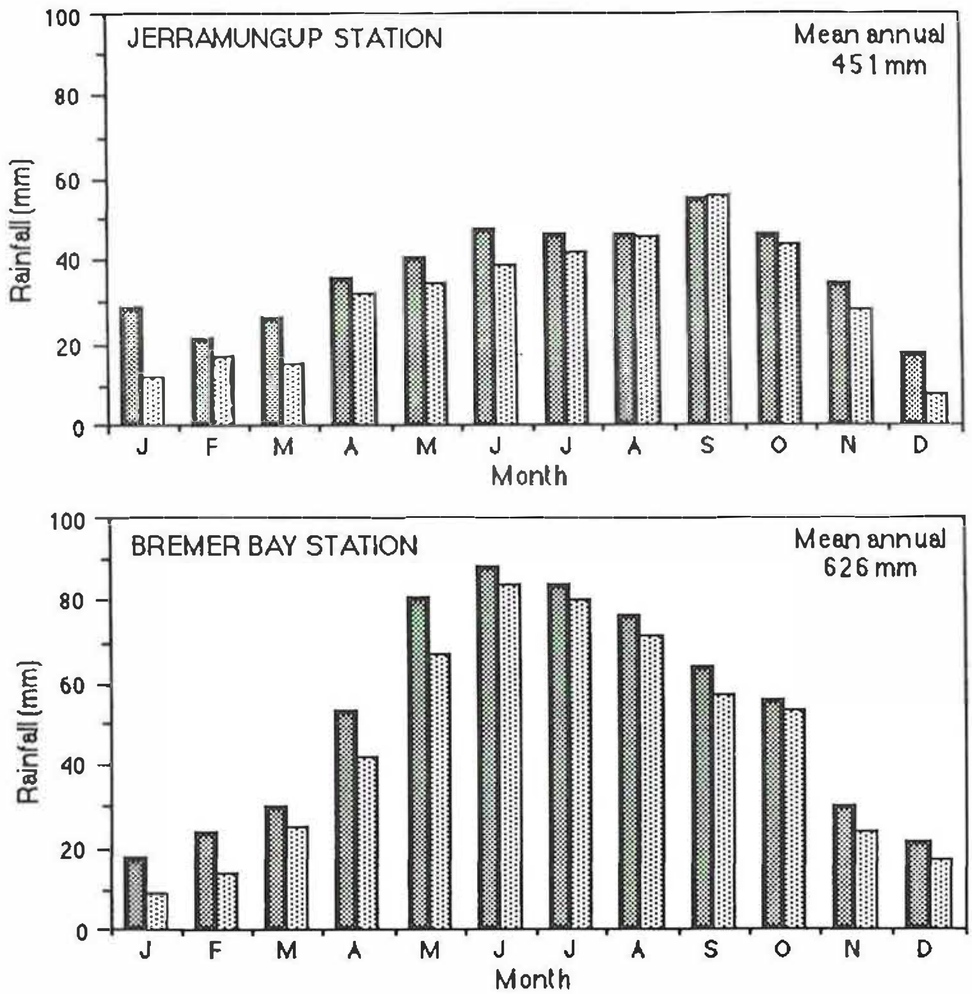


Figure 2.3 Monthly rainfall at Bremer Bay Station (1885-1986) and Jerramungup Station (1963-1986). ▩ means, ▦ medians. (Commonwealth Bureau of Meteorology)

Table 2.3 Rainfalls at the Bremer Bay Post Office and Jerramungup Stations since 1885 and 1963 respectively. (Commonwealth Bureau of Meteorology)

	JERRAMUNGUP	BREMER BAY
Mean annual rainfall	451 mm	626 mm
Lowest annual rainfall	255 mm (1969)	389 mm (1957)
Highest annual rainfall	617 mm (1978)	959 mm (1955)
Highest monthly total	176 mm (Nov 1971)	401 mm (May 1921)
Highest two monthly rainfall	250 mm (Jun/Jul 1978)	443 mm (May/Jun 1921)

DAMS There are no dams on the river.

RUNOFF There are no data on river flow and runoff from the catchment. The estimated mean annual runoff is 3.8 mm, with a mean flow to the estuary of 2.64 x 10^6 m^3 (Ian Loh, WAWA, pers. comm.). Flow follows both from winter rains and from summer cyclonic rains that may cause flash floods.

SEDIMENT TRANSPORT Although there are no data on sediment transport it is clear from the amount of sediment and debris, small trees and other vegetation, that have accumulated on sand banks and in the shallows of the estuary that a considerable quantity has come down the river, probably mainly during floods. However there is no direct evidence that the amount of sediment transported has increased as the result of clearing in the catchment.

WATER CHEMISTRY River water is saline (3-4 ppt in the few samples). There are no available data on nutrients or pollutants.

2.5 LAND OWNERSHIP AND USE

The greater part of the catchment is in alienated land and by 1968 about half, 350 km^2, had been cleared, mainly for pasture (Figure 2.5). A narrow strip of reserve vested in the Jerramungup Shire borders the lower reaches of the river and the upper part of the estuary and this is surrounded by the Fitzgerald River National Park. Crown land borders the northern shore of the lower estuary (Jerramungup Shire Council, 1984).

The townsite of Bremer Bay covers 2 km^2 on the western shore of the estuary. It has a population of about 70 residents, but only one third of the 100 houses are occupied all year. The caravan park and holiday homes accommodate up to 1600 in summer (RAC, 1986). There are no other urban centres in the catchment.

2.6 VEGETATION

Where the land has not been cleared much of the vegetation is high shrubland formations with shrub or mallee eucalypts dominating. *Eucalyptus tetragona, E. redunca, E. gardneri, E. nutans* and *E. eremophila, E. oleosa* alliances form a mosaic over the area, the former on the upper slopes and rises nearer the coast. Patches of mixed heath and low heath of Proteaceae, Myrtaceae and Leguminoseae are present. The heath vegetation merges into and forms the understorey to the high shrubland communities. Low forests of *Eucalyptus platypus, Eucalyptus gardneri, Eucalyptus falcata* alliance occur locally on scarp slopes (K. Newbey, pers. comm.).

The narrow coastal plain has an *Acacia rostellifera, Acacia cyclops, Acacia cochlearis, Agonis flexuosa* scrub alliance. *Banksia baxteri* and *Banksia attenuata* are dominant on the drift sand inland, with *Eucalyptus marginata* and *Eucalyptus cornuta,* the latter restricted to interdunal flats.

