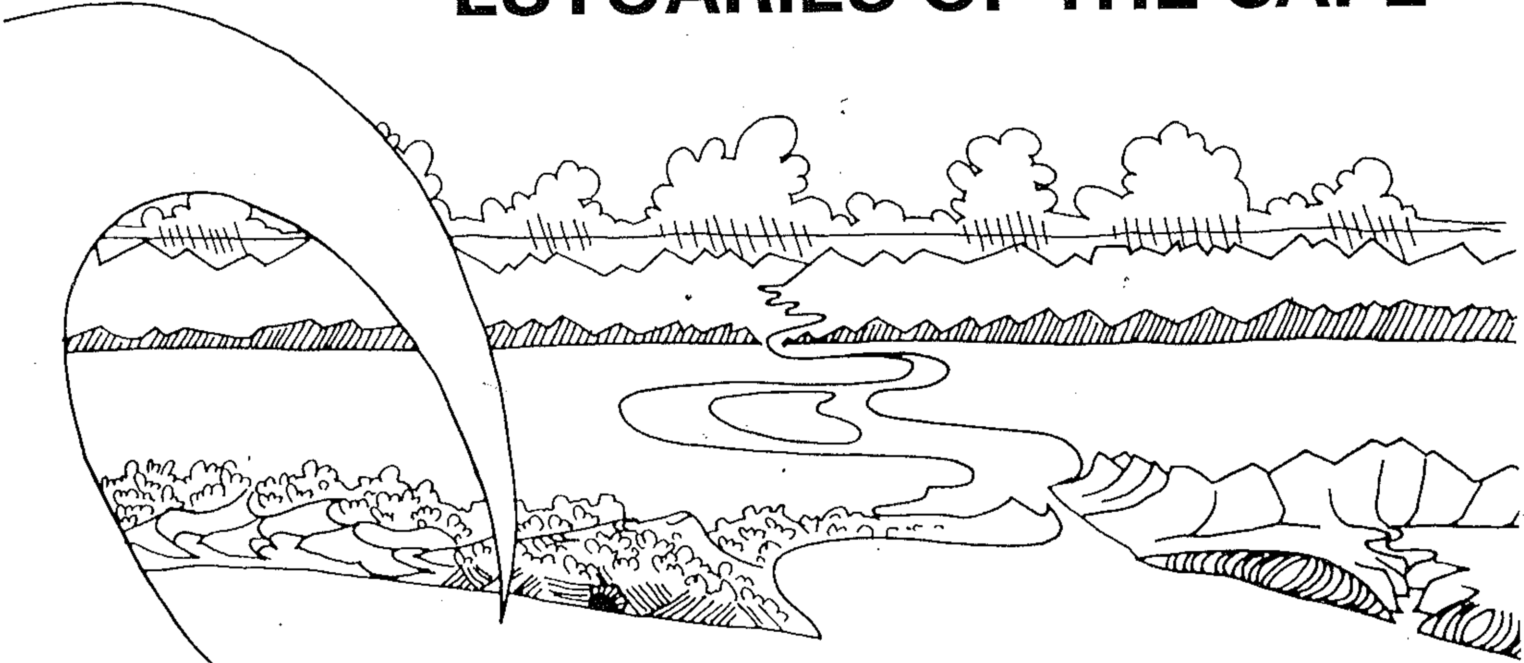
Earth, Marine and Atmospheric Science and Technology

CSIR

ESTUARIES OF THE CAPE



PART II

SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

REPORT NO. 37

PALMIET (CSW 12)

CSIR RESEARCH REPORT 436

Stellenbosch, South Africa
March 1989

ESTUARIES OF THE CAPE

PART II: SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

EDITORS:
A E F HEYDORN and P D MORANT
Division of Earth, Marine and Atmospheric Science and Technology,
CSIR, Stellenbosch

FRONTISPIECE: PALMIET ESTUARY – ECRU 87-01-17

REPORT NO. 37: PALMIET (CSW 12)

(CSW 12 – CSIR Estuary Index Number)

BY: B C CLARKE
Department of Zoology
University of Cape Town

ESTUARINE AND COASTAL RESEARCH UNIT – ECRU
DIVISION OF EARTH, MARINE AND ATMOSPHERIC SCIENCE AND TECHNOLOGY
CSIR

CSIR RESEARCH REPORT 436

Stellenbosch, South Africa
March 1989

ISBN 0 7988 1812 3
ISBN 0 7988 1813 1
ISBN 0 7988 3533 8

Published in 1989 by:

Division of Earth, Marine and Atmospheric Science and Technology
CSIR
P O Box 320, Stellenbosch, 7600

Printed by:

Paarl Printing Co. (Pty) Ltd, Paarl

When citing this document in a bibliography, the reference should be as follows:

CLARKE, B C (1989). Estuaries of the Cape: Part II: Synopses of available information on individual systems. Rep. No. 37 Palmiet (CSW 12). Heydorn, A E F and Morant P D (eds). Stellenbosch, *CSIR Research Report* 436.

Keywords: Estuaries; Coastal Zone Management

PREFACE

The Estuarine and Coastal Research Unit was established by the National Research Institute for Oceanology of the CSIR in 1979 with the following aims:

- to contribute information relevant to the development of a cohesive management policy for the South African coastline;
- to compile syntheses of all available knowledge on the 167 estuaries of the Cape from the Kei to the Orange rivers;
- to identify gaps in information, to conduct research to fill these and to stimulate Universities, Museums and other institutions to become involved in this kind of work;
- to undertake investigations on the impacts of proposed developments in the coastal environment, and especially in estuaries.

The Unit was established at the request of the Government, and the Department of Environment Affairs contributes substantially to the running costs.

In 1980 the Unit published its first report under the title "Estuaries of the Cape, Part I - Synopsis of the Cape Coast. Natural Features, Dynamics and Utilization" (by Heydorn and Tinley, CSIR Research Report 380). The report is an overview of the Cape Coast dealing with aspects such as climate, geology, soils, catchments, run-off, vegetation, oceanography, and of course, estuaries. At the specific request of the Government, the report includes preliminary management recommendations.

The present report is one of a series on Cape Estuaries being published under the general title "Estuaries of the Cape, Part II". These reports summarize, in language understandable to the layman, all available information on individual estuaries. It was found, however, that much information is dated or inadequate and that the compilation of Part II reports is therefore not possible without brief prior surveys by the ECRU. These surveys are, however, not adequate to provide complete understanding of the functioning of estuarine systems under the variable conditions prevalent along the South African coastline. The ECRU therefore liaises closely with universities and other research institutes and encourages them to carry out longer-term research on selected estuarine systems. In this way a far greater range of expertise is involved in the programme and it is hoped that the needs of those responsible for coastal zone management at Local, Provincial and General Government levels can be met within a reasonable period of time.

On 1 April 1988 the National Research Institute for Oceanology was incorporated into the new Division of Earth, Marine and Atmospheric Science and Technology (EMA) of the CSIR. In the process of restructuring, the Estuarine and Coastal Research Unit (ECRU) ceased to exist as an entity. However, the tasks undertaken by the ECRU continue to be performed by the Coastal Processes and Management Advice Programme of EMA.

D H SWART
MANAGER, COASTAL PROCESSES AND MANAGEMENT ADVICE PROGRAMME
DIVISION OF EARTH, MARINE AND ATMOSPHERIC SCIENCE AND TECHNOLOGY

CONTENTS

SECTION		PAGE NO.

FIGURES

TABLES PAGE NO.

TABLES

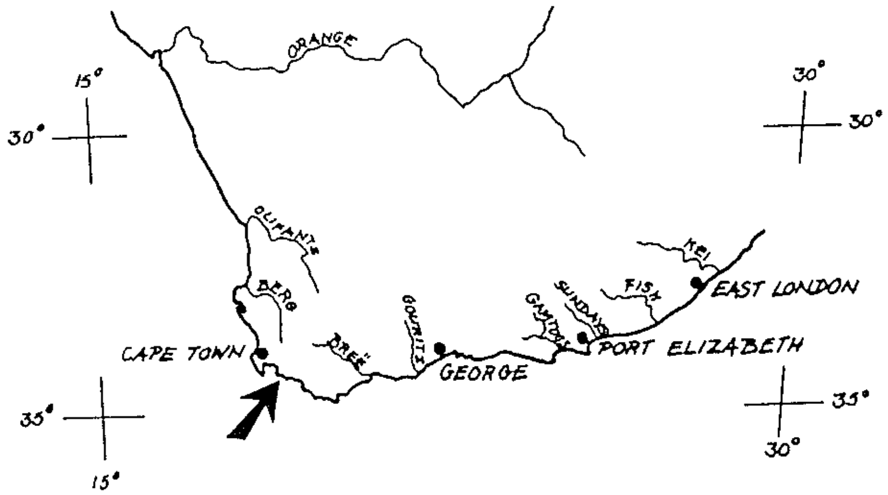
APPENDICES

PLATES

PALMIET

1. LOCATION

The Palmiet Estuary (34°20'S; 18°59'E) is situated between Betty's Bay and Kleinmond about 75 km south-east of Cape Town.



1.1 Accessibility

The estuary is accessible from the east and west by the R44 coastal road which runs from the Strand to the hamlet of Bot River via the towns of Gordon's Bay, Rooiels, Betty's Bay and Kleinmond (Figure 1). The road traverses the Palmiet River at the head of the estuary. The estuary is also accessible from the north by a gravel road which winds along the river from the vicinity of the Highlands Forestry Station to the coastal road bridge (Figure 1). This road passes through the Kogelberg State Forest and a permit issued by the Directorate of Forestry must be obtained to use it.

1.2 Local Authorities

Most of the Palmiet River catchment lies within the boundaries of the Caledon Divisional Council (Figure 1). The extreme north-western area of the catchment lies within the boundaries of the Somerset West Divisional Council and a small segment of the western catchment within the boundaries of the Strand Divisional Council.

The mountainous regions of the catchment fall within the boundaries of six state forests controlled by the Directorate of Forestry: the Jonkershoek and Nuweberg State Forests (parts of which lie within the Hottentots Holland Nature Reserve) in the north, Lebanon State Forest in the east, Highlands State Forest in the south-east, Kogelberg State Forest in the south-west and Grabouw State Forest in the west (Figure 1). The low-lying, central region of the catchment comprises privately owned farmlands.

The estuary and its surroundings lie within the 380 ha Kleinmond Coastal and Mountain Nature Reserve which in turn lies within the proposed Protected Area extending from Rooiels to Botrivier (Figure 1).

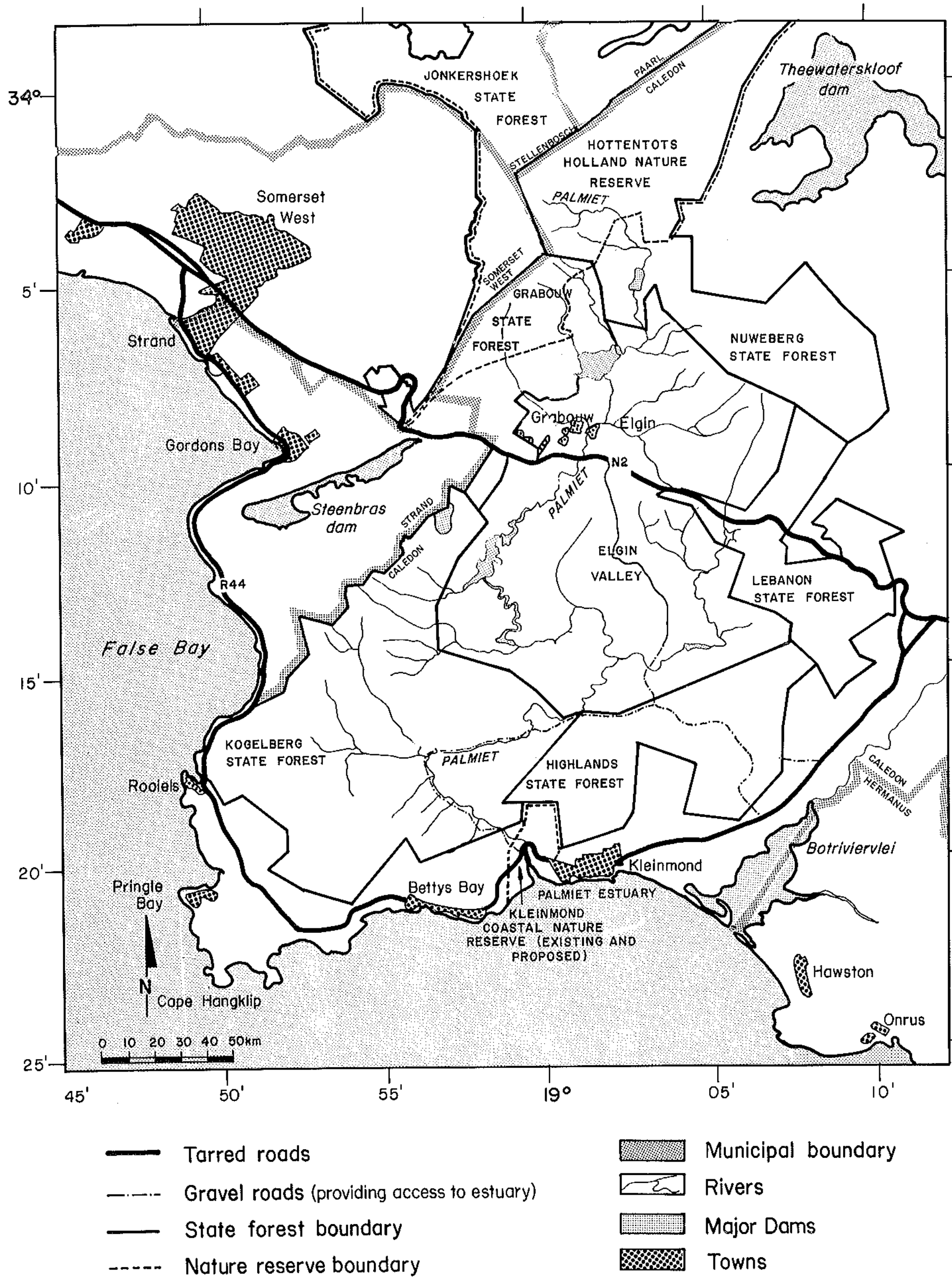


FIG 1: Palmiet River catchment: Municipal, State Forest and Nature Reserve boundaries (after 1:250 000 sheets 3318 Cape Town and 3319 Worcester)

2. HISTORICAL BACKGROUND

2.1 Synonyms and Derivations

HOUTEMA (KOUTEMA, KOUTIMA) The Hottentot name meaning "Snake River" (Burman, 1970; Du Plessis, 1973). There is some uncertainty regarding the origin of this name. According to Mossop (1927) "... the sinuous curves made by the Palmiet in its course to the sea account for this Hottentot name. If its entire course upon the map be glanced at it reminds one forcibly of a snake." Nienaber (1963), however, points out that the Hottentots would not have been able to view the river on this sort of scale. An equally likely possibility is that the river was named after the abundance of snakes encountered along its banks during the earlier days.

PALMIET The name given to the river due to the abundant growth of the Palmiet reed *(Prionium serratum)* along its length.

This name is probably derived from the Dutch words for "palm" and "reed". In 1772 Sparrman (in one of the earliest records of an encounter with the upper reaches of the river) defined Palmiet as "a kind of acorus with a thick stem and broad leaves, which grow out from the top, as they do in a palm tree, a circumstance from which the plant takes its name" (Burman, 1970).

The lower reaches and mouth of the Palmiet Estuary are referred to as the Palmiet Lagoon and Die Mond respectively (Slingsby, 1983; 1:50 000 Sheet 3318BD Hangklip; 1:250 000 Sheet 3318 Cape Town).

2.2 History

Human beings have inhabited the coastal regions adjacent to the Palmiet River mouth for a very long time. Early stone age hunters lived here 120 000 - 140 000 years ago. The appearance of the later stone age man, also known as the "strandloper", extended from about 100 000 years ago into modern times (Boucher, 1982). Remnants of the later inhabitations are still visible today. Between Kleinmond and Hawston, for example, there are Khoisan strandloper fish traps and kitchen middens along the beach and seashells, potsherds and bone tools in the mountain caves (Slingsby, 1983).

After Van Riebeeck's arrival in the Cape in 1652, the relatively rapid European expansion from the Cape to the interior by-passed the mouth region. The Kogelberg mountains were an inhospitable barrier, and the coastal flats between Hangklip and Kleinmond were initially ignored. For nearly two centuries it became the stronghold of outlaws, runaway slaves, criminals and remnants of Khoisan tribes decimated by imported European diseases, such as measles (Slingsby, 1983).

The first known settlement near the Palmiet Estuary was "Welgemoed", a grazing farmstead near Betty's Bay granted to Andries Grove in 1739. Shortly thereafter, the Louw family moved up the Palmiet valley, leaving their mark on the map with names like the "Wynand Louwsbosrivier". Development in the area was, however, slow. In 1771 when William Patterson travelled the coast from Somerset West to the Bot River, he did not report meeting any human beings at all. He did, however, report seeing a rich abundance of wildlife, including hyena, eland, zebra, bontebok, buffalo, Cape lion, hippo and kudu (Slingsby, 1983).

It was not until the mid-Nineteenth Century that small fishing and holiday communities were established along the coast in the vicinity of Kleinmond. In 1910 the original Lamloch farm was subdivided and the present town of Kleinmond established (Slingsby, 1983).

The estuary naturally formed a formidable barrier to coastal travellers. An old wagon track (dating back to about 1865) which leads down to the west bank of the mouth indicates that early crossings were made in this vicinity. In 1914 a footbridge was built across the upper reaches of the estuary and a few years later, in 1925, a ferry service was established. In 1952 the coastal road bridge was built across the head of the estuary (Slingsby, 1983). Both the footbridge and the ferry soon fell into disuse and there is no trace of either structure today.

In 1976 the Town Council of Kleinmond proclaimed the first 55 ha of the Kleinmond Coastal Nature Reserve. Three years later, in 1979, the reserve was expanded to include over 300 ha of land straddling the Palmiet Estuary. In 1982, the Council pledged to incorporate a further 300 ha of land north of the estuary into the reserve (Slingsby, 1983). The reserve is now known as the Kleinmond Coastal and Mountain Nature Reserve.

Further inland, the Palmiet River entered history as a curse (Burman, 1970). Its strong flow during the winter months and its dense beds of Palmiet reeds rendered crossings by European settlers during the colonization of the Cape extremely difficult. Early explorers such as Sparrman, Sir John Barrow and Lichtenstein who crossed the river between 1775 and 1803 all made mention of the perils associated with traversing the river. Records show that several fatal accidents occurred during these early crossings (Burman, 1970).

In 1811, a bridge was constructed in the vicinity of Oudebrug (near present day Grabouw). This bridge is thought to have been the first constructed in South Africa outside the towns, demonstrating the importance attached to the river as a barrier to colonization. A few years later, in 1830, Sir Lowry's Pass was opened. This route replaced the difficult Hottentots Holland Kloof route, making access to the Palmiet area considerably easier. Now that this was the case, some settlers seem to have been attracted to the area. The most prominent of these settlers was an influential Cape Town merchant, John Gadney, who by 1841 owned most of the land between the Palmiet and Kromme rivers. In 1852 the road from Sir Lowry's Pass finally reached the Palmiet River and six years later the town of Grabouw came into being when Wilhelm Landschmidt sold plots on his farm Grabow to a number of purchasers (Burman, 1970).

Development of the area was at this stage still slow, mainly due to the poor grazing and unsuccessful attempts at growing a variety of crops. It was not until 1902 when the railway line from Sir Lowry's Pass was extended to the Palmiet River and success was obtained with apple crops that the Palmiet valley settlement flourished.

Today the Palmiet River valley is the largest fruit exporting area in southern Africa (26,3 percent of the total export, Bulpin, 1980). There are several privately owned farms situated along its banks stretching from Eikenhof just north of Grabouw to Krabbefontein just south of the Kromme River tributary. Winding its way from the Hottentots Holland Mountains to the sea, the river also runs through several reserves and state forests including the Hottentots Holland Nature Reserve in the north and the Kogelberg State Forest in the south-east. Since the turn of the century some 250 odd dams have been constructed in the vicinity of the Palmiet River and its tributaries (1:50 000 Sheet 3418BB Somerset West, 3418BD Hangklip, 3419AA Grabouw, 3419AC Hermanus) (Figure 3). Some of these impoundments are among the largest built by private enterprise in South Africa (Burman, 1970).

3. ABIOTIC CHARACTERISTICS

3.1 River Catchment

3.1.1 Catchment Area

The Palmiet River catchment is one of the smallest in the south-western Cape. It lies between the latitudes 34°02′ and 34°21′ and the longitudes 18°53′ and 19°10′ (Nel, 1980). Its area is given as approximately 465 km^2 (Pitman *et al.*, 1981), 500 km^2 (Heydorn and Tinley, 1980) and 539 km^2 (Midgley and Pitman, 1969; Noble and Hemens, 1978 and Branch and Day, 1984).

3.1.2 River Length and Tributaries

The Palmiet River is approximately 74 km in length (1:50 000 Sheet 3318 BB Somerset West, 3318 BD Hangklip, 3419 AA Grabouw, 3419 AC Hermanus). There are 11 tributaries which are classified as perennial and have catchment areas greater than 4,5 km^2 (Nel, 1980). These tributaries and their approximate lengths (based on the map in Nel, 1980) are shown in Figures 2 and 3.

3.1.3 Topography

A detailed analysis of the topography of the Palmiet River catchment is provided in Nel (1980).

The Palmiet River rises in the vicinity of Landdroskop (1 133 m) in the Hottentots Holland Mountain Range (Figure 3). Initially it flows in an easterly direction, dropping rapidly in altitude over the first few kilometers (about 400 m in 4 km). About 4 km from its source, the river leaves the steep slopes of the Hottentots Holland Range and swings south towards Grabouw, approximately 12 km away. From here to the Eikenhof Dam, the river flows down the less steep foothills between the Hottentots Holland Range and the Groenlandberge. The gradient in this region is still steep but not nearly as dramatic as in the upper regions (about 300 m in 9 km). Just before the Eikenhof Dam, the river enters the Elgin Valley. From here to the sea, the slope of the land traversed by the river is extremely mild, dropping approximately 300 m over a distance of about 60 km. For the next 35 km the river flows close to the western boundary of the Elgin Valley, flanked by the foothills of the Kogelberg mountains on its west bank and the cultivated lands of the valley on its east bank. It flows in a southerly direction until its junction with the Klein Palmiet where it swings north-east for about 6 km before swinging south again. About 15 km from the mouth, the river leaves the Elgin Valley and enters the deep valley between the Dwarsrivierberg and Perdeberg ranges. It flows predominantly in a south-westerly direction until the junction with the Louws and Dwars rivers where it swings south-east and heads for the sea. Near the coastal road which traverses the river, the river begins to broaden out into an estuary about 1,67 km long. The coastal plain at the mouth is extremely narrow (Figure 14) so that the river changes from a mountain stream to an estuary with no intervening stretches typical of a lower river.

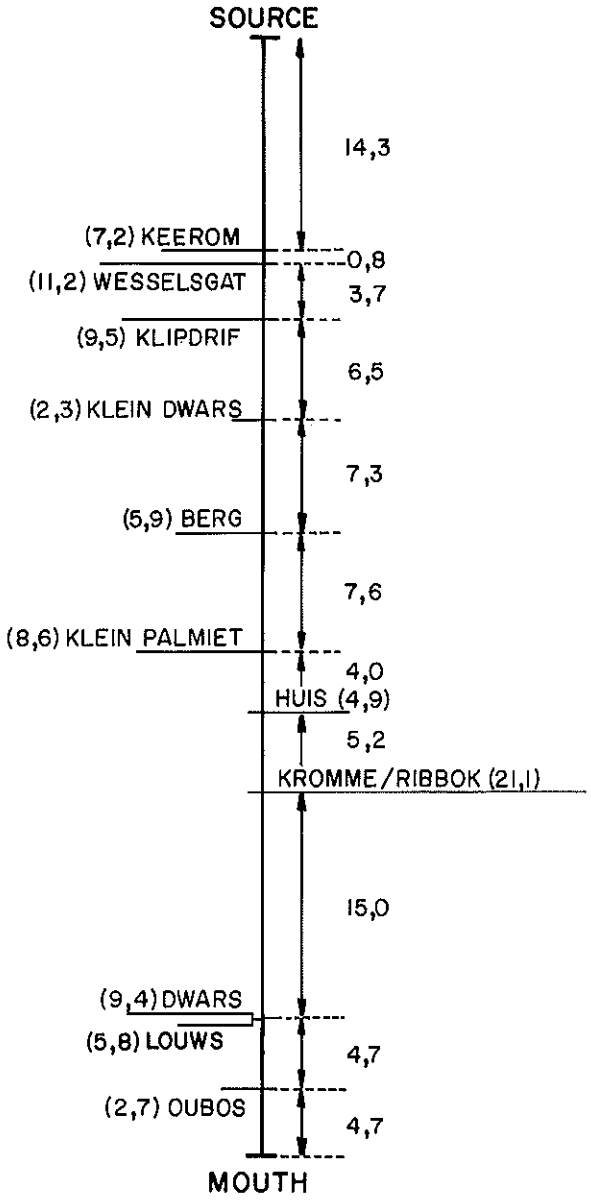


FIG 2: Major tributaries of the Palmiet River. Lengths shown (in kms) are approximate. Tributary lengths are in brackets. (based on map in Nel, 1980 and 1:50 000 sheets 3318 BB Somerset West, 3318 BD Hangklip, 3419 AA Grabouw and 3419 AC Hermanus)

3.1.4 Geology

The geology of the Palmiet River catchment is dominated by Table Mountain Group sandstones, quartzites and shales and Bokkeveld shales and sandstones (Figure 4). Witteberg Group quartzites and shales occur to a lesser extent (Nel, 1980).

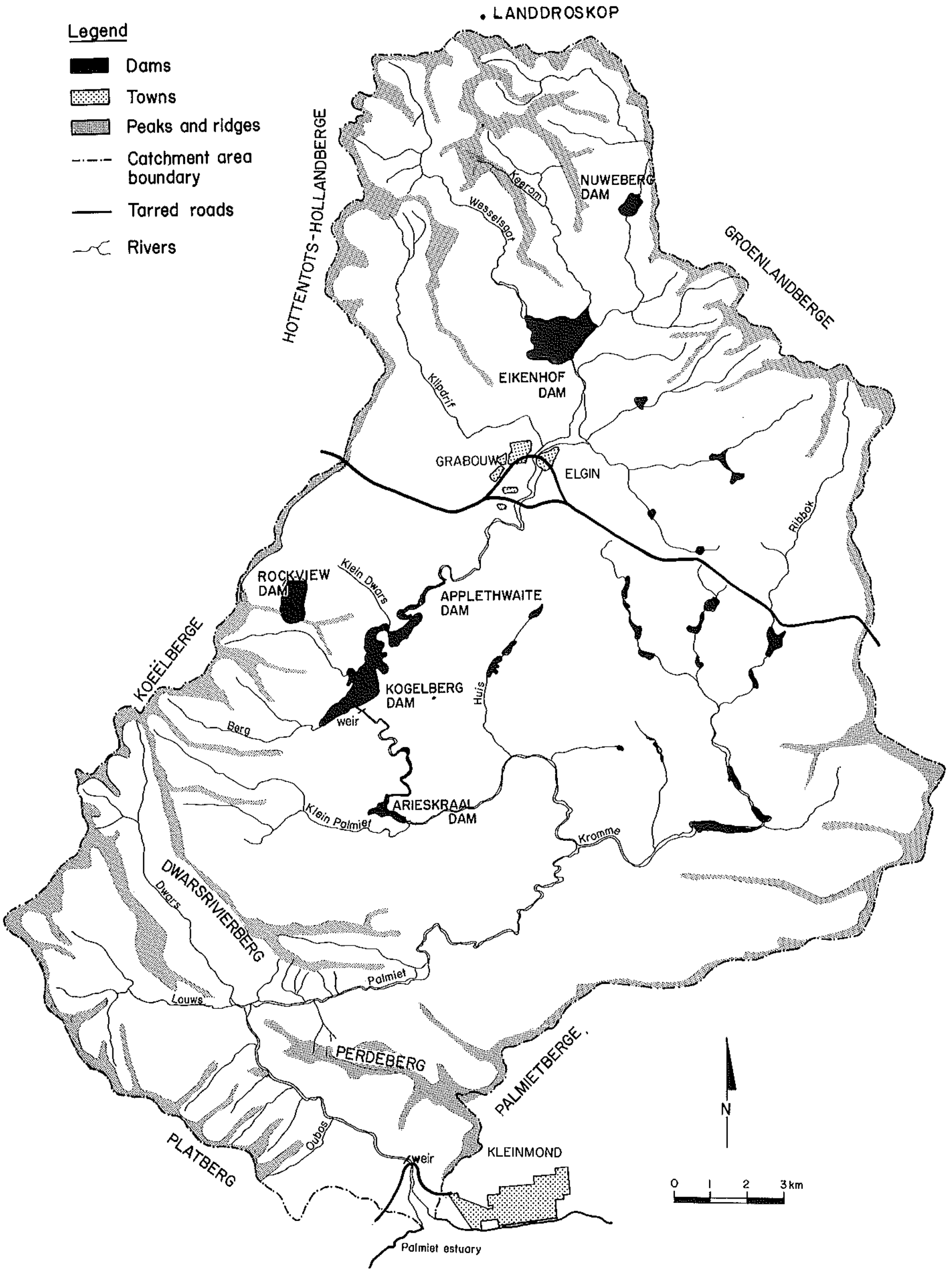


FIG 3: Palmiet River Catchment: Tributaries and topography (after Nel, 1980)
Only the larger dams on the Palmiet River and its major tributaries are shown

Greater resistance to weathering processes has left Table Mountain Sandstone as the most prominant feature of the landscape forming high ground and mountain ranges while the less resistant shales now occur only at the lower elevations.

The mountains and foothills of the catchment consist predominantly of the sandstone and quartzites of the Nardouw Formation. Sandstones and quartzites of the Peninsula Formation, which are generally more resistant to weathering, occur in the northern and south-western mountainous regions of the catchment and along the coast. The Peninsula Formations are separated from the Nardouw Formations by fault lines or by the closely associated shales and tillites of the Cedarberg and Pakhuis Formations respectively. The central regions of the catchment and the foothills of the Groenlandberge consist of the sandstone and shales of the Bokkeveld Group. Substantial Witteberg Formations also occur in the eastern, low-lying regions of the catchment.

There are three major faults in the catchment (Figure 4). In the north-eastern area of the catchment, a fault runs in a north-westerly direction through the foothills of the Groenlandberge. In the central region a fault runs in an east/west direction from the vicinity of Houwhoek Pass to the junction of the Palmiet and Klein Palmiet rivers. In the southern region a fault runs in an east/west direction from the vicinity of the Palmiet/Kromme confluence to Rooi-els on the False Bay coast. Between the Arieskraal Dam and the Dwars River, the course of the river clearly follows portions of the central and southern fault lines.

Various geomorphological features in the catchment indicate that the Palmiet River has a complicated history (De Villiers *et al.*, 1964). It has been proposed, for example, that the Palmiet, Kromme and Jakkals rivers once formed a complex which drained eastwards into the Bot River. Subsequently the Palmiet and Kromme Rivers were captured by a younger river which cut along the weak fault line in the southern part of the catchment.

The geomorphological history and development of the estuary and the lower reaches of the Palmiet River have been largely determined by transgressions and regressions of the sea level during the Tertiary and Quaternary periods (that is, within the last 65 million years). The estuary is currently situated in a palaeo-valley underlain by bedrock composed of Table Mountain Group sandstone of the Nardouw Formation. Due to fluvial erosion during major sea level regressions (such as that which occurred during the Oligocene, (Siesser and Dingle, 1981)) this bedrock is located below present day sea level (J Rogers, Marine Geoscience Unit, UCT, pers. comm.). The depth of erosion has not been investigated but is probably substantially less than 52 m, the depth of the centre of the nearby Bot River estuary palaeo-valley which is composed of less resistant Bokkeveld shale (J Rogers, pers. comm.). The nature of the sediment overlying this bedrock has likewise not been analysed. Judging from a lithostratigraphic survey of the area surrounding the Bot River estuary (Rogers, 1985), however, the sediment is probably composed of distinct layers deposited sequentially during the Pleistocene and early Holocene glacial and interglacial periods, approximately 47 - 4 000 years ago. The number of layers will depend largely on the depth of the palaeo-valley and if extensive vertical erosion has not occurred, the bedrock is probably only overlain by a single layer of beach sand deposited during the last few thousand years (J Rogers, pers. comm.). During major sea level regressions (such as that which occurred during the Wurm IIb glacial, 20 - 18 000 years ago, (Flint, 1981) the Palmiet River would have formed a tributary of the Bot River with the confluence about 5 km south-east of the present day Palmiet Estuary (J Rogers, pers. comm.). The Bot River, in turn, would have reached the lowered coastline at a point south of False Bay (Rogers, 1985).

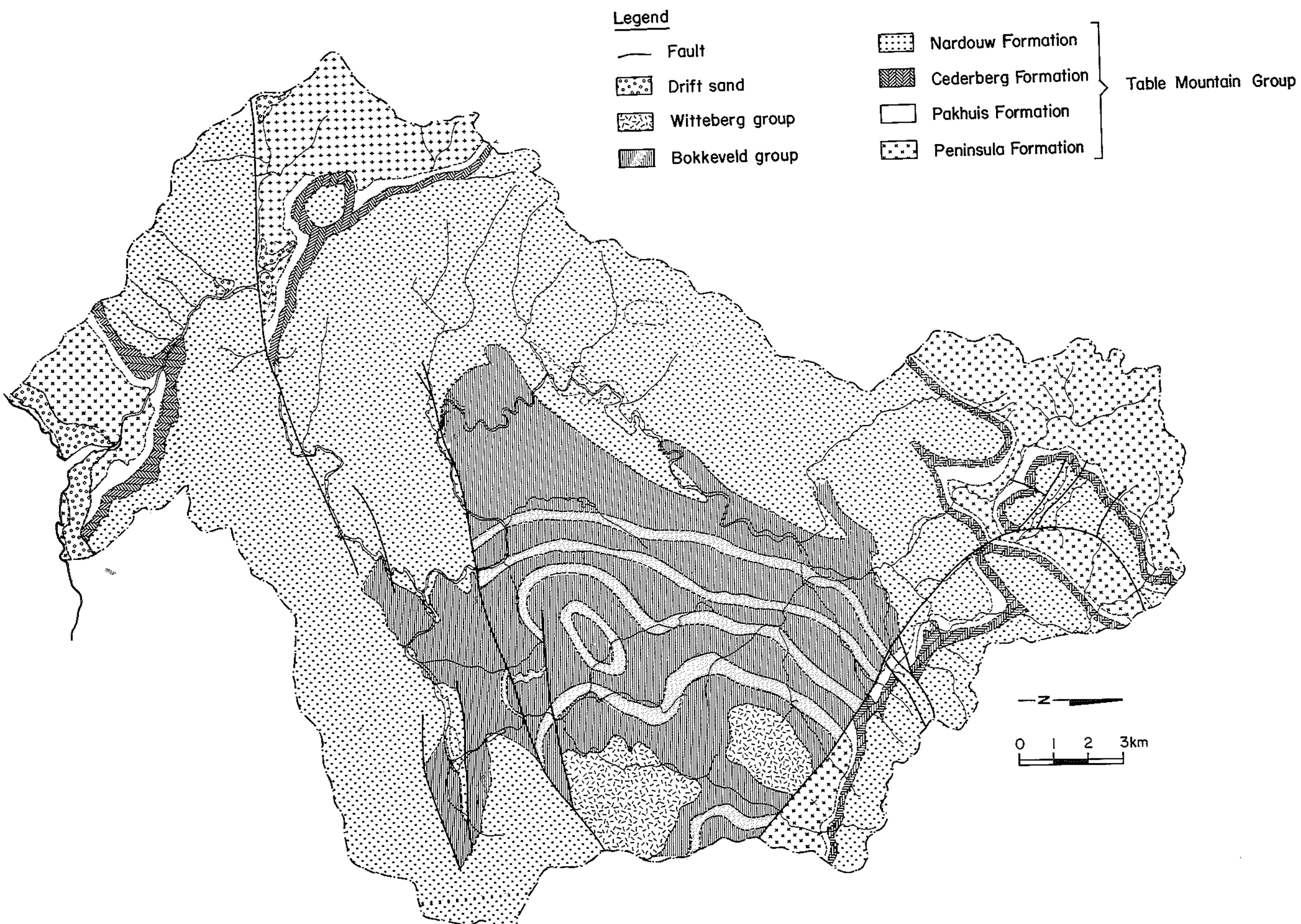


FIG 4: Geological features of the Palmiet River Catchment and Estuary
(after Nel, 1980 and Boucher, 1978)

Sea level oscillations also appear to have been largely responsible for the configuration of the land surrounding the estuary. A gently sloping terrace, which extends to about 30 m above sea level, is prominent at Kleinmond and in the vicinity of the Palmiet Estuary (Figure 14). This terrace is thought to be the product of marine erosion during a 30 m Early Pleistocene transgression, approximately 2 million years ago (J Rogers, pers. comm.). There is also evidence of a 6 m Late Pleistocene (125 000 years ago) transgression east of Kleinmond and a 3 m post glacial (5,5 - 2 000 years ago) shoreline near Hawston (see Figure 1 for location) (Rogers, 1985).

3.1.5 Climate and Run-off

Climate

A detailed summary of the climate of the Palmiet River catchment is provided in Nel (1980). Only a brief synthesis is given here.

The Palmiet River and its catchment lie within climatic region M (Schultze, 1965). Climatic region M has a Mediterranean climate receiving most of its rainfall in winter from about May to September and is characterized by a warm to hot and dry summer.

During the summer months south-easterly to easterly winds predominate while during winter north to north-westerly winds prevail. Calm conditions/light variable winds occur throughout the year but predominate during the early winter months (Boucher, 1978; Figure 20).

The winter rainfall in the Palmiet catchment area is associated with westerly cyclones which move over the south-western Cape. Orographic rainfall also occurs, the mountainous regions receiving more rain than the valleys (Nel, 1980). Rainfall varies from about 700 mm per year in the low-lying central, eastern and coastal region to *ca.* 1500 mm inland. Highest average monthly rainfall generally occurs between June and August whereas lowest monthly averages occur in December and January (Table 1).