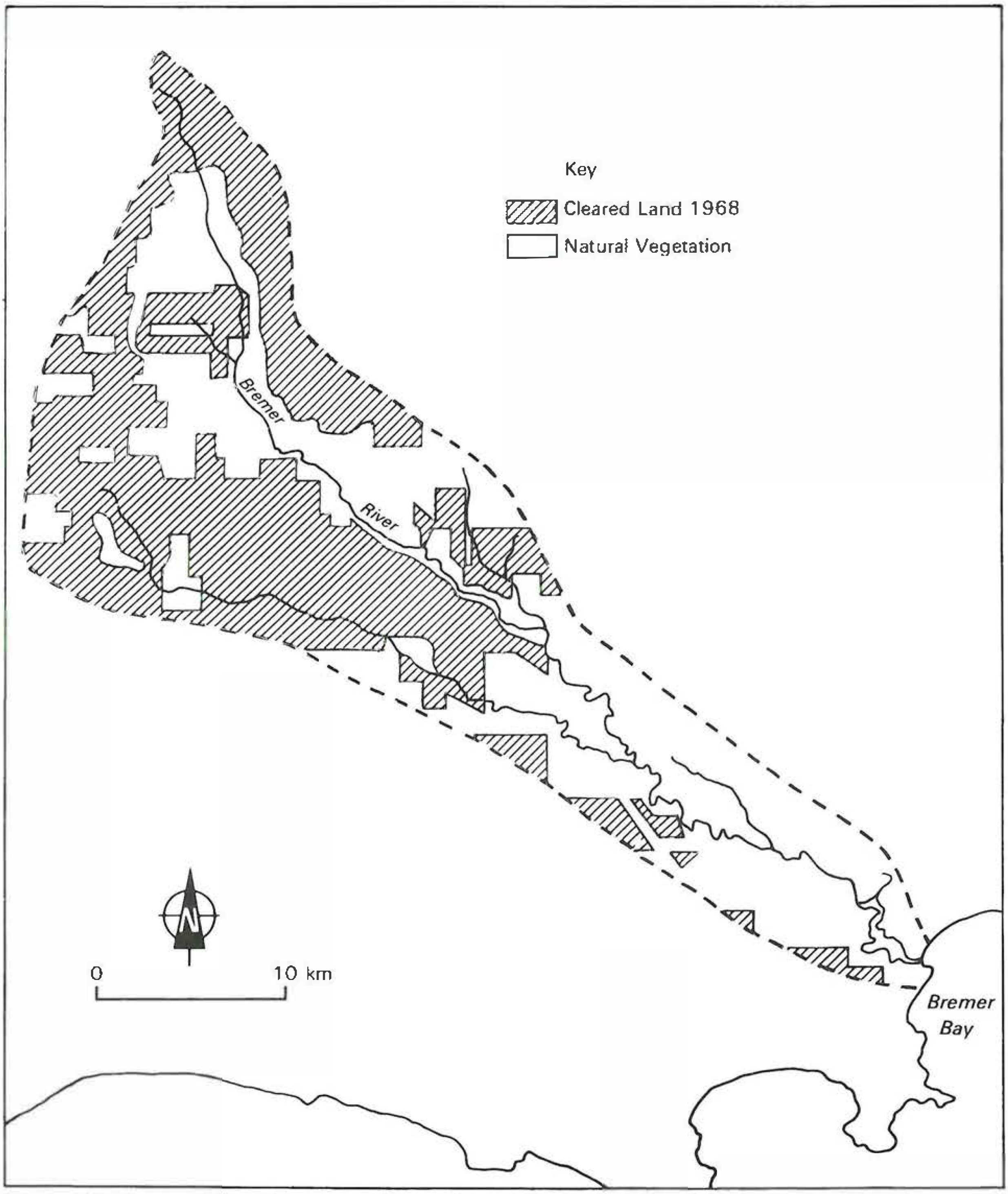


Figure 2.5 Wellstead Estuary. Cleared land in the catchment in 1968. Traced from air photos.

3. ESTUARY

3.1 GEOMORPHOLOGY

The estuary is elongate, running NW to SE perpendicular to the coast. The overall length is 13 km; the upper reaches are in a narrow riverine channel with only the lower 3.5 km widening out to a basin. (Figure 3.11) Flat-bedded Tertiary Siltstone rock borders the whole estuary, except near the mouth, and gives it its special character with steep, tree-clad slopes to the water's edge in the riverine part and low cliffs.

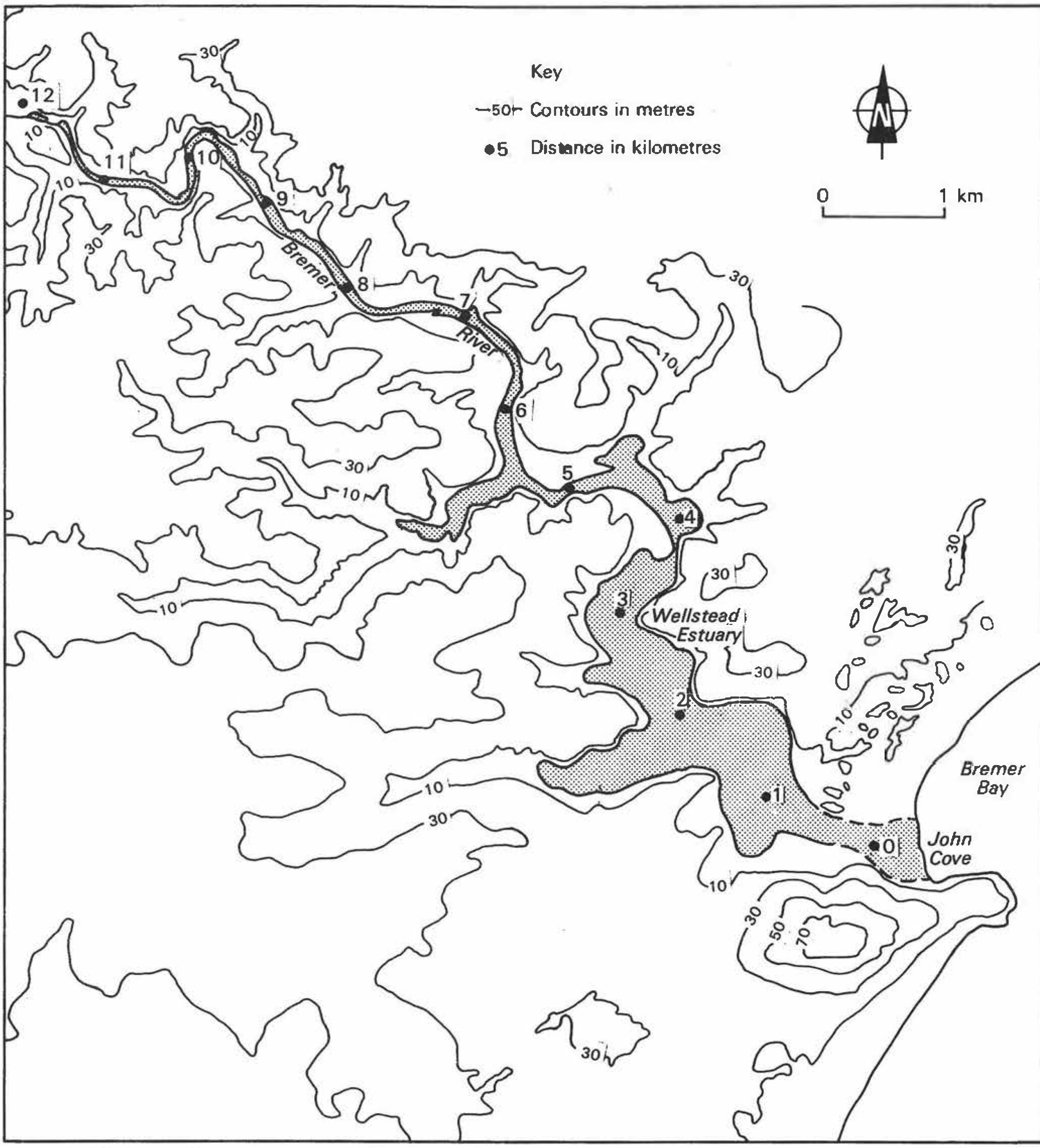


Figure 3.11 Wellstead Estuary. Contour map.

UPPER ESTUARY The riverine part of the estuary occupies a youthful valley cut into the relatively soft Siltstone rock. Several gullies have small creeks that discharge directly into the estuary; only one (Lizzie Creek at 5.5 km) has any length of estuarine water, the others being filled with sediment brought down by the creeks (Figure 3.12, centre fold). At 6 km from the bar the channel is about 100 m wide and from there narrows gradually, but it is navigable in a dinghy almost to the head of the estuary.

There are a number of banks of river sand along both margins, particularly at 4 and 7 km on the south bank and at 5.5 and 8 km on the north bank. Most of these are well vegetated, nevertheless they are clearly subject to erosion under flood conditions. Some contain massive deposits of shells of marine and estuarine molluscs.

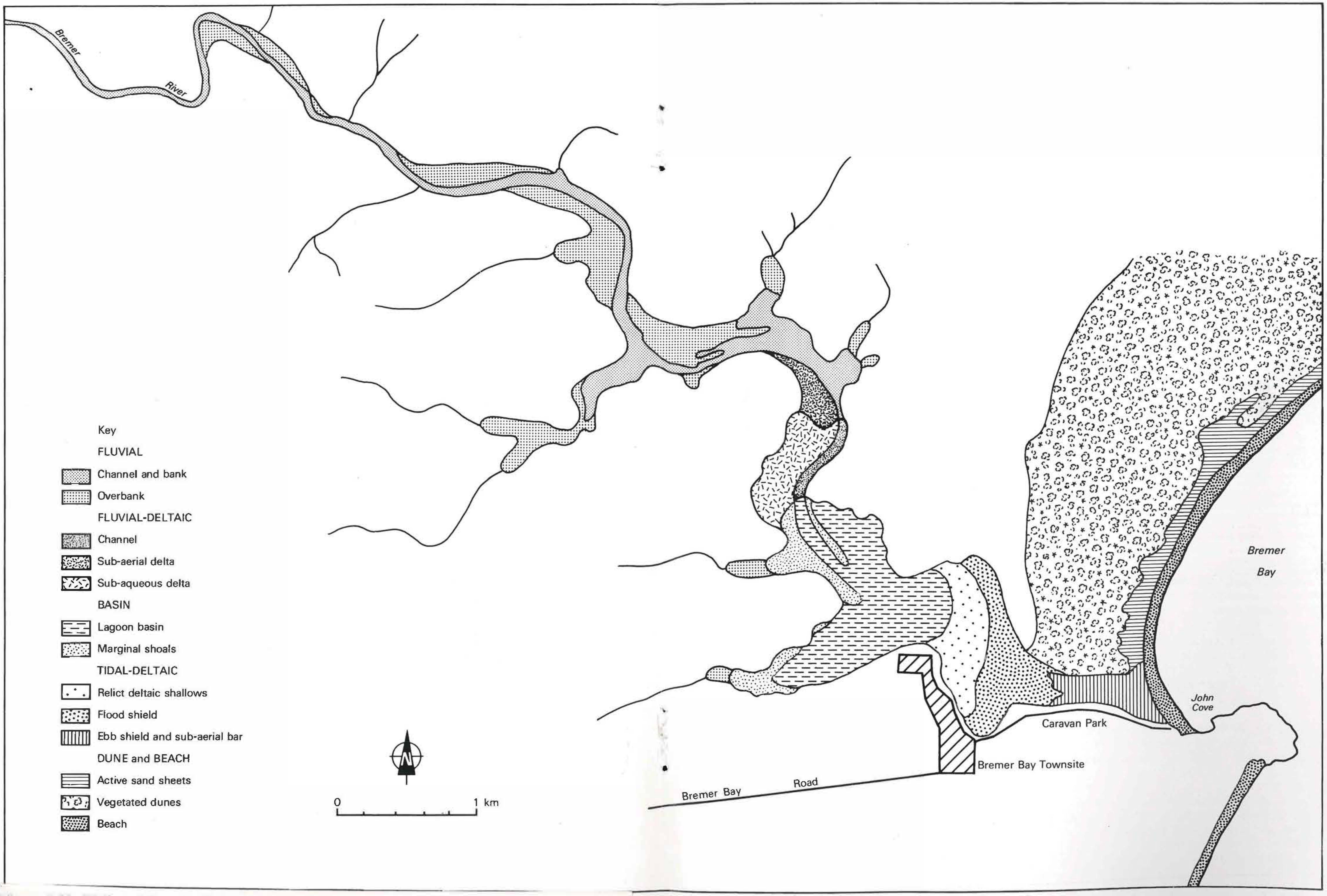


Figure 3.12 Wellstead Estuary. Geomorphology of the Estuary.

MIDDLE ESTUARY Between 4 and 5 km the estuary widens and there are shallow embayments on the northern side backed by swamp and fluvial sand deposits in the gullies. The sandbank on the southern side at 4 km extends downstream as a delta. There is little apparent reworking of deltaic material into beach ridges or bars.

LOWER ESTUARY The basin part of the estuary widens to 600 m with a maximum fetch of 3 km, an area of 2.5 km^2 and an estimated volume of 2.4×10^6 m^3. Most of it is very shallow and generally has an abundance of attached aquatic plants. Steep rocky slopes border much of the shoreline to within one km of the bar. From here to the bar there are extensive shell beds along both shores and in the estuary itself. On the northern shore there are low, well vegetated coastal dunes, with active dunes near the coast. On the southern shore a steep hill of Archaean rock (gneiss) rises behind the shell bed flat on which the caravan park is situated and extends to the headland that shelters the mouth of the estuary. Where the estuary narrows to a 400 m wide inlet channel it is blocked over most of its width by a flood tide delta that extends a kilometre upstream from the mouth. This is reported to overlie shell beds. There are shallow winding channels through the delta, the deepest usually lying along the northern shore.

3.2 THE BAR

The mouth is blocked.by an accumulation of marine sand which forms a 300 m wide bar only 1 to 2 m above mean sea level and continuous with the tidal delta (Figure 3.21). The bar material is a white, moderately well sorted, fine to medium grained quartz sand with only 10-15% shell material, unlike the coarser sand with higher carbonate content of many south coast estuaries.

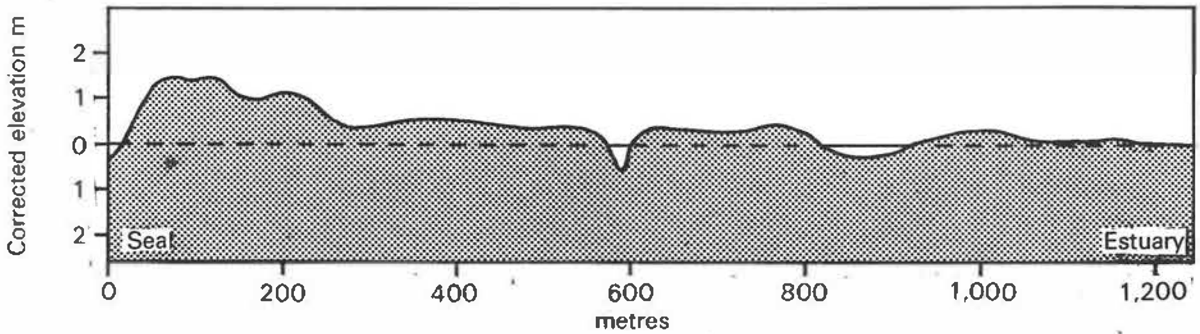


Figure 3.21 Wellstead Estuary. Bar transect, 9 March 1987. (E. Sjerp)

The bar opens every few years following heavy winter or summer cyclonic rain in the catchment and may remain open for relatively prolonged periods, 6 months to 3 years, and may remain closed for even longer periods (Figure 3.22). It was closed for 7 years from March 1972, apart from a 6 week break in 1977, and is said to have been closed for 20 years from 1860 to1880 (Bignell, 1977, p. 128). The estimated flood volume for breaching is 5×10^6 m^3 (Ian Loh, pers. comm.). The bar broke in November 1929 when the estuary water level was high and 122 mm of rain fell in that month . It broke again in July 1945 (Fisheries Department files). Following 250 mm of rain in 3 days in February 1955 the bar scoured across the whole of its present width carrying away an established dune with trees on the south side (M. Wellstead, pers. comm.). Heavy January rain also preceded the 1968 and 1982 breaks.

When the bar is open the water scours a meandering channel 20 to 30 m wide and 1 to 1.5 m deep, generally traversing from the northern side of the tidal delta to the southern shore at the bar and on the beach may divide and flow to the sea across both north and south ends (Figure 3.23).

While the bar is open the estuary is tidal; sea water flows in on a rising tide and penetrates up to 2 km from the bar. Sand, seaweed and other marine debris is carried into the estuary with tidal flow and are washed over the bar during high seas when the bar is closed. Seaweed accumulations have occasionally blocked the channel through the bar, but these blocks are cleared by high seas.