TABLE 1: Seasonality of rainfall at selected stations in the Palmiet River catchment area. (Data supplied by the Weather Bureau, Department of Transport and Nel, 1980)

Station	Nuweberg Forest Station	Grabouw Forest Station	Kleinmond
Elevation	560 m	258 m	15 m
Period of observation	1962-1972	1951-1967	1949-1985
Highest average monthly rainfall (mm)	277 (Jun)	195 (Aug)	98 (Jun)
Lowest average monthly rainfall (mm)	36 (Jan)	30 (Dec)	25 (Dec)
Annual average rainfall (mm)	1 485	1 136	707

The mean annual rainfall for the entire catchment area is given as 1 139 mm per annum (Nel, 1980). Calculations based on data in Pitman *et al.* (1982), however, give a mean value of 1 019,35 mm per annum. In the vicinity of the estuary, the mean annual rainfall is approximately 700 mm per annum (Table 1).

Due to high winds and hot summers, evaporation may reach 1 200-1 500 mm per annum in certain places (Branch and Day, 1984). Data for the proposed Hangklip Dam area show that evaporation is highest in summer (approximately 201 mm per annum in January) and lowest in winter (approximately 32 mm in July) (Effect of the Proposed Hangklip Dam on the Palmiet Estuary, 1980).

Mist occurs throughout the year but is most frequent in spring. Several plant species in the catchment area are adapted to and somewhat reliant on misty conditions (Nel, 1980).

In the Palmiet River catchment the lowest average daily minimum and maximum temperatures occur during July while the highest averages occur during January and February. Due to large differences in elevation, coastal and inland temperatures differ considerably (Nel, 1980).

For example:

Average daily temperature (Nel, 1980)

	Elgin (259 m)		Silversands* (15 m)	
	Max. (°C)	Min. (°C)	Max. (°C)	Min. (°C)
January	34,9	6,6	23,9	16,4
July	23,2	-1,9	16,7	9,6

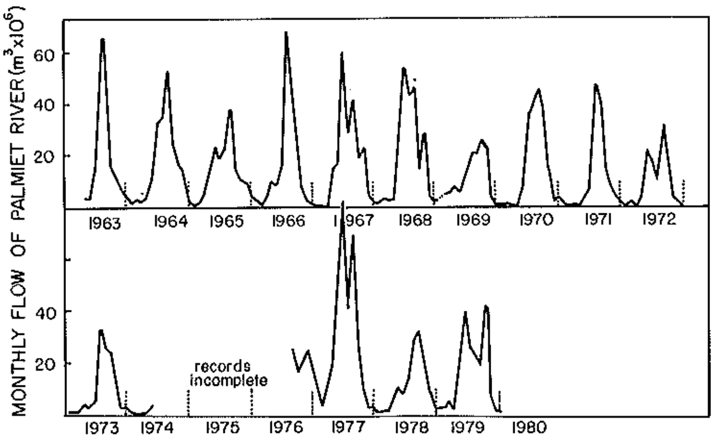
* coastal station just south of the catchment area.

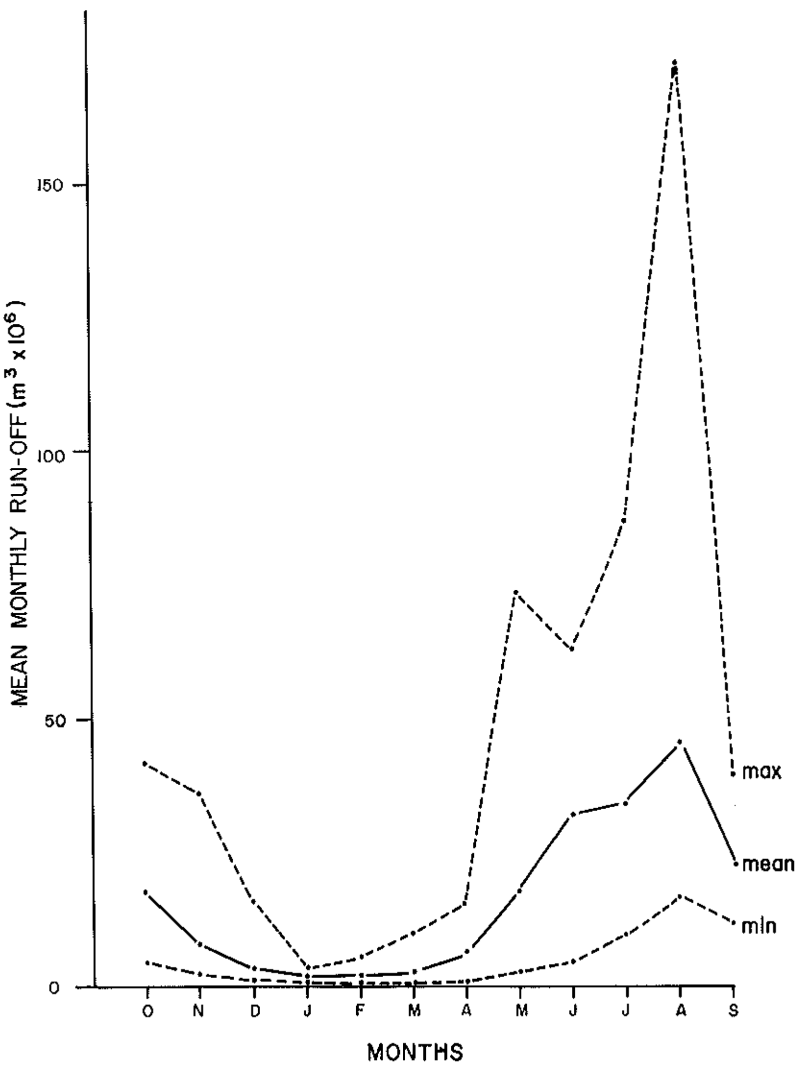
Topographical features of the area also influence temperature. The northern and western slopes are much hotter and drier than the southern slopes as a result of the angle of the sun's rays relative to the earth. Southern slopes are also cooler due to more humid conditions (Nel, 1980).

Run-off

The gross mean annual run-off of the Palmiet River catchment is 310 x 10^6 m^3 (Midgley and Pitman, 1969; Noble and Hemens, 1978). River flow measurements taken at gauging station G4M07 at Welgemoed (34°20'S; 18°59'E) give the mean annual flow for the Palmiet as 192,48 x 10^6 m^3 (Pitman *et al.*, 1982), however, the White Paper (South Africa, 1982) gives a figure of 245 x 10^6 m^3/annum. Run-off varies considerably on both an annual (Figure 5) and monthly (Figure 6) time scale. Between 1963 and 1979 individual annual flow values ranged from a minimum of 105,01 x 10^6 m^3 (1972/3) to a maximum of 422,04 x 10^6 m^3 (1976/7) (Pitman *et al.*, 1982). Generally there is little flow in summer while the highest flow occurs during the period June to September. Peak flow is extremely variable: it can be as little as one-fourteenth of the average monthly run-off and as much as five times as great.

A comparison between the river flow data (Pitman *et al.*, 1982; Department of Water Affairs Flow Records, unpublished; River Flow Data, 1978) from the gauging weirs just below the Kogelberg Dam (Applethwaite - G4M05) and just above the head of the estuary (Welgemoed - G4M07) indicates the relative annual and monthly contribution the upper and lower regions of the river make to the estuary (see Figure 3 for location of weirs). The catchment regions above and below


MONTHLY FLOW OF PALMIET RIVER ($m^3 \times 10^6$)
60
40
20
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
40
20
records incomplete
1973
1974
1975
1976
1977
1978
1979
1980


MEAN MONTHLY RUN-OFF ($m^3 \times 10^6$)
150
100
50
0
max
mean
min
O
N
D
J
F
M
A
M
J
J
A
S
MONTHS

weir G4M05 contribute respectively 135 x 10^6 m^3 (55 percent) and 110 x 10^6 m^3 (75 percent) per annum. The current average annual consumption of water above and below the Applethwaite weir is respectively 43 x 10^6 and 27 x 10^6 m^3. Similarly, future use is estimated at 15 x 10^6 m^3 and 32 x 10^6 m^3 per annum. Thus the projected volume of water available to the estuary will be 97 x 10^6 m^3 per annum.

A more serious threat to the estuary is a proposal to dam the lower reaches of the Palmiet River (see Section 5). This has led to intensive research into the amount of water required to maintain the estuary mouth in its present state. A policy for the release of compensatory water from the proposed dam has been formulated and is as follows:

(a) Evaporation: A low continuous release of 8 litres/second should be made throughout the year to compensate for evaporation from the surface of the estuary.

(b) Flash release: A release rate of 50 m^3/second will be required for a duration of at least 15 hours to allow the mouth to be properly scoured. To coincide with the pre-impoundment action of winter floods this release should take place in the period June to September every year. It is important that the full force of the release water be felt at the mouth on an ebb-tide to obtain the greatest amount of flushing. Care will have to be taken with the timing of the release depending on the sea conditions and a flood warning system should be implemented.

(c) Supportive releases: Supportive releases of low magnitude should be considered which would ensure that the estuary mouth would remain open for most of the year. It is estimated that a discharge rate of 5 m^3/second over a period of 24 hours once a month would be sufficient.

3.1.6 Land Ownership/Uses

The area between the Palmiet and Kromme rivers is intensively cultivated. Apples form the main crop. Other deciduous fruits such as pears and peaches are also grown but are of minor importance (Nel, 1980). The rest of the catchment area lies within the boundaries of State Forests; Jonkershoek and Nuweberg State Forests in the north, Lebanon State Forest in the east, Highlands State Forest in the south-east, Kogelberg State Forest in the south-west and Grabouw State Forest in the west (Figure 1). Several pine plantations have been established within these State Forests. The largest occur to the east and west of Grabouw in the Grabouw and Lebanon State Forests respectively. Cultivated lands and plantations comprise approximately 55 percent of the catchment area. The remaining 45 percent is covered by fynbos, the natural indigenous vegetation of the region (Nel, 1980).

Other than a few saw-mills, a carton factory and a large fruit juice factory there is very little industry in the Palmiet River catchment (Nel, 1980).

3.1.7 Obstructions

Between the Nuweberg and Kogelberg State Forests the Palmiet, Kromme and Huis rivers and their tributaries are extensively impounded, mainly for irrigation purposes. The major impoundments on the Palmiet River itself (Figure 3) are the Nuweberg Dam (built in 1971, capacity 3,9 x 10^6 m^3), Eikenhof Dam (built in

FIG. 7:

Applethwaite Dam and spillway. (Photo: ECRU, 86-09-04).

FIG. 8:

Arieskraal Dam and spillway. (Photo: B R Davies, 1986.

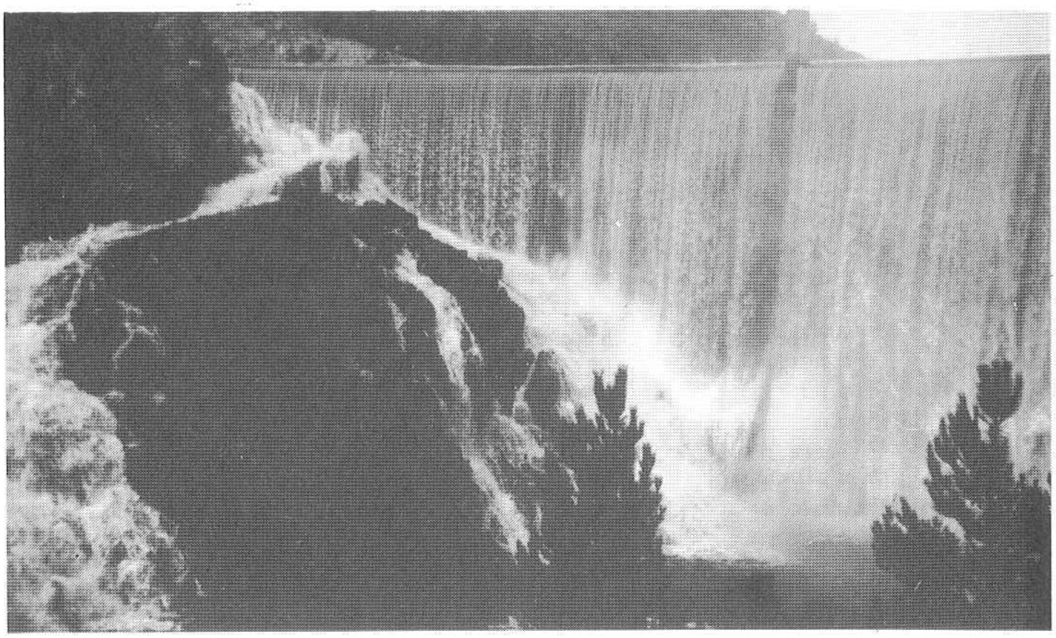
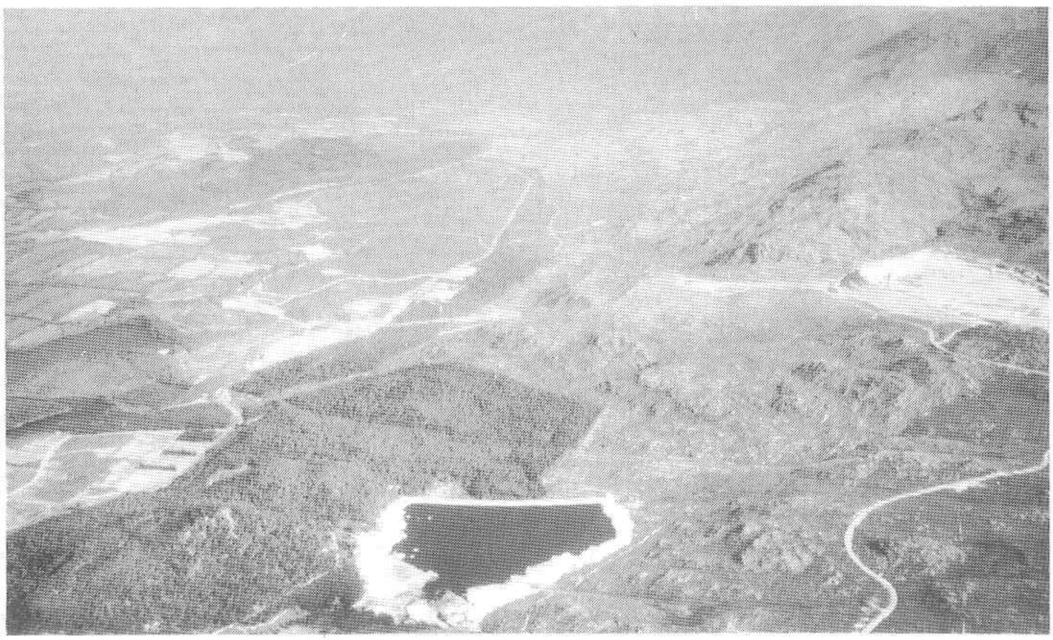


FIG. 9:

Aerial view of Rockview Dam (under construction). (Photo: ECRU, 86-05-01).



1977, capacity 22,7 x 10^6 m^3), Applethwaite Dam (built in 1952, capacity 3,3 x 10^6 m^3) (Figure 7) the Arieskraal Dam (built in 1967, capacity 5,9 x 10^6 m^3) (Figure 8). A fifth dam, the Kogelberg Dam (19,0 x 10^6 m^3), which together with the Rockview Dam (Figure 9) comprises a major pumped storage scheme which was completed in 1987 (G van Zyl, Department of Water Affairs, pers. comm.).

There are several bridges across the Palmiet River. These include the N2 national road bridge just south of Grabouw, main road bridges at Grabouw and north of the Eikenhof Dam, farm road bridges in the Elgin Basin and forestry road bridges in the Nuweberg and Kogelberg State Forests. Bridges are generally well constructed and do not appear to have any effect on river flow (ECRU field trip, 86-09-04; B A Byren, Zoology Department, UCT, pers. comm.). In several cases this can be attributed to the steep-sided nature of the river bank which makes the construction of embankments below the floodline unnecessary. Low-lying bridges are constructed so as to allow unhindered overtopping to occur during peak flow periods.

Just south of the bridge at Grabouw, there have been attempts to construct a causeway by dumping rubble into the river (Figure 10). At the time of the ECRU field trip (86-09-04) the river had washed the middle section of the structure away. The amount of water passing through the gap was substantially less than that which would normally occurs. The effect of the causeway in summer has not been assessed, but as it appears to have no pipe culverts, it is likely to reduce water flow substantially. The river is already severely congested with vegetation below the causeway and attenuation of water flow is probably aggravating the situation. The construction of the causeway appears to be part of a plan to convert the river in the vicinity of Grabouw into a lake (M V Anderson, Ekokonsult Inc., pers. comm.). While acknowledging the need for recreational facilities in Grabouw, it is recommended that the ecological impact of the causeway be assessed and, if necessary, steps be taken to reduce the obstructive effect of the structure.

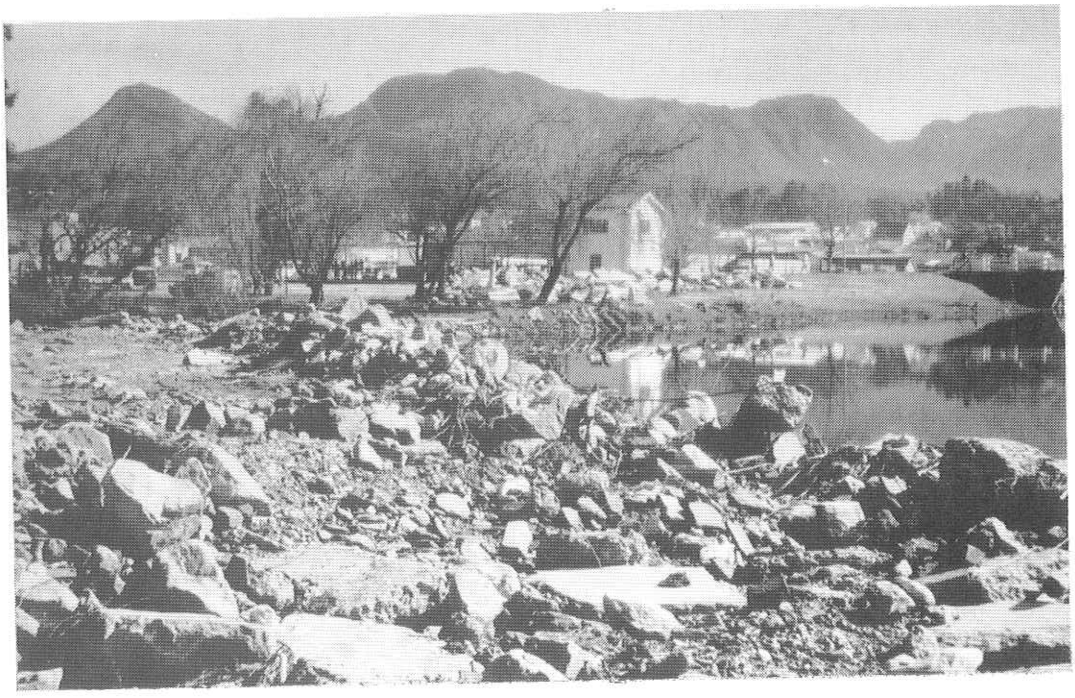


FIG. 10: The unsightly rubble causeway at Grabouw. The main road bridge can be seen in the background. (Photo: ECRU, 86-09-04).