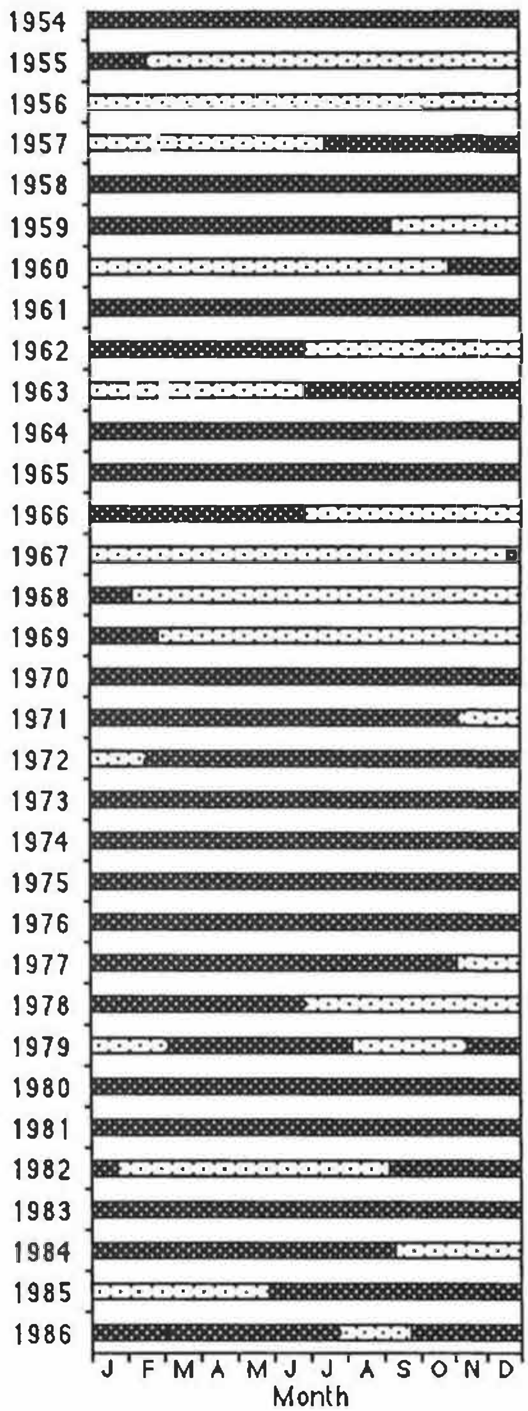


Figure 3.22 Wellstead Estuary. Reported opening and closing of the bar. closed, open. (A. & J. Jury, pers. comm.)

3.3 BATHYMETRY

The upper estuary has sandy shallows along the insides of the bends, but is several metres deep (~ 5 m) in places on the outside of the bends. The lower estuary is very shallow, less than 1 m, except for a slightly deeper channel near the northern shore between 2 and 4 km, and becomes progressively shallower approaching the bar.

When the bar is open, the water level in the estuary varies with the tides, but the range of the tide is considerably reduced. When the bar is closed, the water level varies with river flow and evaporation; it rises to the top of the bar, 1 m above sea level, and during prolonged dry spells falls by about 1 m below sea level exposing rocks along the shore near the town.

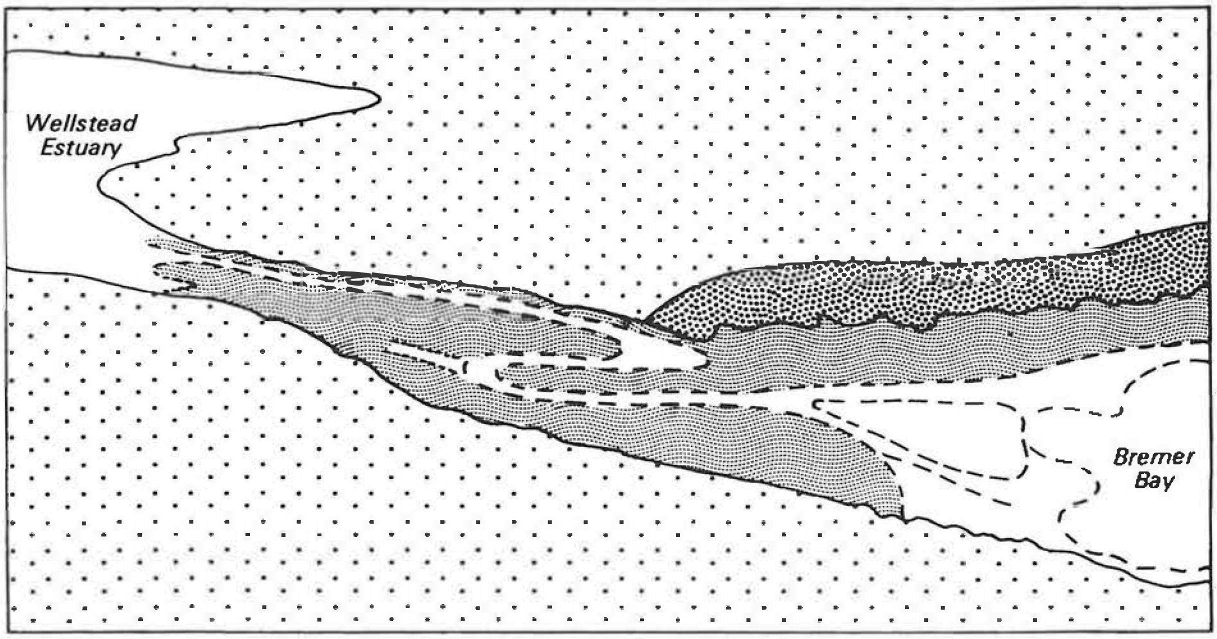


Figure 3.23 Wellstead Estuary. Tidal channel through the bar, October 1978. Traced from air photo.

3.4 SEDIMENTS

The estuarine sediments have recently been cored at several sites to a depth of over 5 m without reaching bedrock (K. H. Wyrwoll, pers. comm.). The cores compacted to about half their length because of the high water content. A preliminary study of two cores taken 3 km and 5 km from the bar showed dark grey to black organic mud through most of the length of the cores. The loss of weight on ignition of the mud was about 10%, showing a high organic content. The mud was overlain by 20 to 40 cm of medium to fine grained sand, mainly quartz, and a few thin layers of similar nature intrude into it, posibly indicative of past flood events. The cores contain few of the mollusc shells that are abundant both in river sand banks and on shores near the bar until near the bottom of the 3 km core, but a shallow core taken in the basin nearer the bar contained a rich fossiliferous layer at about 1 m depth (Treloar, 1977).

The high organic content of the sediment and the abundant diatoms present in some of the samples suggest that the estuary has probably been a fairly productive environment for a considerable time.

3.5 HISTORY OF THE ESTUARY

The estuary has only taken its present form in geologically recent times; probably only within the last four thousand years has the bar closed the estuary off from the sea. When the sea rose to its present level 6500 years ago the estuary was a drowned river valley, with deep water in its lower reaches. The extensive shell beds, which are 2 to 3 m thick in places, are evidence that the estuary was then a sheltered marine embayment. Shells of the cockle *Katelysia scalarina* from the surface of the shell beds have been radiocarbon dated at 3930 ± 265 years before the present, and subsurface samples at 4430 ± 225 and 4900 ± 375. (shell collections by G. Kendrick & dating courtesy of Dr. P. E. Playford) Subsequently, about 4000 years ago, the entrance became obstructed by sand carried along the bay shore and into the estuary forming the bar and tidal delta. Closure of the bar would have accelerated deposition of fine river sediment and organic material in the lower reaches, so shallowing the estuary.

The local view is that the lower estuary has shallowed rapidly in recent years as the result of clearing in the catchment. However, while clearing may have increased sediment transport in the river, much of the abundant organic matter in the basin sediment probably originates from the rich growth of aquatic plants in the estuary itself.

When detailed study of the cores is completed it will give a much clearer picture of the history of sedimentation in the estuary.

4. WATER CHARACTERISTICS

4.1 SALINITY

Water sampling has only been sporadic but the general picture is clear. Salinity varies greatly from almost fresh at the head of the estuary following winter rain, to more than twice sea water salinity in the basin when the bar has been closed for a long period over summer. Figure 4.11 shows what is probably a fairly typical winter profile: at the head of the estuary surface salinity was less than half that of sea water and near the bar it was slightly hypersaline to sea water (36 ppt). The bar was closed at the time and had been for the previous six years. A year later when the bar had recently opened following heavy rain, and there had been insufficient time for mixing, there was a steeper salinity gradient along the estuary, with only 12 ppt at 4 km from the bar. Other records are shown in Table 4.1.

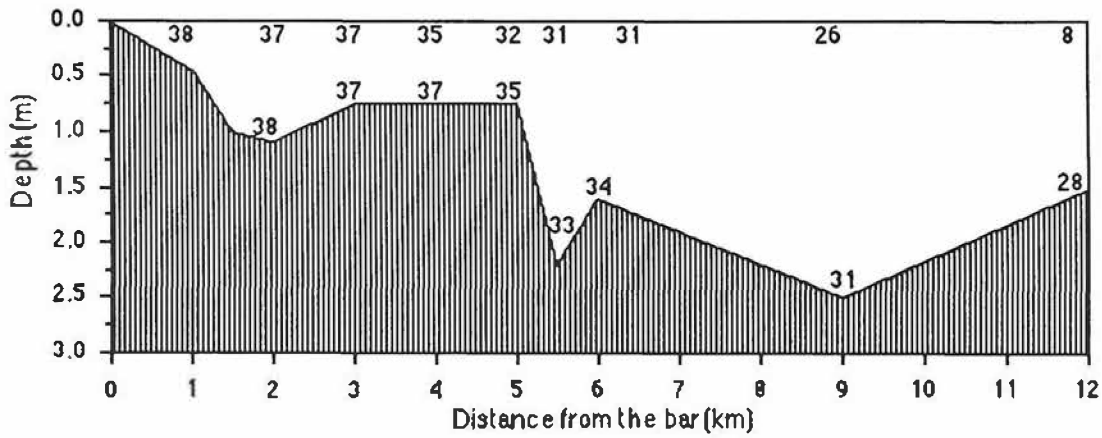


Figure 4.11 Wellstead Estuary. Salinity profile along the estuary. 16 August 1977. (Congdon and McComb, 1986)

Table 4.1 Wellstead Estuary, salinity (ppt) records. S - surface, B - benthic

Date		Approximate distance from the bar (km) 1	2	4	6	12	Condition of the bar
27/9/71	S	38	38	37	33	-	Closed
27/9/71	B	38	38	37	34	-	Closed
29/2/72	S	38	-	-	-	-	Open
-/11/74	S	38	-	-	-	-	Closed
27/4/77	S	50	-	-	-	7	Closed
16/8/77	S	38	37	35	32	8	Closed
16/8/77	B	38	38	37	35	28	Closed
1/8/78	S	34	18	12	4	-	Open
18/10/78	S	31	30	25	-	-	Open
13/1/79	S	36	40	40	-	-	Open
4/4/79	S	37	-	39	-	-	Open
28/10/79	S	36	-	-	-	-	Open
28/5/82	S	36	-	32	30	-	Open
12/5/83	S	80	-	-	-	-	Closed
21/1/87	S	43	40	42	27	-	Closed
21/1/87	B	43	42	42	28	-	Closed
25/3/87	S	66	-	-	-	-	Closed
3/5/87	S	-	-	50	42	22	Closed
3/5/87	B	50	-	-	-	26	Closed

In the deeper reaches the water may be stratified, with lower salinity water overlying more saline water and a halocline between them that delays mixing. On the occasion illustrated in Figure 4.12 the difference was only 3-4 ppt, but it is probably considerably greater following the first rains. When the bar is open and salinity is low following heavy rain, sea water intrudes under the less saline river water and penetrates some distance upstream. Wind stress is the main cause of mixing and is greatest in the open water of the basin.

4.2 WATER TEMPERATURE

Observed surface temperatures range from 12°C in winter to 25°C in summer. There will often be a temperature gradient along the length of the estuary with warmer water in the shallow basin and colder water in the riverine reaches. This is true especially when the bar is open in winter and tidal exchange brings warm sea water into the basin.

When the water is stratified, surface and deep water temperatures may differ by several degrees. Figure 4.2 shows a winter condition when colder water overlies warmer, more saline water trapped below the halocline. The reverse condition, with warm water overlying cold, probably occurs at times in early summer.

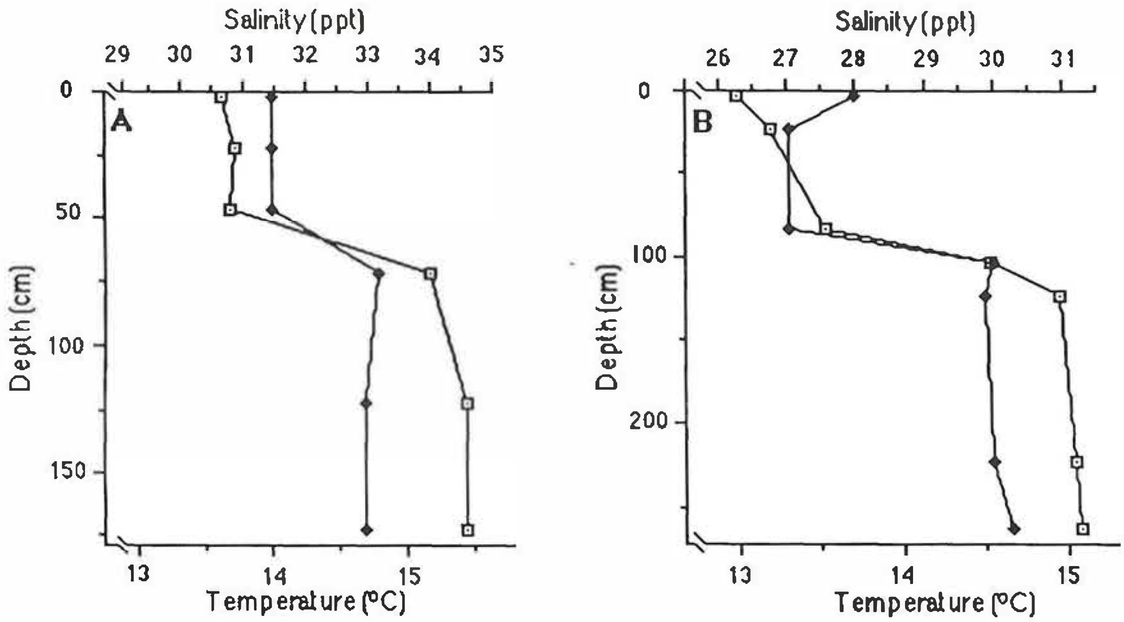


Figure 4.12 Wellstead Estuary. Salinity and temperature profiles. A at 6 km and B at 9 km from the bar. -□- Salinity, -◆- Temperature. 16 August 1977. (Congdon and McComb, 1986)

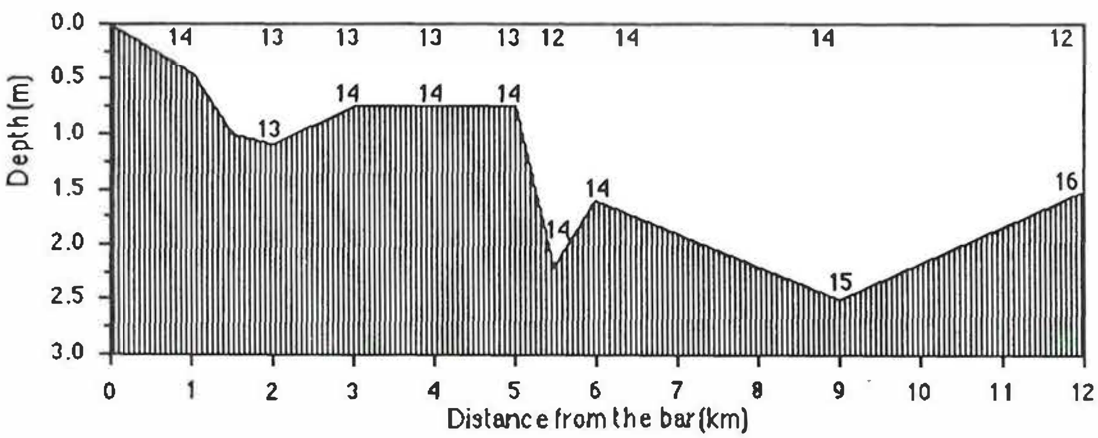


Figure 4.2 Wellstead Estuary. Temperature profile along the estuary. 16 August 1977. (Congdon and McComb, 1986)

4.3 OXYGEN

It is to be expected that surface water will generally be well oxygenated, but when the water is stagnant or stratification is prolonged, there will be some degree of deoxygenation in water below the halocline as in May 1987 (Table 4.3).

Table 4.3 Dissolved oxygen (ppm) in estuary water, May 1987. (J. Shaw pers. comm.)

	kilometres from the bar				
	at bar	2	4	5.5	10.5
S	6.4	4.4	5.2	6.5	7.2
B	6.3	3.4	2.3	-	3.8

4.4 NUTRIENTS

The limited data available suggest that nutrient concentrations are low (7 µg reactive $P.l^{-1}$ and 38 µg total $P.l^{-1}$).

4.5 POLLUTION

There is no evidence of pollutants entering the estuary, but runoff from the town roads following rain may contribute undesirable amounts of oil to the stagnant estuary.