A second causeway, just south of the Kogelberg Dam wall, is less restrictive to water flow. This causeway has several pipe culverts and is constructed so that during periods of peak flow, overtopping of the structure can occur (Plate I). The causeway is thus probably only severely obstructive when river flow is strong, but not strong enough for substantial overtopping to occur.

There are three gauging weirs along the course of the river; one near the Eikenhof Dam, one just below the second causeway (Plate I) and the third just above the coastal road bridge (Figure 11). The design of the weirs is such that there is little obstruction to river flow. During periods of peak flow, overtopping of the weirs occurs (ECRU field trip, 86-09-04).

In certain regions, dense growths of riparian vegetation can obstruct river flow, particularly in the summer months. This is clearly visible in the vicinity of the N2 national road bridge. Two major tributaries of the Palmiet, the Louws and Dwars rivers, are practically overgrown with vegetation of the *Prionium - Wachendorfia* Swamp Community (Boucher 1978; Figure 12). At the time of the ECRU field trip (86-09-04) when the Palmiet River was flowing stongly, the fluvial contribution of these tributaries was negligible.

3.1.8 Siltation

Monthly measurements (February to June) of total suspended solids along the entire length of the Palmiet River indicate that siltation rates are generally low (B A Byren, Zoology Department, UCT, *in litt.)*. Even in winter, when river flow rates are high, total suspended solids rarely exceed 20 mg/l. Suspended solids entering the estuary are notably low, ranging from 1,1 mg/l (May) to 7,5 mg/l (July). This seems to be for a number of reasons. Firstly, the mountains are composed almost entirely of sandstone of the Table Mountain Group with some tillite derived from Bokkeveld shale in the valleys. The hardness of these rocks results in low levels of erosion and consequently a relatively low

FIG. 11: The gauging weir (Welgemoed) just above the coastal road bridge. (Photo: ECRU, 86-08-20).

FIG. 12: Dwars/Louws River overgrown with vegetation. Palmiet reeds in foreground. (Photo: ECRU, 86-09-04).

sediment load in the water (Branch and Day, 1984). Secondly, the Palmiet River passes through several large dams in the upper middle reaches and a weir in the lower reaches. These impoundments act as silt traps. Thirdly, a large proportion of the catchment area is covered with natural fynbos. This vegetation type forms a thick "mat" which covers the sandy ground and limits erosion to a large extent (Nel, 1980).

At the time of the ECRU field trip (86-09-04) the water in the Kromme River was dark brown and appeared to be carrying a fairly heavy silt load. This discolouration was clearly visible in the Palmiet River south of its confluence with the Kromme and extended right down to the estuary (Plate II). A preliminary analysis of a water sample taken just below the confluence revealed that the Palmiet River was carrying a silt load in excess of 100 mg/l (M V Anderson, Ekokonsult Inc., pers. comm.). Deep alluvial deposits were also observed along the banks of the lower reaches of the Palmiet River. These two observations suggest that the river is periodically capable of carrying a high silt load.

The construction of dams inevitably leads to increased silt loads in the water. It is gratifying to note that considerable precautions were taken to minimize the introduction of sediments into the river at the Kogelberg Dam construction site (Figure 13). The maximum acceptable silt load in the river water below the construction site was 25 mg/l and levels were constantly monitored (M V Anderson, pers. comm.). Suspended solid measurements taken just below the construction site indicated that levels were consistently lower than this acceptable standard (B A Byren, *in litt.*). There was, in fact, not much difference between silt levels below the dam and silt levels in other regions of the river.

It is uncertain to what degree the river has contributed to the extensive superficial sediment deposits in the middle reaches of the estuary (see Section 3.2.4). A predominantly riverine origin of these deposits would indicate that the river is capable of carrying a heavy silt load. A predominantly marine origin, on the other hand, would indicate that deposits in the estuary are due to tidal action rather than siltation. What is clear, however, is that sediments throughout the estuary contain a very low percentage of mud (see Section 3.2.4). This is probably due to a combination of low siltation rates and the fast flow regime of the estuary.

FIG. 13: Silt traps at the Kogelberg Dam construction site. (Photo: ECRU, 86-09-04).

3.1.9 Abnormal Flow Patterns

The following information is derived from a computer-produced table (supplied by the former Department of Water Affairs, Forestry and Environmental Conservation) which shows the run-off of the Palmiet River after compensation for upstream usage over the period 1923/4 to 1975/6 (Effect of Proposed Hangklip Dam on the Palmiet River mouth, 1980). Since the gauging station (G4M07 Welgemoed) just above the head of the estuary only came into operation in 1963, a monthly rainfall/run-off regression model has been used to extend the period of observation to 1923.

(i) No flow is listed on 28 occasions, covering a period of 38 months (6 percent of the observation period). This implies that the chance of no flow is 53 percent in any one year.

(ii) Of these 28 occasions, 20 percent persisted for one month, seven for two months and one for four months.

(iii) The estuary mouth was continuously open during 29 of the 53 years (55 percent of the total number of years). Furthermore the mouth was closed once a year during 20 years and twice a year during four years.

(iv) The greatest predominance of mouth closures is in February with a probability of occurrence of 26 percent, followed by May, March and November with 13, 11, and 11 percent each, respectively.

(v) The longest period without any mouth closure was seven years (1936/37 - 1942/43), whereas the most consecutive years during which a mouth closure took place was nine years (1927/28 - 1935/36).

At present, the mouth closes on average once every two to three years, mainly during February.

Data obtained from the gauging station G4M07 was used to determine the total run-off greater than the mean monthly run-off during single peak flow events (Effect of the Proposed Hangklip Dam on the Palmiet River mouth, 1980). Total run-off greater than the mean varied from 0,15 x 10^6 m^3 (January) to 7,7 x 10^6 m^3 (July). The maximum value obtained for July is approximately 20 percent of the mean monthly run-off for that month. This indicates a low probability of abnormal peak flow events causing floods. As far as can be ascertained major floods have never occurred along the banks of the river or in the estuary area.

3.2 Estuary

3.2.1 Estuary Characteristics

The Palmiet Estuary is 1 670 m long and 282 m at its widest point (Branch and Day, 1984) (Figure 14). The average spring tide area is approximately 214 000 m^2 and the average spring tide volume approximately 217 000 m^3 (Largier, 1986). The upper extremity of the estuary is delineated by a series of rocky sills which reach the surface in places (Figure 15). At this point the estuary is about 50 m wide and gradually increases to a width of 150 m about halfway towards the mouth. This entire stretch lies within steep rocky banks which gradually become lower and less steep downstream (Figure 16). South of the jetty, the estuary broadens out into a calm, shallow lagoon, about 700 m long. The mouth takes on the form of a shallow channel, variable in width and length, between the sandspit and rocky promontory. A channel starts off close to the east bank near the head and halfway down the estuary moves across to the west bank, leaving a wide sandflat on the east bank which is usually exposed at low tide (Figure 17). The sandflat has an area of approximately 110 000 m^2 and it is here that the estuary reaches its widest point (Branch and Day, 1984). The channel becomes less pronounced towards the mouth where sand from the spit is brought into the estuary on the high tide and forms a bar immediately inside the mouth.

In general the morphology of the estuary is very stable due to the predominantly rock-lined banks. Only on the central eastern bank of the estuary are there major sand deposits. These, however, consist mainly of consolidated sand dunes.

3.2.2 Coastal Hydraulics

(Section contributed by L. Barwell, Coastal Processes and Management Advice Programme, EMA, CSIR)

The functioning of an estuary mouth and therefore an estuary as a whole, is influenced by the local deep-sea wave climate. Waves approaching the coast at an oblique angle are responsible for the generation of longshore currents and therefore longshore sediment movement.

Waves

Wave data from Voluntary Observing Ships (VOS) and Waverider accelerometer buoys were used to determine the wave characteristics offshore of the Palmiet River area (CSIR, 1980).

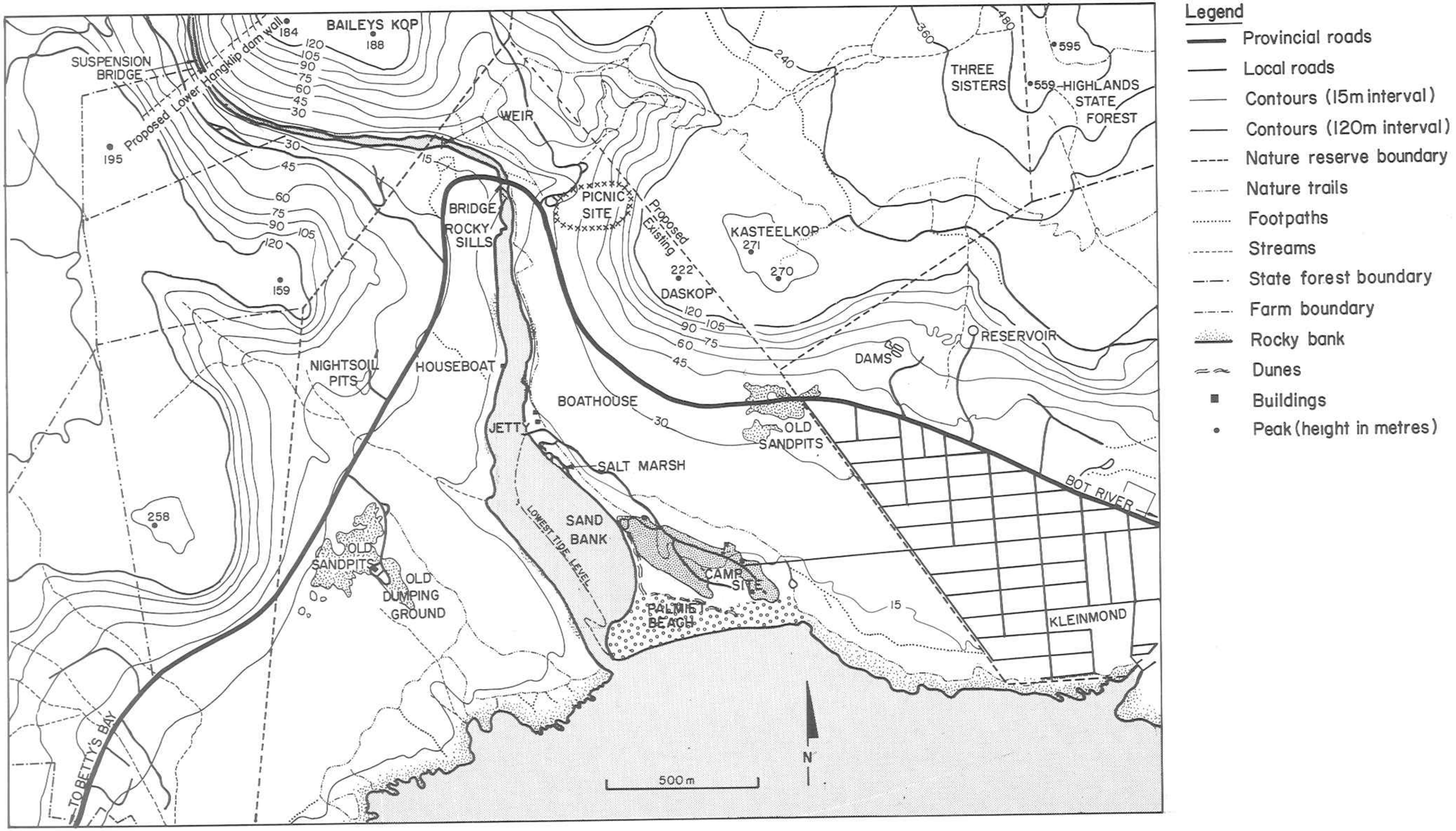


FIG 14: Palmiet Estuary (after Slingsby, 1983).

FIG. 15:

The rocky sills that delineate the head of the estuary. (Taken from coastal road bridge). (Photo: ECRU, 86-08-20).

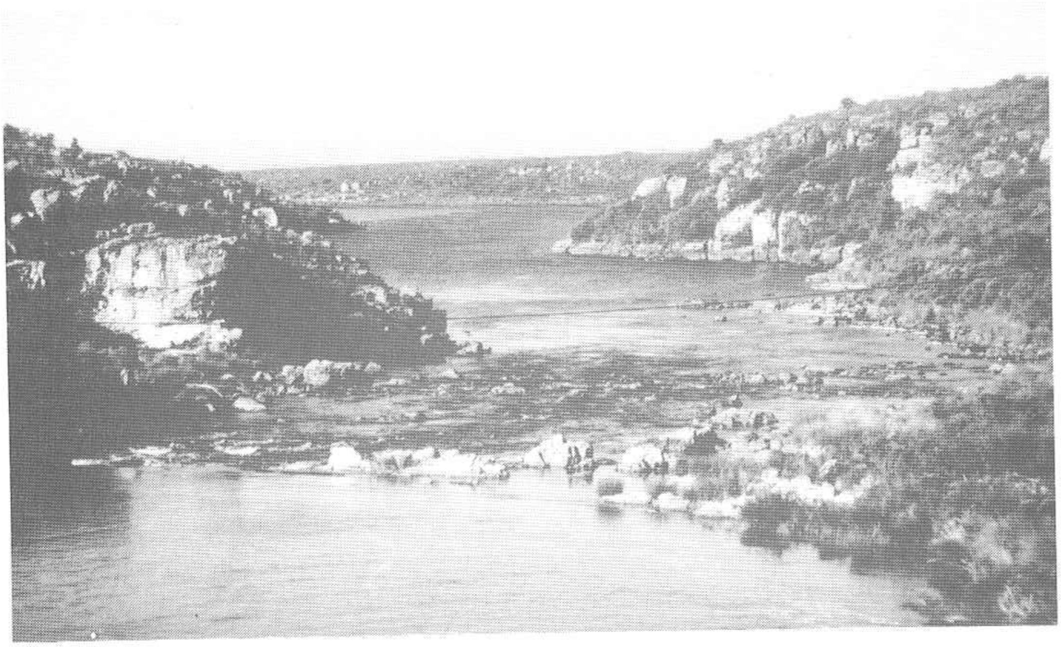


FIG. 16:

Palmiet Estuary in 1962 showing steep sided banks. (Photo: A F P J Heydorn, 62-05-02).

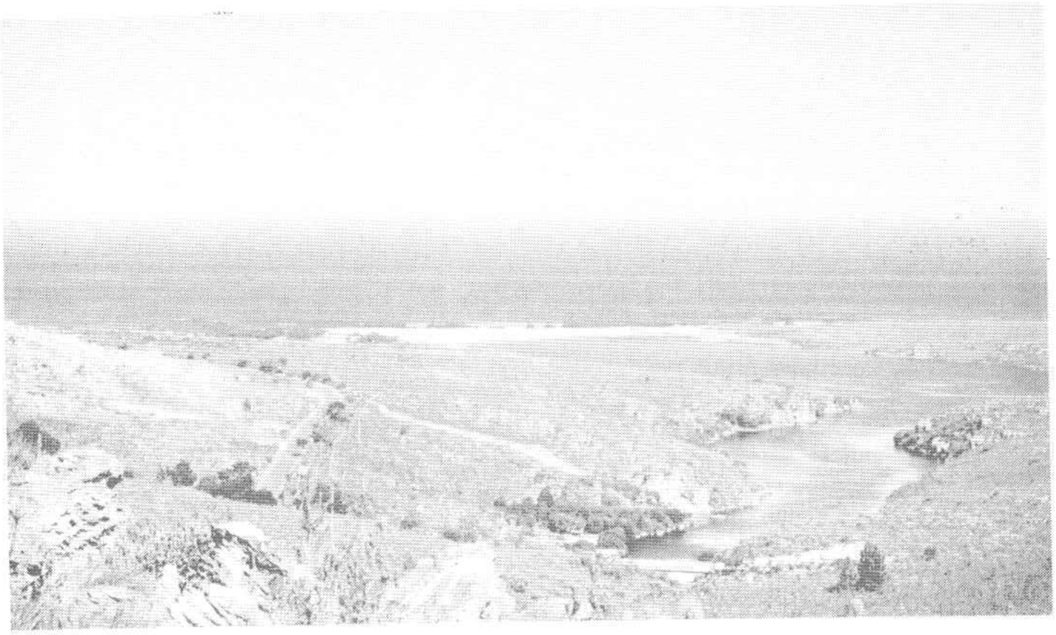


FIG. 17:

Palmiet Estuary at spring low tide showing extensive eastern sandbank. (Photo: ECRU, 86-08-20).

Due to the orientation of the coastline at Palmiet, only waves from a sector between directions 90° (east) and 270° (west), that is, southerly waves, can reach the area under consideration (see Figure 18).

An analysis of the deep-sea wave data related to the refraction of the waves due to the change in seabed topography as they approach the coastline, was done (CSIR, 1980). The results were used to determine the wave characteristics within the breaker zone at the Palmiet beach. From this the movement of sediment within the breaker zone could be calculated.

Sediment movement

Because of wave action there is a continuous change (flux) of momentum in the direction of wave approach. Inside the breaker zone, as waves dissipate their energy by breaking, the difference in momentum flux causes a rise in water level and, if the waves approach the shore obliquely, a current occurs alongshore, predominantly within the breaker zone. Bottom sediment, which has been stirred up from the bed by wave action and especially by the turbulence due to breaking waves, is transported in the longshore direction by the longshore current. Therefore the direction of this longshore sediment movement depends on the direction of the approaching waves.