5. VEGETATION

The vegetation of the estuary was surveyed in August 1977 (Congdon & McComb, 1986) and in January 1987 (J. Chambers, pers. comm.). The bar was closed on both occasions and the water only slightly hypersaline to sea water (Table 4.1).

5.1 AQUATIC PLANTS

There are beds of the seagrass *Ruppia megacarpa* in shallow water throughout the estuary, especially on the flood shield of the tidal delta and on shallows in the middle and upper estuary (Figure 5.1). In the basin the attached charophyte *Lamprothamnium papulosum* is dominant, forming a continuous cover over the soft mud except in deeper holes and where boat tracks have cut through it. Both persist over a wide salinity range, but growth is probably inhibited at the higher salinities sometimes experienced. *Ruppia* often carries a heavy load of epiphytic filamentous green algae. Both are subject to heavy grazing by swans. The attached leaf-like algae *Polyphysa peniculus* is found in shallow nearshore areas of the lower estuary where it is mixed with the *Lamprothamnium*.

The green algae *Enteromorpha* and *Vaucheria* were observed in a saltmarsh at 4 km in 1977, and patches of unidentified filamentous green algae have been observed near the bar. Marine algae are washed into the estuary when the bar is open and add to detrital material in the basin, but apart from these there is no record of marine algae establishing in the estuary even when the bar is open and the salinity approximately that of sea water. Microalgae caused patchy staining of the sand in shallows near the mouth in January 1987.

Congdon and McComb (1986) record finding a large number of phytoplankton species in Wellstead Estuary in 1974, including a colonial green algae (probably *Gloeocystis*), the chlorophyte *Scotiella,* two species of dinoflagellate, a few diatoms and a filamentous blue-green algae.

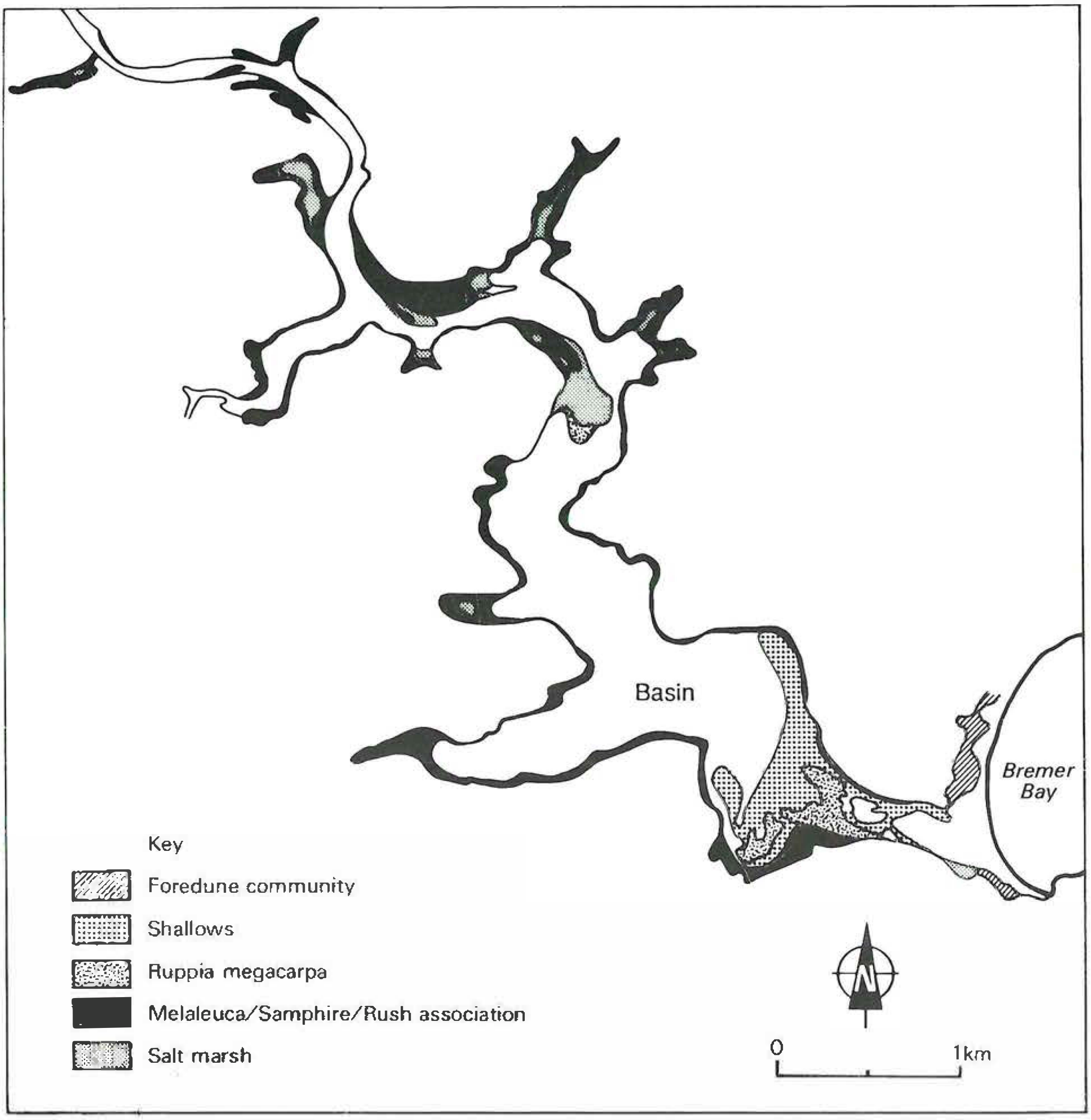


Figure 5.1 Wellstead Estuary. Aquatic, marsh and terrestrial vegetation. (J. Chambers pers. comm.)

5.2 SALT MARSH PLANTS

Salt marshes are well developed in some of the small coves along the estuary and on a large flat at 4 km from the bar (Figure 5.1). These areas have no tree cover and are often almost monospecific stands of the samphire *Sarcocornia blackiana*. The dominant salt tolerant plants of the samphire community are: *Sarcocornia blackiana, Suaeda australis* and *Samolus repens*. These occur at lower levels subject to frequent inundation, while a rush community dominated by *Juncus kraussii* and *Gahnia trifida* occur on slightly higher ground behind the samphire community. Other less common species on the flat at 4 km include *Wilsonia humilis, Disphyma clavellatum* and *Halosarcia halocnemoides*. (Table 5.2)

The small marsh on the south side of the bar is degraded and has been colonised by various introduced grasses including *Erhata calycina, Avena* sp. and *Polypogon monospieliensis* with *Samolus repens* and *Acacia cyclops* on higher ground behind the flats. Further back again *Melaleuca cuticularis* replaces *Acacia cyclops* and *Juncus kraussii* replaces *Samolus repens*.

Table 5.2 Plant species recorded in salt marshes throughout the estuary. (Congdon and McComb, 1986; J. Chambers pers. comm.; R. Humphries pers. comm.)

Sarcocornia blackiana	*Suaeda australis*	*Samolus repens*
Juncus kraussii	*Gahnia trifida*	*Frankenia pauciflora.*
Wilsonia humilis	*Lagurus ovatus*	*Carpobrotus aequilaterus*
Lomandra sp.	*Sporobolus virginicus*	*Isolepis nodosa*
Acacia bidentata	*Acacia cyclops*	*Agonis flexuosa*
Threlkeldia diffusa	*Medicago polymorpha*	*Halosarcia halocnemoides*
Cotula australis	*Cotula coronopifolia*	*Disphyma clavellatum*
Lolium sp.	*Senecio glossanthus*	*Lycium australe*
Vaucheria sp.	*Enteromorpha* sp.	*Erhata calycina* *
Polypogon monospieliensis *	*Avena* sp.*	

* introduced grass

5.3 FRINGING VEGETATION

The plant communities of the fringing vegetation are similar throughout the estuary, the type and nature of the community being controlled by the slope and width of the area available for colonisation. They are dominated by the paperbark *Melaleuca cuticularis,* which varies in cover from a dense canopy to scattered trees with an understorey of saltmarsh plants in lower flatter areas. On the north bank, steep slopes often restrict the fringing vegetation to a narrow band of *Melaleuca* with the rush community beneath. Other species in these communities depend on surrounding vegetation; in areas near the mouth of the estuary coastal species such as *Scaevola crassifolia* are common, and near the town other species include*Wilsonia humilis, Lagurus ovatus, Carpobrotus aequilaterus* and *Lomandra* sp.

Dead stands of paperbarks in the fringing vegetation have been noted from time to time, but the cause of their death is not evident.

5.4 TERRESTRIAL VEGETATION

The bar is sparsely colonised by *Arctotheca populifolia, Cackile maritima* and *Isolepis nodosa.* To either side of the bar and on the foredune *Ammophila arenaria* is first to colonise, with well vegetated hummocks behind it composed of *Euphorbia paralias,* the shrubs *Olearia axillaris, Spyridium globulosum, Accacia cyclops, Acacia bidentata, Angianthus cunninghamii,* the grass *Festuca pubinervis* and the three species present on the bar. On stable dunes the vegetation is dominated by the peppermint *Agonis flexuosa* with a community of the species listed above, the shrubs *Exocarpus sparteus, Scaevola crassifolia, Billardiera varifolia* and the sedge *Lepidosperma gladiatum* (Table 5.41).

Further inland this coastal asociation changes to one dominated by *Hakea laurina* (Table 5.42).

Table 5.41 Coastal beach and dune vegetation at Wellstead Estuary. (J.Chambers pers. comm.)

Arctotheca populifolia	*Cakile maritima*	*Ammophila arenaria*
Euphorbia paralias	*Olearia axillaris*	*Spyridium globulosum*
Angianthus cunninghami	*Festuca pubinervis*	*Exocarpus sparteus*
Scaevola crassifolia	*Billardiera varifloia*	*Euphorbia paralias*
Lepidosperma gladiatum	*Atriplex cinerea*	

Table 5.42 Terrestrial vegetation (a) near Bremer Bay townsite and (b) 7 km upstream. (J. Chambers pers. comm.)

(a)	(b)
Agonis flexuosa	*Agonis flexuosa*
Hakea laurina	*Hakea laurina*
Templetonia retusa	*Templetonia retusa*
Eucalyptus platypus var. heterophylla	*Eucalyptus occidentalis*
Westringia dampiera	*Acacia cyclops*
Spyridium globulosum	*Bossiaea dentata*
Rhagodia baccata	*Gastrolobium* sp.

6. THE ESTUARINE FAUNA

There are great changes in the composition of the fauna depending on whether the bar is open or closed and the consequent hydrological condition of the estuary. When the bar is closed for a prolonged period only a few true estuarine species survive, but when the bar is open a considerable number of marine species enter and may survive and flourish in the lower estuary until the salinity becomes too extreme. When the bar closes these species die off progressively.

6.1 ZOOPLANKTON

The only true planktonic species recorded is the estuarine-marine copepod *Acartia clausi* (? *tranteri*), taken when the bar was closed. The estuarine species *Gladioferens imparipes* may also be expected to be present and possibly *Sulcanus conflictus*, particularly in the upper reaches. Marine species probably enter the lower estuary when the bar is open.

6.2 BENTHIC FAUNA

The principal invertebrate species that live permanently in the estuary are common estuarine species that are able to tolerate the great range in salinity (Table 6.21). These are the main food of most species of fish. However, marine species may settle near the bar when it is open and salinity approximates that of sea water. The mollusc species listed in Table 6.22 were found settled near the bar in January 1979 when it had been open for the previous five months. Some of these were still present in October 1979 and *Katelysia* had shown normal growth (to 30^{+} mm). These species are common in sheltered marine bays of the south coast, such as Princess Royal Harbour, but not in closed waters where there are extreme salinities. Similar settlements of marine species were noted near the bar in January 1972 (G. Kendrick pers. comm.) and March 1987 (E. P. Hodgkin).

Table 6.23 lists Foraminifera recorded from the estuary.

Table 6.21 Benthic fauna; permanent, estuarine species.

Polychaeta		*Ficopomatus enigmatica*	**Crustacea**		
		Ceratonereis aequisetes		Amphipoda	*Melita* sp.
		Capitella capitata			*Corophium minor*
		Scoloplos simplex		Talitridae	talitrid
		Spio sp.		Palaemonidae	*Palaemonetes australis* (shrimp)
		Prionospio sp.		Isopoda	*Sphaeroma quoyana*
				Decapoda	*Halicarcinus ovatus* (crab)
Mollusca					*Leptograpsodes* sp. (crab)
	Bivalvia	*Arthritica semen*			
		Spisula trigonella	**Insecta**		Chironomid larvae (midge)
		Sanguinolaria biradiata			Trichopteran larvae (caddis fly)
	Gastropoda	*Hydrococcus brazieri*			

Table 6.22 Mollusc species collected near the mouth, 13 January 1979. (D. Roberts pers. comm.)

Bivalvia	Gastropoda
Mytilus edulis planulatus	*Adamnestia arachis*
Fulvia tenuicosta	*Bulla quoyii*
Spisula trigonella	*Philine angasi*
Sanguinolaria biradiata	
Katelysia scalarina	
Katelysia rhytiphora	
Laternula creccina	

Table 6.23 Protozoa, Foraminifera recorded by Hassell (1962).

Haplophragmoides canariensis	*Quinqueloculina elongata*
Quinqueloculina seminula	*Quinqueloculina vulgaris*
Discorbis araucana	*Discorbis rosacea*
Heronallenia translucens	*Elphidium crispum*
Elphidium macellum	*Elphidium poeyanum*
Elphidiella artica	*Rotalia beccarii*

6.3 FISH

Fish populations change greatly with the condition of the estuary and a considerable number of species may be present when salinity approaches that of sea water. The fish can be broadly categorised as either estuarine, species which spend the whole of their life cycle in the estuarine environment, or as marine, species which spawn at sea and are recruited to the estuary at some stage of their life cycle (Table 6.3). With closure of the bar, conditions become unfavourable

Table 6.3 Fish species recorded from Wellstead Estuary. (Lenanton, 1974 and pers. comm.)

Common name	Scientific name
Estuarine	
Black bream*	*Acanthopagrus butcheri*
Hardyhead	*Atherinosoma elongata*
Hardyhead	*Atherinosoma wallacei*
Goby	*Pseudogobius olorum*
Spotted minnow	*Galaxias maculatus*
Marine	
Yellow-eye mullet*	*Aldrichetta forsteri*
Sea mullet*	*Mugil cephalus*
Cobbler*	*Cneidoglanis macrocephalus*
King george whiting*	*Sillaginodes punctatus*
Australian herring*	*Arripis georgianus*
Australian salmon*	*Arripis trutta*
Tarwhine*	*Rhabdosargus sarba*
Southern sand flathead*	*Platycephalus bassensis*
Trevally*	*Pseudocaranx* sp.
Long-snouted flounder*	*Ammotretis rostratus*
Small toothed flounder*	*Pseudorhombus jenynsii*
Six spined leatherjacket*	*Meuschenia freycineti*
Banded toadfish	*Torquiqener pleurogramma*
Soldierfish	*Gymnapistes marmoratus*

* Commercial and/or recreational angling species.

for the more marine species and the number surviving decreases progressively. Leather jackets are said to be the first to die, within two weeks of closure. Few species can be expected to survive the extreme salinities sometimes experienced when the bar remains closed over summer.

It will be noted from Table 6.3 that all commercial species are marine, with the exception of black bream. Recruitment of juvenile marine fish depends on the bar being open when they are present in coastal water following spawning; eg mullet in winter (March to September) and cobbler in summer (November to January). On the other hand black bream are probably recruited mainly from pools in the river. King prawns also enter the estuary as juveniles and survive in it for a year.

6.4 WATERBIRDS

Eleven species of waterbirds are listed in Table 6.4.