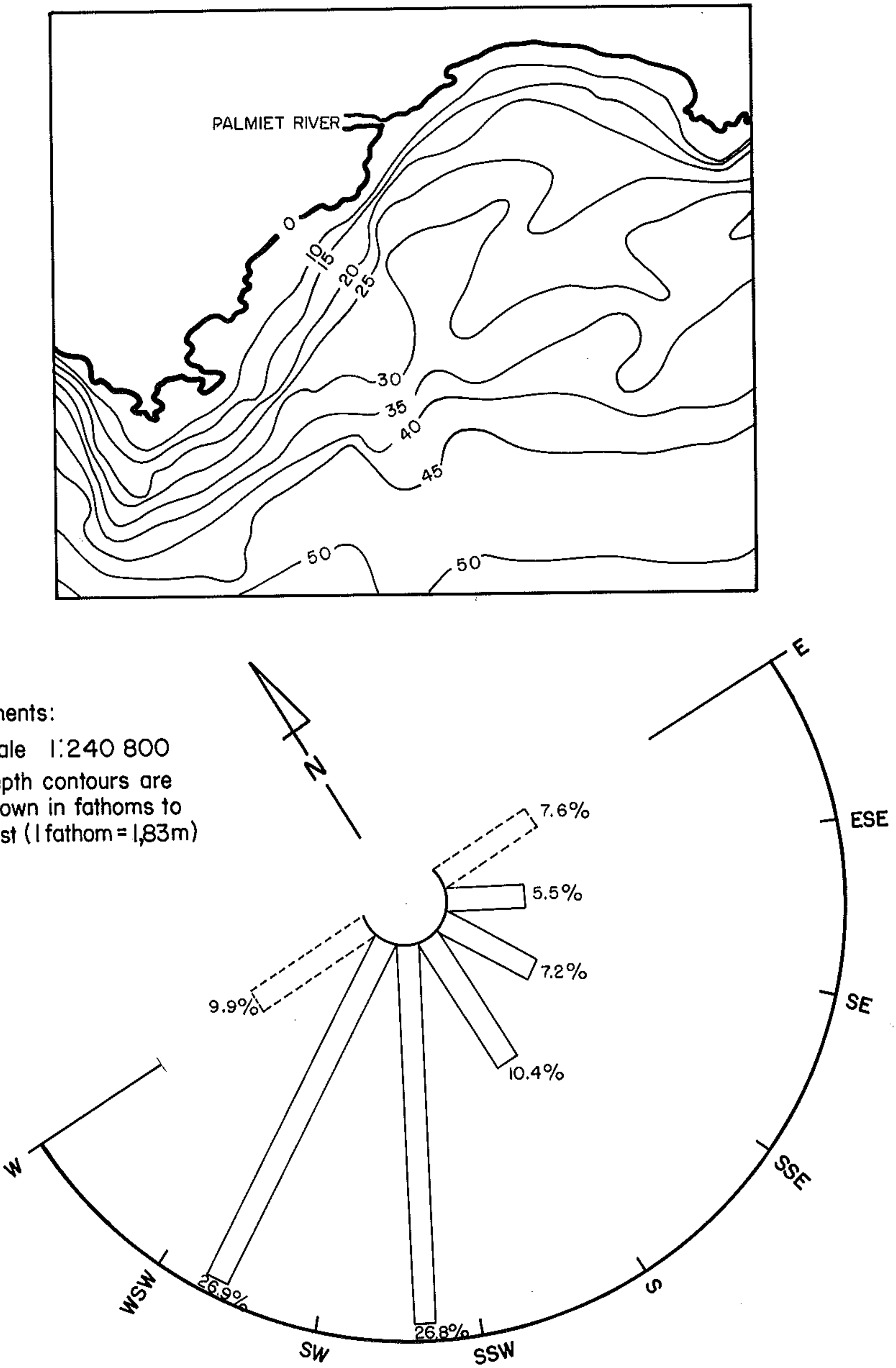
Calculations (CSIR, 1980) show that a net eastbound sediment movement of 1,0 million cubic metres per year can occur. The actual sediment transport rate attained on site however does not only depend on the longshore component of the wave energy flux and the grain size, but also on the availability of movable material. For Palmiet, which has a limited stretch of sandy beach, nested in a rocky coastline, the available material is moved around within these limits resulting in a net longshore transport rate of zero at the centre of the beach to the east of the river mouth.

The situation is different at the mouth, however, because westbound sediment can be moved unhindered towards the mouth which is sheltered by the rocky promontory. Part of the sediment arriving at the estuary mouth will be transported into the estuary during flood-tide. Since the wave action inside the estuary mouth is less during ebb-tide, only part of this material can be transported out to sea again. Measurements taken during two complete tidal cycles (neap tide in April and spring tide in July) verify this (Branch and Day, 1984). As a result, the volume of material arriving at the estuary mouth (from the east) would be more than the volume transported away (towards the east), causing a build-up of sand within the estuary mouth. This material remains within the estuary until flushed out during periods of peak freshwater run-off.

Mouth stability

The stability of an estuary mouth is governed by the interaction between the longshore wave-driven sediment movement, which represents the blocking mode, and the tidal flow (or peak freshwater run-off), which represents the flushing mode.

Calculations based on the relationship between the longshore sediment movement and the peak freshwater run-off were done for the Palmiet (CSIR, 1980). Results show that the estuary mouth is flushed by peak freshwater run-off on average for five months per year during the period May to September. This can be regarded as the flushing period of the estuary. Furthermore it was shown that the estuary mouth was narrowest during the period December to February, which can be considered to be the blocking period. Observations by local inhabitants (such as Messrs Niemand and Langenhoven) verify these results.



Comments:

(1) Scale 1:240 800

(2) Depth contours are shown in fathoms to lwst (1 fathom = 1,83m)

FIG 18: Offshore bathymetry and wave rose showing the direction of waves in the vicinity of the Palmiet River mouth

Weekly, on-site estimates of the cross-sectional flow area at low tide at the narrowest point at the Palmiet Estuary mouth have been recorded for the period October 1981 to October 1986. Matching these with river discharge measured at the head of the estuary (flow gauging station G4M07), a relationship between river discharge, Q (m^3/s) and mouth cross-sectional area, A (m^2), was determined as $A = 2{,}6Q^{0{,}6}$ (Barwell, 1988) (Figure 19).

The predictions and observations outlined above indicate that the mouth, although almost permanently open, is in a sensitive state of dynamic equilibrium, that is, it opens wide during peak freshwater run-off whereafter it closes gradually, only to be flushed open again during the next peak event. If these peak events do not occur with sufficient regularity, the westbound longshore sediment movement could close the mouth. At present this occurs on average only once every two to three years. Unless cognizance is taken of this, future development in the catchment area (such as the building of the proposed Hangklip Dam), could have profound effects on the dynamics of the mouth and therefore the estuary as a whole.

3.2.3 Estuary Hydraulics

Since the Palmiet River mouth is almost permanently open, tidal surges have profound effects on the flow patterns within the estuary. Flow patterns recorded at the mouth indicated that as much as 50 percent of the total basin volume could be exchanged during a neap tidal cycle, during low freshwater inflow (Branch and Day, 1984) and Largier (1986) observed that up to 194 percent of the spring low tide basin volume was imported during a spring tidal cycle. This resulted in a higher current velocity during the incoming tide. During periods of high river flow it was estimated that outflow through the mouth during a spring tidal cycle amounted to about 150 percent of the total volume of the estuary with highest velocities recorded during the ebb-tide.

Results from water level measurements taken at Palmiet from 21 to 24 May 1986 and over the period from 13 to 29 August 1986, show that for an average tidal cycle of 12,5 h, inflow through the mouth occurred for 4 h while water flowed out for 8,5 h. Under normal conditions the outflow reached a maximum about 1,5 to 2 h after the highest water level was recorded in the estuary and gradually reduced until a change in flow direction in the mouth occurred. It was shown that the mean water level in the estuary was higher than mean sea level and that high water occurred half an hour later, and was 0,05 to 0,20 m higher in the estuary, than in the sea. Similarly, low water occurred two hours later and was about 0,50 to 0,80 m higher in the estuary.

Branch and Day (1984) recorded velocities in the estuary mouth during spring tide and concluded that inflow took place for about 3,5 hours while outflow occurred for 9 hours with low tide in the estuary lagging 3 hours behind that in the sea.

In summer, tidal flow predominates and current velocities are greatest during the flood-tide, while in winter the reverse is true with river flow being more important and velocities highest during the ebb flow. The temperature, salinity and chemical studies of Taljaard (Taljaard, 1987a) indicate quite clearly that in summer, tidal influence extends at least two-thirds the way up the estuary during spring tide (Station 5 in Figure 24) and roughly halfway up the estuary during neap tide (Station 3 in Figure 24). Most of the water that enters the estuary during the spring tidal cycle remains there whereas the water that enters during the neap high tide, is immediately lost to the sea again on the ebb-tide. Riverine influence is, on the other hand, limited to the upper reaches of the estuary. During winter the riverine influence is far more extensive and all the water entering the estuary from the sea during spring

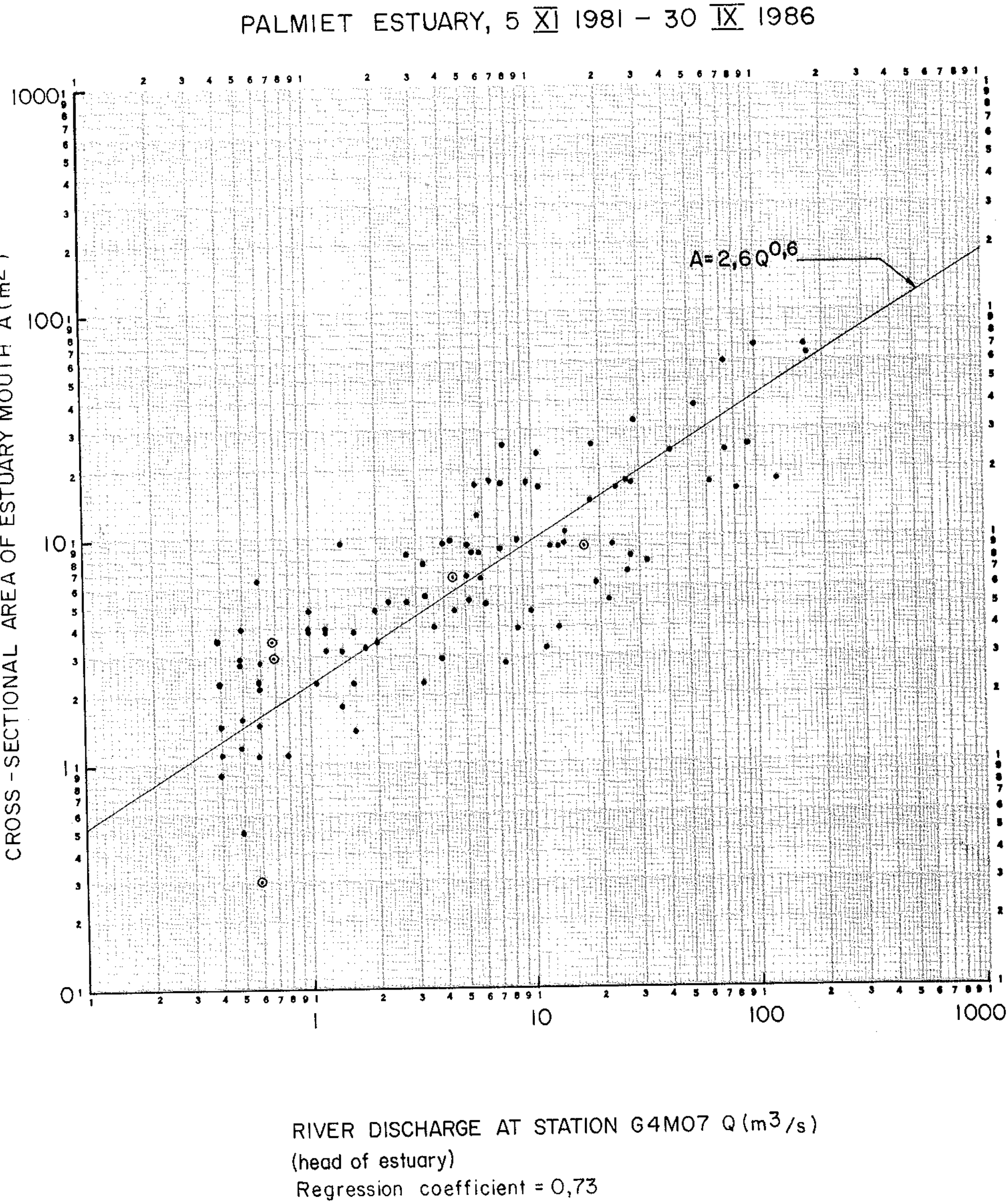


FIG 19 : Relationship between mouth cross-sectional area and river discharge. 1981 to 1986 tides can be lost to the sea during subsequent neap tidal cycles (Taljaard and Largier, *in litt.)*. The fast flow regime which is maintained throughout the estuary and especially at the mouth has important consequences for several biotic and abiotic (including sediment transport and the stability of the mouth) components of the system.

Tidal ranges in the estuary are moderate and due to the effect of the sandspit considerably lower than those occurring in the sea. During summer the tidal range is about 0,8 m under calm spring tide conditions but can reach 1,25 m under stormy conditions (Taljaard *et al.*, 1986). Overtopping of the sandspit occurs during spring tides. During neap tides, the average tidal range is about 0,5 m. During winter tidal ranges are more extreme, 1,7 m (spring tide) and 0,2 m (neap tide) (Taljaard and Largier, *in litt.)*.

3.2.4 Sediments

As a result of the rapid flow regime within the Palmiet Estuary, the sediments are very coarse. An analysis of the estuary sediment indicated that the coarsest particles were found at the head of the estuary, comprising 65 percent gravel (>2 mm) and 34 percent sand (63 µm to 2 mm) and that the gravel component declined towards the mouth where the sand fraction is about 99 percent of the total (Willis, 1981).

The mud or silt fraction (<63 µm) was found to be insignificant throughout the estuary, forming less than 3 percent of the sediment even in the lower reaches where the flow is the slowest.

The dense populations of the sand prawn, *Callianassa kraussi,* that occupy most of the estuary have a dramatic influence on the sediments. The burrows of *Callianassa* are lined by a thin layer of fine (98,91 percent <90 µm) particles which have a high organic content. The ability of *Callianassa* to concentrate fine particles from the water column is thus formidable and without this action, much of the particulate material would probably be lost from the system (Branch and Day, 1984).

Near the head of the estuary the sediments are derived mainly from quartzite and feldspar sandstone mixed with tillite from Bokkeveld shale, all of riverine origin, while in the lagoon and in the mouth, finer marine sands predominate (Branch and Day, 1984; Nel, 1980). Fricke (EMA, pers. comm.), however, has noted that sediments in most parts of the estuary have a very low carbonate content. The predominantly marine origin of sediments in the lagoon is thus questionable. Because the sediments consist predominantly of quartz, trace element concentrations are extremely low. The concentrations for Zn, Cu, Ni are generally less than 2 ppm and mostly less than 1 ppm (Willis, 1981). In addition to this, organic content is always low in coarse sediments and never exceeds 0,6 percent in the Palmiet Estuary.

The concentration of sediment particles suspended in the water column varies with the state of the tide and is highest in the middle reaches of the estuary. This is probably due to flocculation of riverine compounds in the saline estuary (Branch and Day, 1980).

Grain size distributions for samples taken on the beach and at the estuary mouth indicate that the sand at the mouth can be classified as being medium sand (0,2 to 0,6 mm) with a uniform distribution (Barwell, 1988).

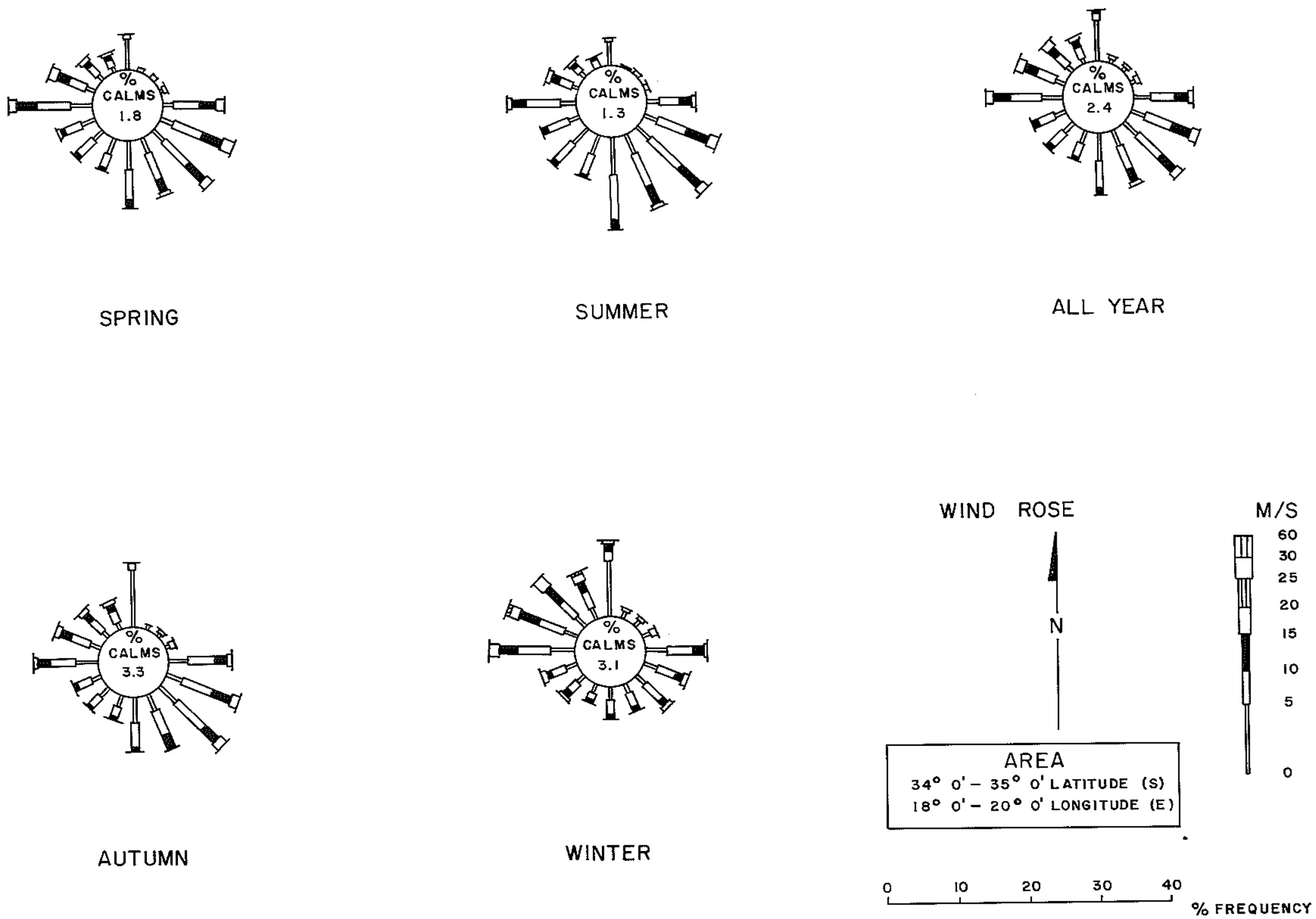
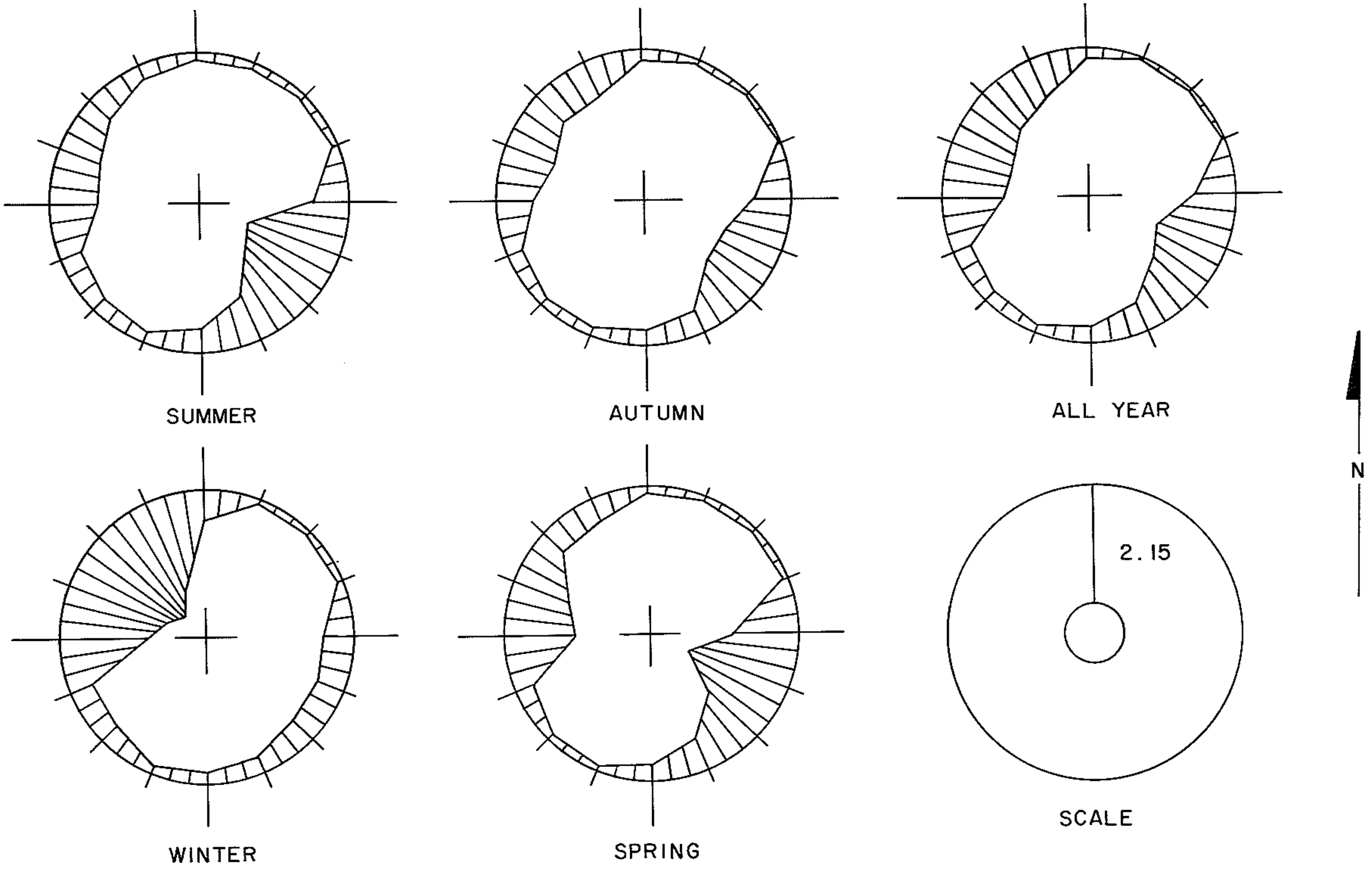


FIG 20: VOS wind roses



Aeolian transport rates are given in fractions of 10000 cubic metres/year/kilometre with due cognizance for frequency of occurrence of wind events

FIG 21: Aeolian creep diagrams for Palmiet Estuary Mouth

3.2.5 Wind and Aeolian Transport

Data obtained from Voluntary Observing Ships (VOS) (Figure 20) indicate that south-easterly winds occur most frequently and have the highest velocity during the drier spring and summer months as well as during autumn. During winter, westerly and north-westerly winds occur most frequently while the north-westerly winds have the highest velocity. On average for the whole year, winds from the south-east and eastern sectors dominate.