Table 6.4 Waterbirds at Wellstead Estuary on 21 January 1987. (R. Clark)

Common name	Scientific name
Black Swan	*Cygnus atratus*
Australian Pelican	*Pelecanus conspicillatus*
Little Pied Cormorant	*Phalacrocorax melanoleucos*
White-faced Heron	*Ardea novaehollandiae*
Australian Shelduck	*Tadorna tadornoides*
Pacific Black Duck	*Anas superciliosa*
Sooty Oystercatcher	*Haematopus fuliginosus*
Hooded Dotterel	*Charadrius cucullatus*
Red-capped Plover	*Charadrius ruficapillus*
Pacific Gull	*Larus pacificus*
Silver Gull	*Larus novaehollandiae*
Caspian Tern	*Sterna caspia*
Crested Tern	*Sterna bergii*

7. MANAGEMENT PROBLEMS

The estuary presents a number of intractable problems for management. The basin is gradually shallowing and the rate of sedimentation may have accelerated as the result of clearing in the catchment. When the bar is closed and there is no river flow in summer to replace evaporative loss, the water level drops, areas of decaying weed become exposed near the town and it is difficult to launch boats into the estuary. With prolonged closure recruitment is denied to populations of marine fish and the water may become seriously hypersaline. When the bar is open the channel swings from the north to the south side behind the bar and tends to erode both shores. These are all matters for concern, the significance of which can only be evaluated in the light of what is known about the estuary and the demands placed upon it; but this is not the place to make recommendations for management.

It will be evident that although the available data on Wellstead Estuary is greater than that for many estuaries of the south west it is still inadequate to describe with any certainty either its history in the Holocene or the effect that human activities have had on it in the last 150 years. More particularly it is not clear what effect clearing in the catchment has yet had on transport of sediment to the estuary. Coarser, bed load sediment is deposited on sand banks along the riverine part of the estuary, in tributary valleys and in the river delta where the river discharges into the basin. Fine suspended sediment is deposited mainly in the basin, but organic matter originating in the estuary itself or washed in over the bar and fine beach sand also contribute to sediment accumulation in this part of the estuary. The bar is low and wind and waves carry the fine sand of which it is built far into the estuary to augment the tidal delta. Floods of sufficient magnitude to scour much delta sand to sea are infrequent.

The above natural processes have been going on for a long time and there is no objective measure to show whether they have accelerated as the result of human interference. There can be little doubt that clearing has increased the mobilisation of sediment from the catchment, but how much of this additional load has yet reached the estuary is uncertain. Much of the coarser sediment has probably been trapped in pools of the river upstream of the estuary, as has happened in the Avon and other rivers. This sediment can be flushed to the estuary by flash floods. It is regretable that clearing has been permitted so close to the river channel, even spanning it, thus increasing the mobilisation of sediment, especially in the steeper sections and on the more readily eroded soils.

The estuary is small, shallow and has a low bar. It has a small catchment in an area of low rainfall, high evaporation and small tidal range; neither tidal exchange nor the intermittent river flow is great enough to keep a channel open through the massive bar and tidal delta. In these respects the estuary differs little from estuaries to the east which often dry up in summer (except the deep Stokes Inlet). Further, gradual, shallowing of the estuarine basin will not only reduce the recreational value of the estuary, but exacerbate the tendency of the water to become hypersaline in late summer to the point at which few fish and other aquatic animals can survive.

The condition of the estuary would clearly be improved if the bar was kept open to allow exchange with the sea, so maintaining a relatively constant water level and preventing the water becoming so hypersaline, though this would probably require costly engineering measures and might hasten growth of the tidal delta. Both shorelines are subject to erosion near the bar as the channel sweeps from north to south and may require protection by training walls. Premature opening of the bar reduces the scouring action of flood water and allows it to close sooner than it would do otherwise. The disadvantages of development on the shores below potential flood level are obvious.

Bremer Bay is the most heavily used beach in the area, with the focus on recreational activities on the sheltered, southern corner of John Cove. This has placed pressure on dune vegetation. People compete for space, and swimming classes and boat launching requirements conflict. Currently, swimming activities have use of John Cove in summer between 9 a.m. and noon. Boaters are required to work in rougher water which may be dangerous. Water skiing is prohibited in the swimming area. In winter, John Cove assumes a different appearance and large banks of weed collect on the beach. Many activities are seen on the bar during summer including three wheeler biking, motor cycling, bicycling, horse riding and beach buggying (Jerramungup Shire Council, 1984). To what extent these activities damage the bar is not clear, in particular to what extent they prevent establishment of vegetation on it.

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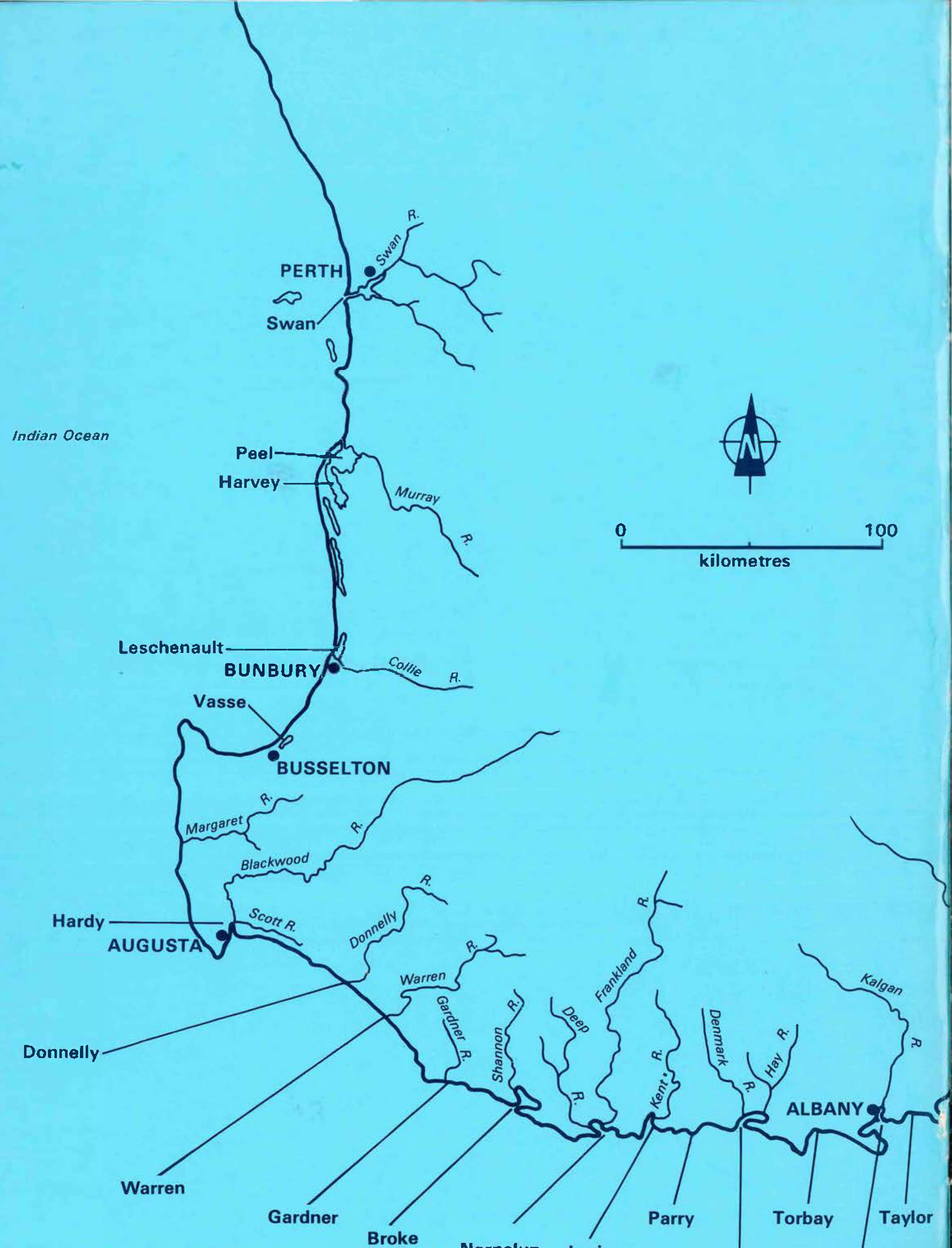
Wellstead Estuary bar
17 October 1978.

The north shore at
7 km from the bar.

Sub-fossil shells,
north shore of the
basin.



Indian Ocean
PERTH
Swan R.
Swan
Peel
Harvey
Murray R.
Leschenault
BUNBURY
Collie R.
Vasse
BUSSELTON
Margaret R.
Blackwood R.
Hardy
AUGUSTA
Scott R.
Donnelly R.
Warren R.
Gardner R.
Shannon R.
Deep R.
Frankland R.
Kent R.
Denmark R.
Hay R.
Kalgan R.
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Oyster Harbour
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