The VOS wind data were analysed and aeolian creep diagrams (Figure 21) for the Palmiet River area were deduced (Swart, 1986). These diagrams indicate how wind-blown sand would encroach from different directions on the centre of an imaginary circle on the ground.

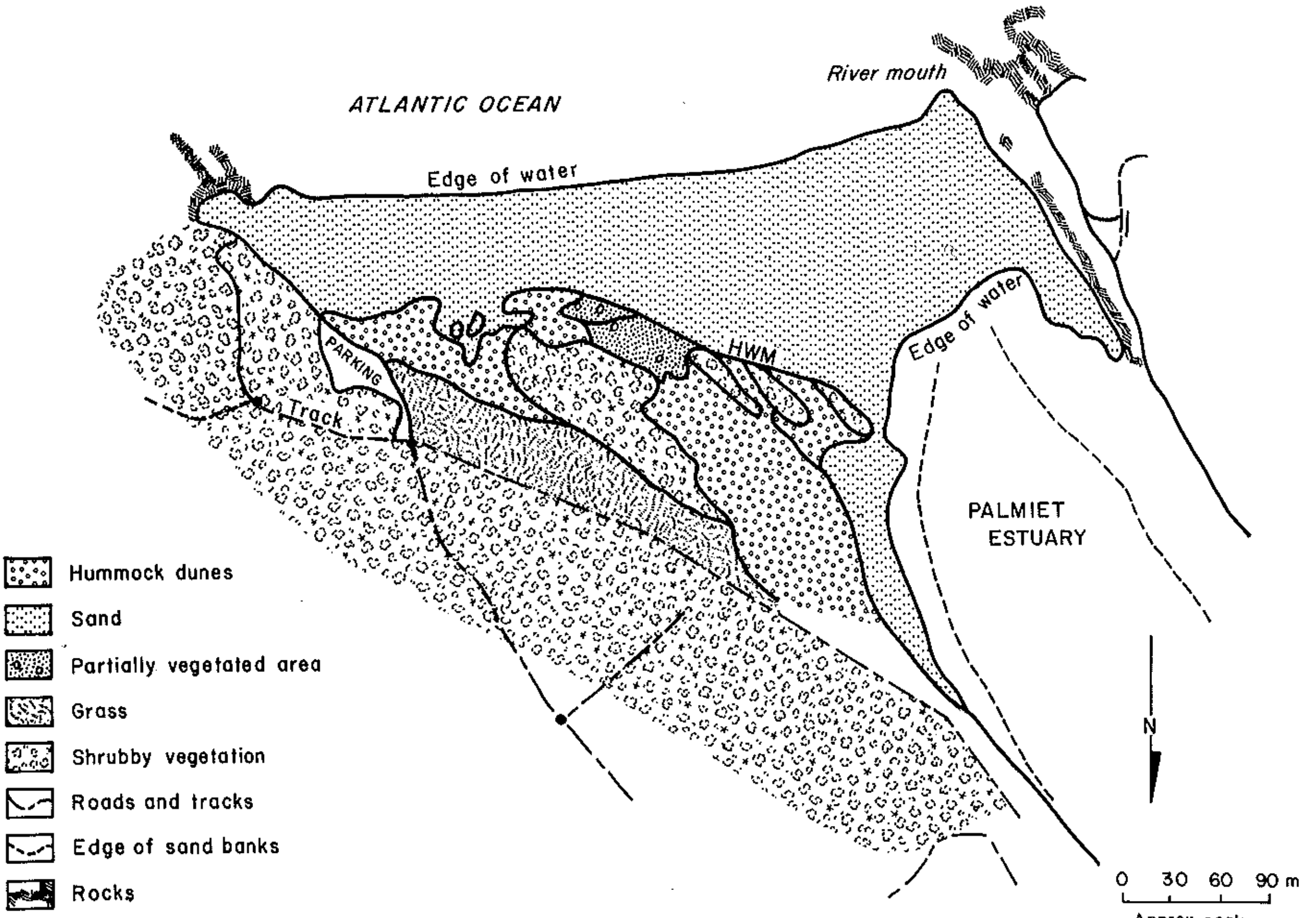
From these diagrams the potential aeolian sand transport rate (m^3 per yr per km beach width) can be calculated for various winds. This indicates that during the drier spring and summer months the predominantly south-easterly winds can cause a net sand movement towards the north-west. During autumn the potential sand movement is well-balanced all round with a slight net movement towards the northern sector. The net potential aeolian sand movement during winter occurs towards the south-east due to the predominantly north-westerly winds. From the diagram showing the "All Year" aeolian transport rate (Figure 21) it can be deduced that an equilibrium exists with a slight net movement towards the northern (inland) sector.

Although the aeolian creep diagrams indicate potentially active sand movement for the area, the lack of a sand source has a limiting effect on actual sand movement. The well-vegetated frontal dune system absorbs the bulk of the wind-driven sand resulting in a relative high frontal dune with a well-protected area behind. This area has been developed as a caravan park and picnic area (Figure 14).

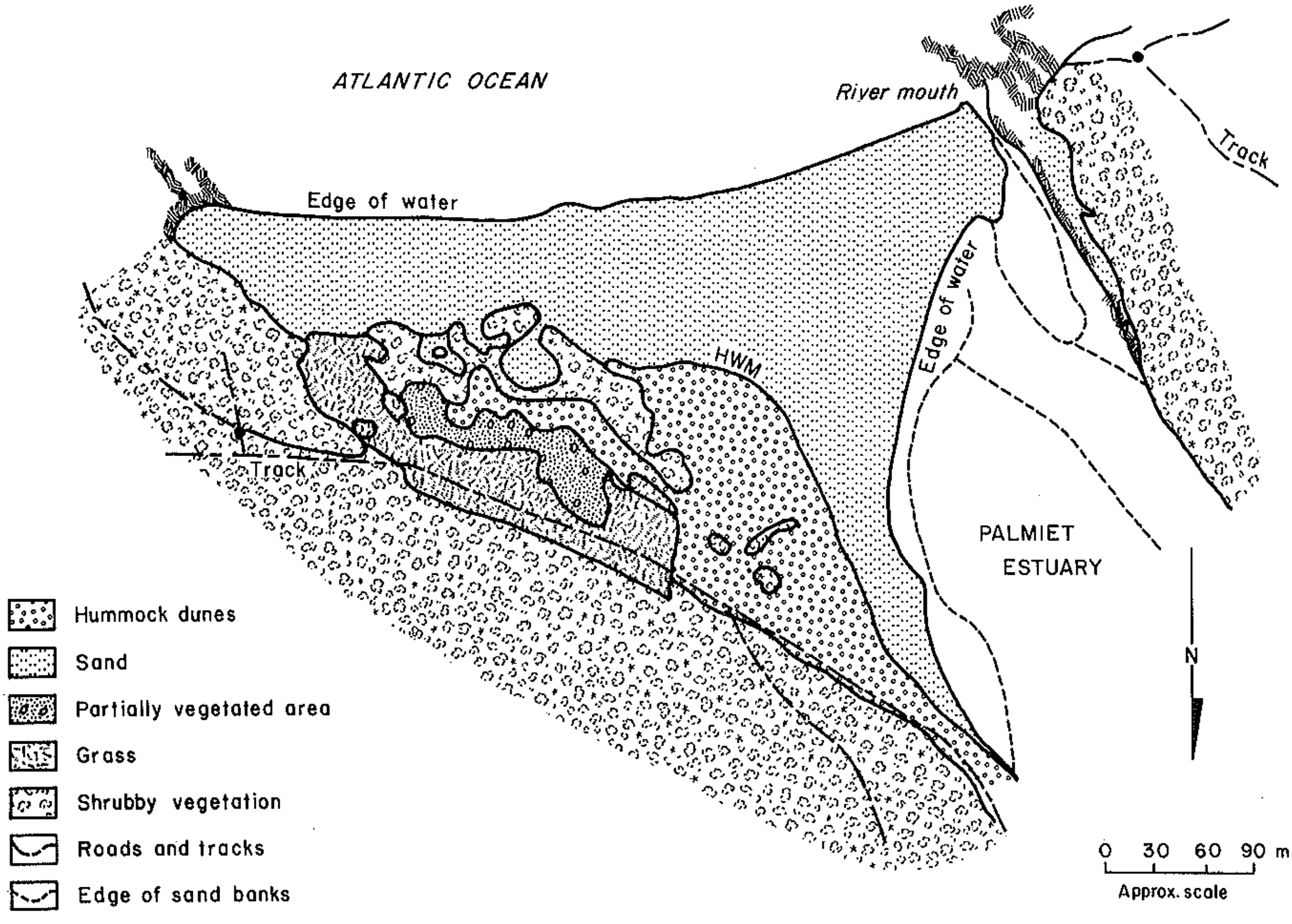
3.2.6 Bathymetry

Estuary

The bathymetry of the Palmiet Estuary has been investigated by Nel (1980), Branch and Day (1984) and Taljaard *et al.*, (1986). These investigations each involved a single survey and different profile transect positions. Consequently, the results are not strictly comparable and no conclusions can be drawn with regard to the bathymetric dynamics of the estuary. Nevertheless, the results of the three surveys appear similar for most parts of the estuary, suggesting a fairly stable bathymetric regime. It is, however, highly probable that the bathymetry is variable when seasonal differences in the flow regime are considered. The most detailed survey to date was conducted in summer when fluvial input was low, (Taljaard *et al.*, 1986). The estuary is generally shallow except for a steep sided channel which runs along its entire length. The channel is deepest near the head of the estuary where it averages about 4 m in depth. Winter conditions: similar bathymetry to summer slightly deep near the mouth (Taljaard and Largier, pers. comm.). The deepest recorded high tide channel depth is 7 m (Nel, 1980). About half way down the estuary the channel starts shelving and moves across from the west bank to the east bank, where it is approximately 2 m deep. From here to the mouth the channel hugs the west bank, leaving a wide, shallow sand flat, which is usually exposed at low tide, on the east bank. Just inside the mouth there is a large fan-shaped bank (flood tide delta) in the channel which has been formed by sand which is washed into the estuary from the sandspit. Immediately to the east of this there was, at the time of the survey of Taljaard *et al.* (1986) a fairly deep (3 m) hole.



PALMIET ESTUARY MOUTH 1938



PALMIET ESTUARY MOUTH 1961

FIG 22: Palmiet Estuary mouth 1938 and 1961

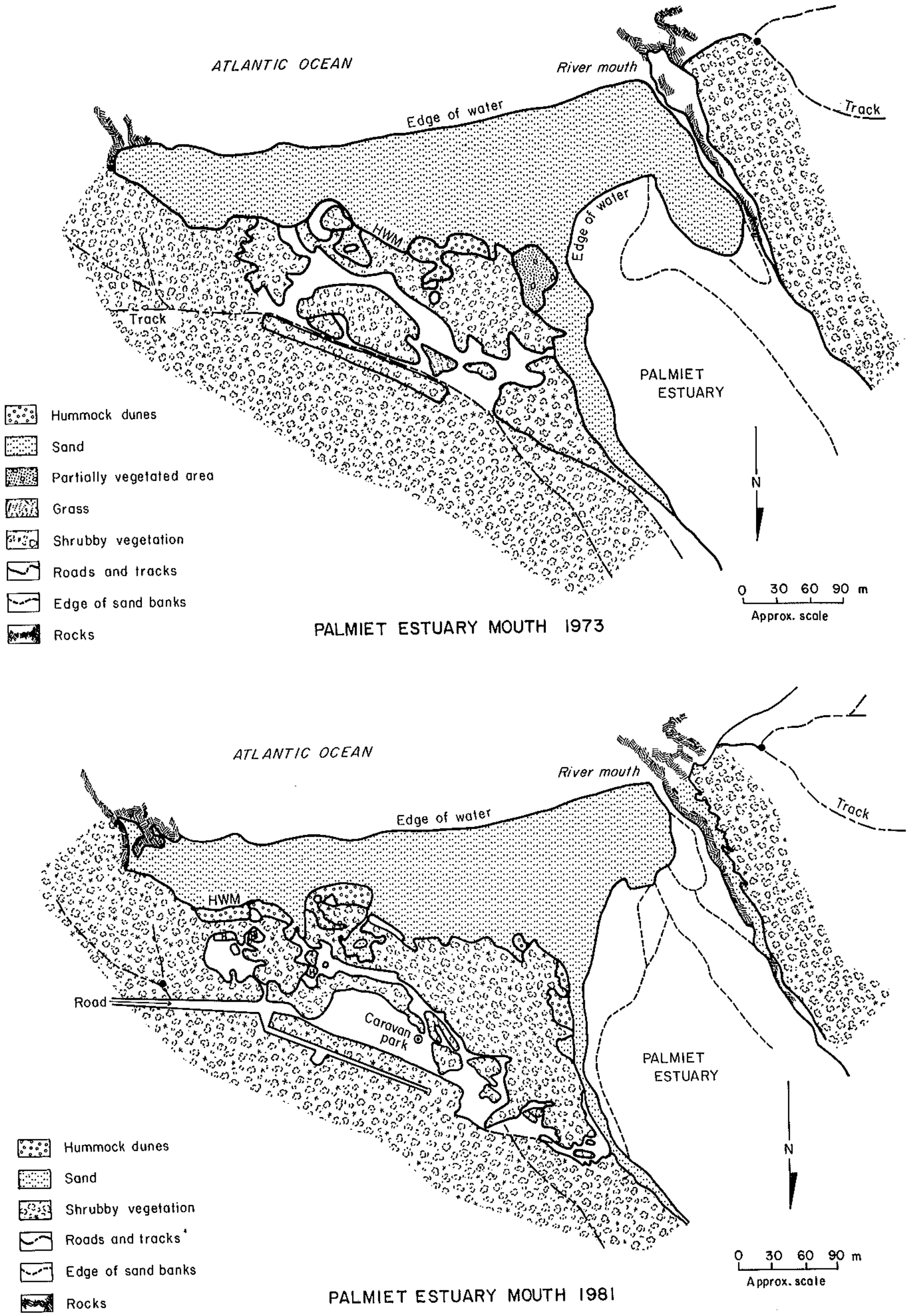


FIG 23: Palmiet Estuary mouth 1973 and 1981

Estuary mouth, sandspit and beach

The Palmiet Estuary mouth is classified by Heydorn and Tinley (1980) as "Type A": a single spit with rock on the opposite bank. In this case a rocky promontory forms the west bank of the mouth while an extensive mobile sandspit forms the eastbank (Figure 14, Frontispiece and Plate III).

A tachymetrical survey of the mouth area was carried out on 21 August 1986 (Van der Merwe, 1988). The mouth, at that time, was about 30 m wide and 0,5 m below MSL at the narrowest point. Upstream of the mouth and along the western side of the estuary, the bottom level reached 1,5 m with deeper areas (-2,0 m) at places. The main river channel was about 90 m wide at a point 100 m upstream of the narrowest point at the mouth. The sandspit was *c.* 350 m long and varied in width. The seaward face had a slope of 14 percent adjacent to the mouth, flattening to 4 percent along the beach to the east.

The more stable beach is about 300 m long and 100 m wide with rocks on the eastern side. Well-vegetated dunes form the northern edge of the beach and the eastern side of the estuary adjacent to the sandflat which is partially covered during high tides.

Historical changes

A list of available aerial photographs is given in Section 6. Tracings of the mouth area were done to show the mouth configuration, sandbanks and the changes in vegetated area for different years (Figures 22 and 23).

Although the sandspit and sandbanks in the vicinity of the mouth underwent slight positional changes, the only major change was an increase in the total vegetated area to the north of the sandspit. The stabilization of the foredune area has led to an accumulation of sand along the edge of this area. These high dunes effectively shield a caravan park and low intensity recreational area from the prevailing winds.

3.2.7 Land Ownership/Uses

The entire estuary falls within the boundaries of the Kleinmond Coastal Nature Reserve, 3,4 km^2 in extent, which is under the jurisdiction of the Kleinmond Municipality (J J du Plessis, Town Clerk Kleinmond, pers. comm.). The Municipality also runs a caravan park and two picnic sites on the eastern bank of the estuary. There are several short nature trails on both the eastern and western banks of the estuary (Figure 14). Development in the immediate vicinity of the estuary is extremely limited. The only structures within 350 m of the water's edge are ablution blocks serving the caravan park and picnic sites, a privately--owned house boat moored on the west bank and a boat house belonging to the Kleinmond power-boat and ski club on the east bank. The lagoon is well used as a recreational area, particularly in summer, since it offers safe swimming, boating and fishing in comparison to the adjacent coast which is very dangerous. Memorials, such as that to the memory of members of the crew of the barque *Gustav Adolf,* wrecked near the estuary in 1902, stand in testimony to the dangerous nature of this coast (Slingsby, 1984). Power-boating and water-skiing are permitted despite the small size of the estuary. The Chief Directorate: Nature and Environmental Conservation controls the collection of bait *(Callianassa)* . Line fishing and throw netting are permitted (J J du Plessis, pers. comm.). Gill-netting is, however, only permitted on the seaward side of the mouth and is restricted to Sea Fisheries permit holders only (P Slingsby, resident of Kleinmond, pers. comm).

3.2.8 Obstructions

There is only one man-made obstruction in the estuary. This is a short jetty on the east bank about halfway down the estuary (Figure 14). The jetty does not impede water movement and appears to have no effect on the ecology of the estuary.

The embankments of the coastal road bridge are situated well above the flood-line. This structure therefore has no influence on water flow.

The effects of obstructions on a river may extend to an estuary itself. The physico-chemical properties of water released from dams, for example, invariably differ from those of pre-impoundment waters. The weir just above the coastal road bridge probably has a negligible effect on the estuary since it was designed not to impede water flow seriously. Impoundments further upstream (namely, the Arieskraal, Kogelberg and Applethwaite dams) have no effect on the estuary. The long distance between these dams and the estuary allows released impoundment waters to "recover" completely before reaching the estuary (B A Byren, pers. comm.). In addition to this, undisturbed water from a number of tributaries between the dams and the sea probably has a moderating effect on released impoundment waters.

3.2.9 Physico-chemical Characteristics

The Palmiet Estuary usually exists as a stratified system. Its waters are protected from the full force of the sea by the sandspit which blocks most of the mouth. Furthermore, the steep, well defined banks of the estuary limit the water circulation potential of surface winds (Nel, 1980), consequently the estuary is stratified. This stratification suggests different physico-chemical characteristics for bottom and surface waters.

Data on the physico-chemical characteristics of the Palmiet Estuary are available from several surveys; Willis (1981), Branch and Day (1980), Branch and Day (1984), Taljaard *et al.* (1986), Largier (1986), Taljaard (1987a, b), Largier and Taljaard (1988) and Fricke and Jensen (1989). The first survey (Willis, 1981) has already been dealt with in Section 3.2.4. The second survey was conducted between April 1979 and September 1980 and involved taking surface and bottom water samples at six stations (Figure 24) at both low tide and high tide (Branch and Day, 1984). The third survey was conducted during the summer of 1985, (Taljaard 1987a, 1987b), and winter of 1986 (Taljaard, pers. comm. and Largier and Taljaard, 1987) and involved monitoring changes in physico-chemical levels in surface and bottom waters at nine stations (Figure 24) over a full 13 hour tidal cycle during both spring- and neap tides. Data for the winter months have been analysed and will be published by Taljaard in a CSIR Research Report during 1989. Some preliminary results are reported here. During the summer neap tidal cycle two events occurred which had a significant effect on results. Firstly, rain in the catchment area increased the river flow and secondly, an upwelling event occurred in the sea. During winter measurements, copious rainfall in the catchment area resulted in a very high fluvial input.

pH

Surveys conducted by Branch and Day (1984), Taljaard *et al.* (1986), Taljaard (1987a, 1987b), B A Byren *(in litt.)* and Taljaard (pers. comm.) show that the pH of water entering the Palmiet Estuary is variable, but almost always acidic. This is to be expected from a river which drains an area consisting predominantly of Table Mountain Sandstones (Nel, 1980). Recorded values range from 4,0 (Branch and Day, 1984) to an average of 7,2 over a two-week summer period (Taljaard *et al.*, 1986) and Taljaard (1987a, 1987b).

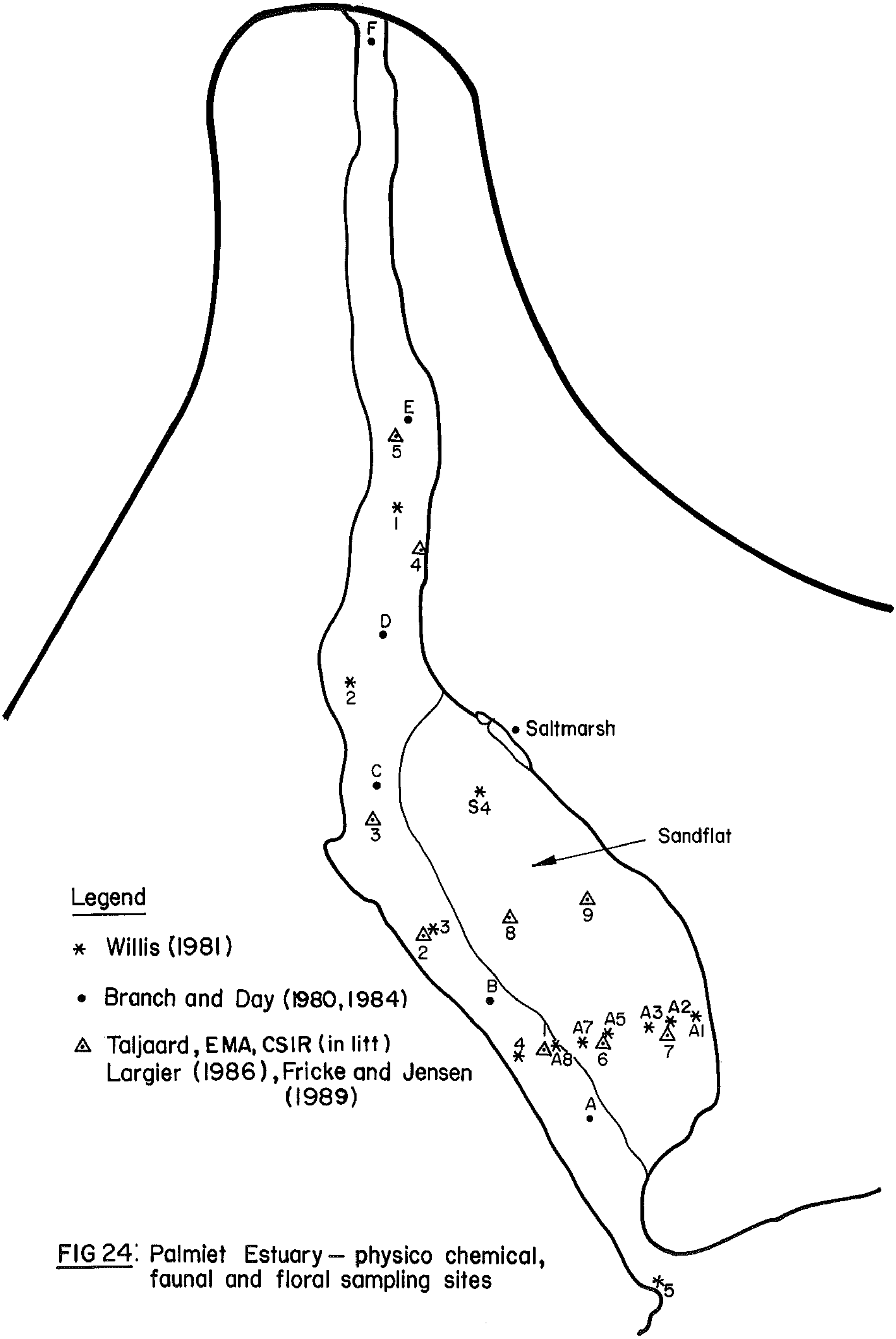


FIG 24: Palmiet Estuary – physico chemical, faunal and floral sampling sites

During summer the pH of sea-water entering the estuary is consistently higher (approximately 7,4-8,0) than that of the river water (Taljaard, 1987a, 1987b). This has three important consequences for the pH regime of the estuary. Firstly, surface waters are always slightly more acidic than the underlying saline bottom waters. Secondly, entrainment between surface and bottom water near the mouth leads to horizontal pH gradients within the estuary. These two consequences are illustrated by the survey of Branch and Day (1984) who found that from the head to the mouth of the estuary, pH increased from 5,0 to 7,0 and from 6,5 to 7,0 in surface and bottom waters respectively. Thirdly, the relative proportions of fresh and saline water entering the estuary at a particular time have a profound effect on pH levels. This is illustrated by the survey of Taljaard *et al.* (1986) and Taljaard (1987a, 1987b) who demonstrated a drop in pH between spring- and neap tidal cycles (7,9 to 7,1 to 7,4 and 8,2 to 7,6 to 7,8 in surface and bottom waters respectively) due to increased fluvial (surface water) and decreased marine (bottom water) input into the estuary.

Temperature

The temperature regime of the Palmiet Estuary has been investigated by Branch and Day (1984), Taljaard *et al.* (1986), Taljaard (1987a, 1987b) and Largier and Taljaard (1988). Results show that horizontal and vertical temperature gradients are variable and dependent on the season and the degree of marine and fluvial input.

In summer, the river (20°C) was up to 7° warmer than the sea (13°-17°C) and consequently the fresh surface waters were generally warmer than the saline bottom waters. This temperature gradient was not, however, always significant, especially during enhanced spring tides when entrainment occurred at the shallower stations near the mouth (Taljaard *et al.*, 1986 and Taljaard, 1987a, 1987b). In winter the sea (16°C) was slightly warmer than the river (13°C) and the reverse situation existed with surface waters being slightly cooler than bottom waters. Once again this temperature difference was not always significant. Under strong fluvial input conditions sea-water penetration through the mouth was severely restricted. This resulted in temperatures being uniform throughout the estuary (Largier and Taljaard, 1988).

During summer, the only horizontal temperature gradient observed in surface waters was a decrease in temperature from the head to the mouth of the estuary. This gradient was only observed during certain tidal phases (Taljaard *et al.*, 1986) and was presumably due to mixing with colder sea-water near the mouth. This is indicated by the observation that the gradient was more pronounced during the spring tidal cycle when sea-water penetration through the mouth was more extensive. During the neap tidal cycle the temperature of the whole surface of the estuary also increased due to diurnal heating (Taljaard *et al.*, 1986 and Taljaard, 1987a, 1987b). In winter, horizontal temperature gradients in surface waters appeared to be dependent on the degree of sea-water penetration through the mouth. When fluvial input was weak enough to allow substantial sea-water penetration, surface waters near the mouth (16°C) were, presumably (due to mixing with warmer sea-water) warmer than those near the head (12,5°C) of the estuary (Branch and Day, 1984). When fluvial input was strong and sea-water penetration through the mouth restricted, surface waters (13°C) showed no temperature gradient (Largier and Taljaard, 1988).

Horizontal temperature gradients in bottom waters were also slight. In summer, bottom waters near the mouth were generally cooler than those near the head (Taljaard *et al.*, 1986; Taljaard, 1987a, 1987b). The reverse situation has, however, been observed during a spring tidal cycle (Branch and Day, 1984), presumably due to penetration of warmer sea-water near the mouth. In winter, horizontal temperature gradients in bottom waters once again appeared to be largely dependent on the degree of sea-water penetration through the mouth. When substantial sea-water penetration occurred (during a spring tidal cycle) bottom waters near the mouth (16°C) were warmer than those near the head (12,5°C) of the estuary (Branch and Day, 1984). When, however, sea-water penetration was prevented (as occurred during a neap tidal cycle), the temperature of bottom waters (13°C) was uniform throughout the estuary (Largier and Taljaard, 1988).

During the summer spring tidal cycle, temperature data from the stations on the sandflats were similar to those of the bottom channel water. During summer neap tide, however, the water over the flats was similar to the channel surface water (Taljaard *et al.*, 1986). This indicates that the water on the sandflats underwent a weekly temperature cycle. Marine conditions dominated the system during spring tide whereas during neap tide, fresh water conditions dominated. In winter, fresh water conditions dominated the sandflats during both the spring and neap tidal cycles (Largier and Taljaard, 1988).

Transparency

No quantitative data on the transparency of the estuary water are available.

The transparency of water is determined to a large extent by its sediment load. Nel (1980) reports that the water of the estuary is usually very transparent because of its limited sediment load. Furthermore, the coarse, sandy nature of the estuary bottom results in little sediment being agitated by currents in bottom waters. Only during peak winter flows is the water turbid due to the suspension of bottom material.

The colour of the water is dark brown due to the presence of humic substances (King *et al.*, 1979). This so-called "black water" is characteristic of the Cape southern coast rivers draining from sandstone of the Cape Fold Belt Mountains (Heydorn and Tinley, 1980).

Salinity

Salinity of both surface and bottom waters generally declined from the mouth to the head of the estuary (Branch and Day, 1984; Taljaard *et al.*, 1986; Taljaard, 1987a, 1987b and Largier and Taljaard, 1988). The increase in surface salinity from the head to the mouth was due to entrainment of sea-water into the surface layer near the mouth. This phenomenon was pronounced during the summer months. The decrease in bottom salinities from the mouth to the head was due to the presence of mixed (lower salinity) water near the head of the estuary and newly entered sea-water at the mouth. This was more pronounced during the winter months. Horizontal salinity gradients can break down during periods of extreme fluvial input. During the dry summer months, strong tidal flow can maintain uniform bottom salinities throughout the estuary (Branch and Day, 1984). During the winter months, strong river flow can flush all sea-water from the system and prevent sea-water penetration through the mouth, resulting in totally fresh surface and bottom waters throughout the estuary (Largier and Taljaard, 1988).

Vertical salinity gradients are likewise dependent on the season and the degree of marine and fluvial input. This is well illustrated by the surveys of Branch and Day (1984); Taljaard *et al.* (1986); Taljaard (1987a, 1987b) and Largier and Taljaard (1988) which were conducted at similar times of the year but under different marine and fluvial input conditions.

During a spring tidal cycle in summer, Branch and Day (1984) found that virtually all the bottom water was between 30 and 35 parts per thousand while surface water increased steadily from 0 at the head to 35 parts per thousand at the mouth. During a spring tidal cycle in summer, Taljaard *et al.* (1986) and Taljaard (1987a, 1987b) found a similar situation. During a neap tidal cycle in summer (which coincided with a relatively stronger fluvial input), new sea-water only penetrated during flood tide up to the vicinity of station 3 and then retreated on the ebb-tide. Although the bottom waters at stations 4 and 5 moved back and forth with the tide, no exchange of water with the sea took place. The salinity of surface waters remained low with a slight increase at the mouth of the estuary due to entrainment. Vertical salinity gradients were thus prominent throughout the estuary (Taljaard *et al.*, 1986 and Taljaard, 1987a, 1987b).

During a spring tidal cycle in winter, Branch and Day (1984) found that the surface waters remained fresh except at the mouth during high tide. Bottom waters up to station E (Figure 24) remained saline (20 - 35 parts per thousand) throughout that tidal cycle except at the mouth during low tide. During a winter spring tidal cycle (which coincided with a relatively higher fluvial input), Largier and Taljaard, 1988 found a similar situation except that bottom waters were more diluted and only penetrated up to station 4 (Figure 24) where a maximum salinity of 17 parts per thousand was recorded. During the ebb-tide the diluted saline water remained in the deeper pools at station 4 but all other sea-water was lost from the system. Stratification was thus only observed at stations 1 to 4 on the flood-tide and at station 4 on the ebb-tide. During the following neap tide, all sea-water was flushed out of the estuary and no sea-water penetration occurred (Largier and Taljaard, 1988).

During summer the sandflat undergoes a weekly salinity cycle (Taljaard, *et al.*, 1986 and Taljaard, 1987a and 1987b). Marine conditions dominate the system during spring tide whereas during neap tide, fresh water conditions dominate. In winter, fresh water conditions dominate the sandflat during both spring- and neap tides (Largier and Taljaard, 1988).

Sandflat interstitial salinities down to a depth of 100 cm have been monitored during both summer and winter spring tidal cycles (Fricke and Jensen, 1989). Salinities varied both in the vertical dimension and over a short time-scale. In summer salinities ranged from 11 to 25 parts per thousand in the sediment column and fluctuated as much as 13 parts per thousand between low and high tides. In winter salinities were much lower, ranging from 0 to 7 parts per thousand and fluctuations less severe (up to 6 parts per thousand between low and high tides). These tidal and seasonal fluctuations in salinity have important consequences for interstitial meiofaunal and possibly macrofaunal distribution and abundance (Section 4.2.2).

Channel interstitial salinities down to a depth of 100 cm have also been measured during a winter neap tide. Salinity in the top layer of sediments (0-5 cm) was about 19 parts per thousand. Salinity in the rest of the column was uniform and averaged about 27 parts per thousand. These values are surprising when it is considered that the sediment was, at the time, covered by a completely fresh water layer (A H Fricke EMA, pers. comm.).

Dissolved Oxygen

Branch and Day (1984) report that oxygen levels of the surface waters along the entire length of the estuary remained high throughout the year (85 to 104 percent). This is presumably due to the fact that the river is perennial. Oxygen levels in bottom waters were consistently lower, ranging from 58 to

90 percent saturated, as might be expected from the permanent stratification. Tides play an important role in the maintenance of oxygen levels in bottom waters, especially in the upper reaches of the estuary.

Taljaard (1987a, 1987b) has shown that in summer, there was not much difference between neap and spring tidal cycle oxygen levels, these levels indicate a well oxygenated system. Surface waters generally had a higher oxygen concentration than the more saline bottom waters, although the difference was not always significant.

Although there was no consistent difference between spring and neap tide dissolved oxygen levels on the sandflat, the average spring tide level was lower than that of neap. This is due to the fresher water body (over the sandflat during neap tide) having a higher oxygen solubility than the more saline water body (over the sandflat during spring tide).

Nutrients

Data on nutrient levels in the estuary are mainly available for summer. The results of Branch and Day (1984), Taljaard (1987a, 1987b) are listed in Tables 2 and 3. Winter nutrient samples have been collected and are currently being analysed. Results will be reported in 1989 (Taljaard, pers. comm.).

Phosphates

Summer levels of phosphate in the Palmiet Estuary are low, ranging from 0,68-1,85 µmol/l (Table 2). Levels in bottom samples were higher than those at the surface, a condition that is common in estuaries since the sediments trap organic material which later releases phosphates. Branch and Day (1984) point out that in the case of the Palmiet Estuary the organic content of the sediments is extremely low and that phosphates probably originate from the decaying detritus that accumulates in the basin of the channel. However, Taljaard (1987a, 1987b) has shown that, although interstitial phosphate levels were high, there was little or no interchange with the overlying water.

The work of Taljaard (1987a, 1987b) shows that in summer the sea has a major influence on phosphate levels in the estuary. The extent of mixing between surface and bottom layers and the extent to which sea-water penetrates the estuary depends on the state of the tide (that is, whether it is at the spring or neap phase). Consequently the concentration of phosphates in most of the estuary is influenced by the state of the tide. During spring tide sea-water entered the estuary (bottom water) forcefully and penetrated right up to station 5 (Figure 24). Consequently there was an increase in phosphate levels in bottom waters with the incoming tide right up to station 5 (from approximately 0,4 µmol/l to 1,0 µmol/l). Due to mixing between surface and bottom layers, surface waters at the shallower mouth stations also showed increases in phosphate levels with the incoming tide (from approximately 0,4 to 0,7 umol/l). The upper two surface stations were unaffected by the tide and only received phosphate input from the river. Consequently their phosphate levels remained constant and were lower than those at surface stations 1 and 3. Sandflat levels remained uniform throughout the cycle (approximately 0,44 µmol/l).

During neap tide, sea-water did not penetrate as far up the estuary as during spring tide. Consequently only the bottom waters of stations 1, 2 and 3 and the surface waters at station 1 showed a marked increase in phosphate levels with the incoming tide. However, on the outgoing tide the levels decreased again. Stations 4 and 5 showed no tidal influence. The phosphate levels in the incoming sea-water during this neap tide period were elevated as a result of

TABLE 2: NUTRIENT LEVELS IN PALMIET ESTUARY IN DECEMBER 1979. Stations are shown in Figure 24 (from Branch and Day, 1984)

Stn	Nitrate µg at.l^{-1}				Ammonia µg at.l^{-1}				Reactive phosphate µg at.l^{-1}				Silicates µg at.l^{-1}			
	High tide		Low tide		High tide		Low tide		High tide		Low tide		High tide		Low tide	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
A	6,23		7,00		0,96		1,67		0,68		0,80		14,71		20,00	
B	6,95	3,14	7,76	4,97	3,50	3,25	1,17	2,15	0,76	1,10	0,72	1,27	18,24	8,24	13,75	10,00
C	7,38	3,65	11,43	6,28	1,23	2,55	1,17	2,43	0,34	1,35	0,59	1,31	13,53	8,82	11,88	2,50
E	10,10	4,02	35,71	4,08	1,77	-	1,13	5,64	0,76	-	0,97	1,35	26,25	-	15,63	12,50
F	12,33	3,09	7,29	3,09	1,93	3,87	1,59	2,88	0,29	1,23	0,58	1,85	1,39	8,82	0,84	3,57

TABLE 3: NUTRIENT LEVELS IN THE PALMIET ESTUARY IN FEBRUARY 1985. Stations are shown in Figure 24 (after Taljaard, 1987a, 1987b)

Station	PO_4 (µmol.l^{-1})				NO_3 (µmol.l^{-1})				NO_2 (µmol.l^{-1})		DOC (µmol.l^{-1})			
	Spring		Neap		Spring		Neap		Spring	Neap	Spring		Neap	
	S	B	S	B	S	B	S	B			S	B	S	B
1	**0,4**	**0,3**↑	0,3	**1,0**	4,19	3,26	$\bar{x}$ = 13,87	**7,0**↑↓	VERY LOW REL. TO NO_3 LEVELS		$\bar{x}$ = 2,70	$\bar{x}$ = 2,50	$\bar{x}$ = 9,04	$\bar{x}$ = 2,92
2			$\bar{x}$ = 0,33		2,77	3,19								
3					2,64	2,70								
4	$\bar{x}$ = 0,39			$\bar{x}$ = 0,76	2,86	2,29		$\bar{x}$ = 3,06	approx. 10% NO_3 levels	approx. 2% NO_3 levels				
5					4,22	1,61					4,03			5,95
SF	0,44		0,27		2,57		13,33				1,43		8,53	
R	0,22		0,16		9,64		18,50				4,50		9,0	
S	1,18		1,56		3,0		14,97				2,0		1,4	

Bold print = fluctuations over 13 h tidal cycle. (↑increase on flood tide; ↓decrease on ebb-tide values indicated are initial values at low tide).

upwelling, but, as stated above, little of this phosphate-rich water remained in the estuary. However, should upwelling have occurred during spring tide, the effect on nutrient levels could be expected to have been much larger in the bottom channel layer and on the sandflat.

Sandflat levels remained constant throughout the tidal cycle. The level was, however, lower than that recorded during the spring cycle indicating a sea-water influence in this area during spring tide and a fresh water influence during neap tide (see *Salinity*).

It is interesting to note that levels of phosphate entering the estuary from the river are extremely low (station F, Table 3). Branch and Day (1984) and B A Byren, (pers. comm.) report that phosphate levels do not appear to exceed 2 µmol/l anywhere along the river. This is surprising in view of the fact that the central catchment area is intensively cultivated. Either levels of phosphorous are low in the fertilizers applied or are complexed extremely rapidly by the humic substances in the acidic, black waters of the river (Branch and Day, 1984).

Nitrates

Nitrate levels in summer ranged from 3,09 to 35,71 µmol/l, being clearly higher in the surface waters and in general showing an increase from the head to the mouth of the estuary. This suggests a riverine origin for most of the nitrates (Branch and Day, 1984). However, Taljaard (1987a, 1987b) found nitrate concentrations in the estuary, sea and river were similar when sampled during the spring tide. During neap tide, after rain in the catchment, surface nitrate levels increased. Upwelling at sea led to increased bottom water nitrate levels with a similar circulation pattern to that of phosphate (Table 3).

During both the spring and neap tidal cycles, nitrate levels on the sandflats remained uniform. During spring tide the nitrate concentration was similar to that of the sea, suggesting a major sea-water influence during this period. During the neap tidal cycle, nitrate levels on the sandflats were much higher than those during the spring cycle, suggesting a major fresh water influence during this period (Taljaard, 1987a, 1987b).

Branch and Day (1984), found values for combined nitrates and nitrites in the river a few kilometres above the estuary to be considerably higher than those entering the estuary, ranging from <2 to 300 µmol/l. This suggests that most nitrogen from agricultural fertilizers is rapidly removed from the river in its course to the sea, presumably by volatilization.

Nitrites and ammonia

Taljaard (1987a, 1987b) found nitrite and ammonia levels to be very low in comparison with other nitrogen nutrients during their summer study. This is usually the case in well-oxygenated systems such as the Palmiet Estuary.

In their survey Branch and Day (1984) found a summer ammonia range of 0,95 to 5,64 µmol/l (Table 2). There were no horizontal trends and bottom samples were with one exception markedly higher than top samples. This presumably reflects the more reducing conditions at the bottom of the estuary.

Silicate

Branch and Day (1984) obtained summer silicate levels of between 0,84 and 26,25 µmol/l which corresponds to the normal range for estuaries (Table 2). In most cases the surface water was richer in silicates than was the bottom water, although station F surface water had the lowest value. Figures from water higher up the river averaged about 35 μmol/l suggesting that much of the silicate in the estuary is supplied by the river.

Dissolved organic carbon (DOC) and nitrogen (DON)

The dissolved organic carbon (DOC) levels were similar throughout the estuary during the summer study (Taljaard 1987a, 1987b. However, during the neap tide cycle the river DOC concentration increased after rain in the catchment. This was reflected in the surface water of the estuary (Table 3). Sandflat DOC levels resembled the bottom water levels during spring tide and the surface water during neap tide.

During both spring and neap tides the dissolved organic nitrogen (DON) levels in the river were much higher than those in the sea. Consequently surface DON concentrations in the estuary tended to be higher than those in the bottom layer particularly during neap tide (Taljaard, 1987a, 1987b). However, these surface values were still lower than those for the incoming river water. This suggests that removal of DON takes place. It is known that the humic acids present in the river water form insoluble complexes with proteins. Since proteins form part of the DON pool even the small increase seems to favour protein complex formation. Sandflat DON levels showed no consistent pattern or change between the tides (neap and spring) in this summer study.

Suspended particulate matter

Branch and Day (1980) found that in December and April particulate organic matter (POM) suspended in the water column was generally higher at the mouth than at the head of the estuary. This is to be expected in view of the low particulate matter load in the river. POM reached highest levels (approximately 4 mg/l) in the middle of the estuary, possibly due to flocculation of riverine compounds in the saline water.

POM is an interesting component in terms of import and export into the estuary (Branch and Day, 1984). Over two tidal cycles POM occurred at higher levels in the incoming than the outgoing water and, because of the different rate of water transport during the ebb and flood (see Section 3.2.3) more POM was introduced than lost from the estuary (Figure 25). During April neap tide, 337 kg (dry mass) was imported from the sea, 51 kg (dry mass) from the river while only 262 kg (dry mass) were exported, resulting in a net input of 126 kg (dry mass). During July spring tide figures were even more dramatic with 1 092 kg from the sea, 883 kg from the river and 1 707 kg (dry mass) exported, resulting in a net input of 268 kg (dry mass). If these figures are representative, the annual net input of POM would be greater than 140 000 kg (dry mass) (see Appendix VII).

In an investigation of the tidal influence on suspended particulate matter Taljaard (1987a, 1987b) found the actual concentration of total particulate carbon (TPC) showed little variation throughout the estuary. Total particulate nitrogren (TPN) values displayed a similar uniformity. However, the percentages of these two parameters, when compared with the total suspended matter were higher in the fresher than in the more saline waters. A possible reason for this is that the saline water introduced from the sea contained more sand particles in suspension than the river water.

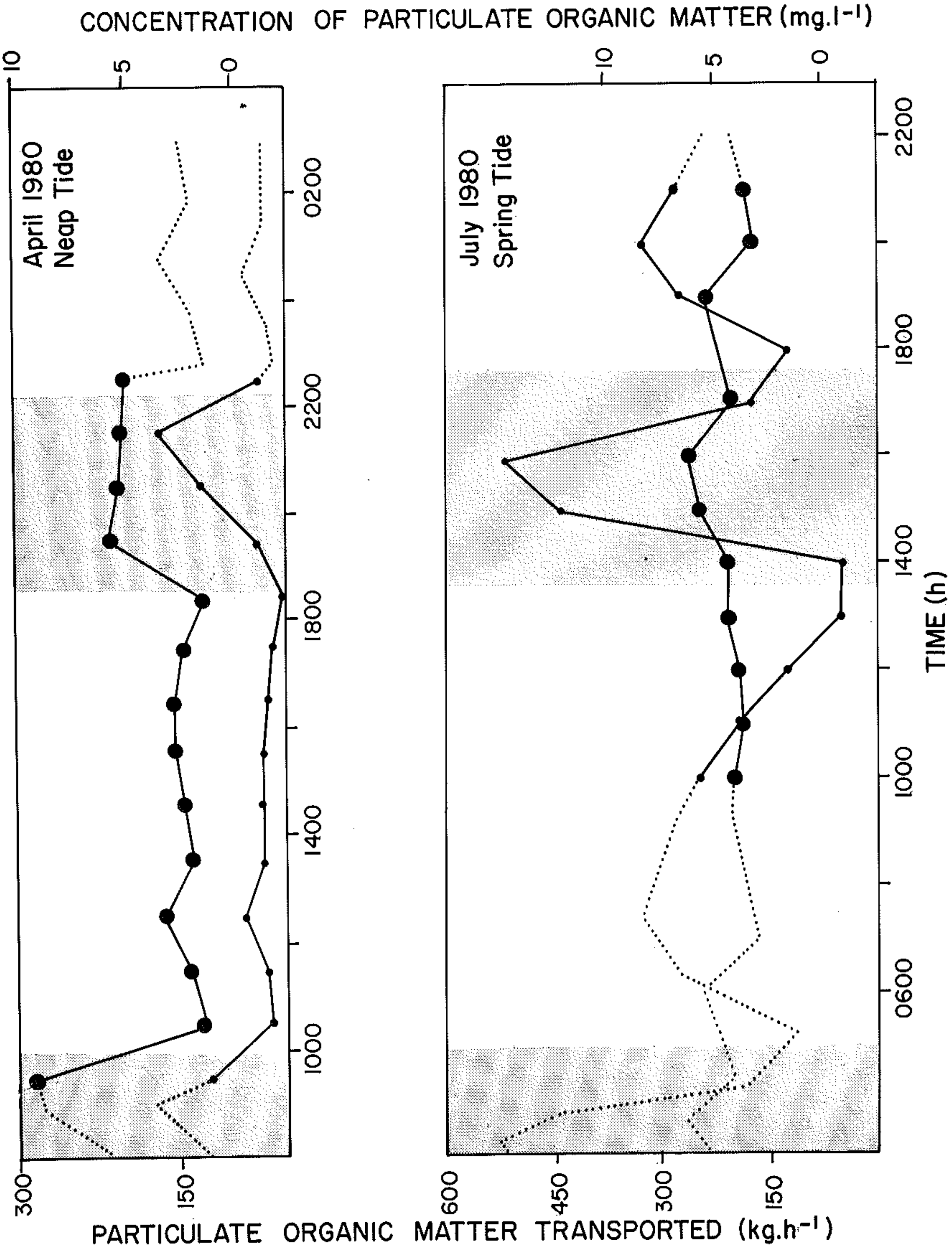


FIG 25: The concentration of particulate organic matter (mg/l) and its rate of transport (kg/h) through the Palmiet Estuary mouth over two contrasting tidal cycles. Shading indicates the period of inflow into the estuary (from Branch and Day 1984)

Detritus

Data collected between December 1979 and April 1980 show that detritus tends to accumulate below the halocline in the deeper, calmer parts of the channel (Branch and Day, 1984). Levels of detritus were lowest at the head and mouth of the estuary (maximum standing stock of approximately 75 and 200 g (dry mass) per m^2 respectively) where currents are strongest. The highest level (in excess of 5 000 g (dry mass) per m^2) occurred approximately one metre below LWS in the vicinity of sampling station B (Figure 24). The mean standing stock for the estuary was 390 g (dry mass) per m^2 which amounts to a total standing stock of 89 764 kg (dry mass) for the entire estuary (Appendix VII).

The detritus in the estuary comes from two sources, that in the narrow upper half of the estuary being mainly *Prionium serratum* from the river, while kelp *(Ecklonia maxima)* washed in through the mouth forms a dense mat in the channel of the lagoon. The kelp seems more important quantitatively, and it also clearly decomposes more readily then does *Prionium* (Branch and Day, 1984).

Gains and losses of kelp over two contrasting tidal cycles were monitored. 188 g (dry mass) was imported during the April neap tide and 3 740 g (dry mass) during the spring tide cycle in July. If these figures are representative, import could amount to an annual input of approximately 1 400 kg (dry mass) (Appendix VII). In relation to the measured standing stock (270 kg, dry mass) this means that kelp must decay and be dispersed as particles within about 68 days of its introduction into the estuary. No quantitative figures are available for the import of *Prionium* but although large quantities are introduced it would appear that the material does not decay easily and is probably not readily used as a source of nutrients (Branch and Day, 1984).

Organic matter in sediment

As discussed in Section 3.2.4, the sediments in the Palmiet River estuary are unusually coarse with gravel and sand forming a minimum of 97 percent of the substratum throughout the estuary. Organic content is always low in coarse sediments (Branch and Grindley, 1979) and the Palmiet is no exception. Branch and Day (1984) found that organics in the sediment never exceed 0,6 percent (Figure 26). Taljaard (1987a, 1987b) found a maximum organic content of approximately 0,7 percent. Branch and Day (1984) estimated the mean standing stock of organics in the sediment (down to a depth of 10 cm) to be about 900 g (dry mass) per m^2 which amounts to a total standing stock of over 200 000 kg (dry mass) for the entire estuary (Appendix VII). Because the concentration of organics in the sediments is so low, it is doubtful whether they make any substantial contribution to nutrients within the estuary.

The dense populations of the sand-prawn, *Callianassa kraussi,* have a dramatic influence on the concentration and turnover of organic material in the sediment (Branch and Day, 1984). The burrows of *Callianassa* are lined by a thin layer of remarkably fine, black sediment. In strong contrast with the surrounding sediment, this layer has a relatively high organic content (4 to 10 percent). Furthermore each *Callianassa* hole yields an average of 1,50 g (dry mass) of faeces each tidal cyle. These faeces have a 35 percent organic content, representing a 165-fold increased concentration over that of the surrounding sediment. The mean standing stock of *Callianassa* faeces was estimated at 84 g (dry mass) per m^2 which amounts to a total standing stock of 19 347 kg (dry mass) and potential turnover of more than $1,7 \times 10^6$ kg (dry mass) per annum for the entire estuary (Appendix VII).

Other sources of organic matter in the Palmiet Estuary include the alga *Cladophora*, phytoplankton, zooplankton, benthic diatoms and invertebrates. These are discussed in detail in Section 4.

Concluding remarks

In summer it appears that the greater part of the estuary is marine dominated with the sea having the largest influence on the nutrient budget of the system. The fresh water layer has a very short residence time within the estuary since it flows almost continuously seawards and does not seem to contribute significantly to the nutrient regime in the estuary (Taljaard, 1987a, 1987b). The effect of the sea depends to a large extent on the state of the tide. During spring tide new sea-water replaces a large proportion of the bottom water in the estuary. During neap tide, on the other hand, most of the water that moves into the estuary during the high tide is removed during the low tide.

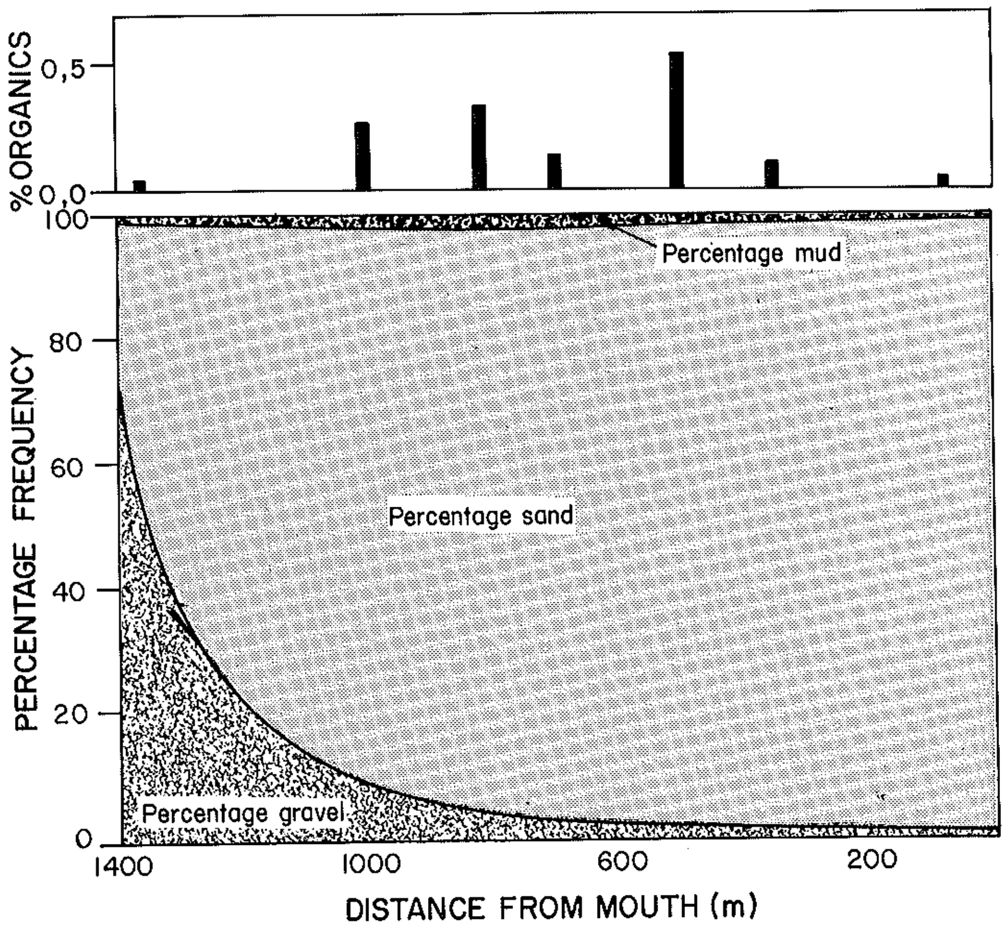


FIG 26: Palmiet Estuary. Composition and organic content of the sediment (from Branch and Day, 1984)

Data on nutrient levels are not yet available for the winter months. It is, however, hypothesized that in winter the river will have the largest influence on the nutrient budget of the system. As saline water input into the estuary is extremely limited in winter, the marine contribution of nutrients will probably be negligible in comparison to the fluvial contribution (Taljaard, pers. comm.).

3.2.10 Pollution and Public Health Aspects

Due to the virtual absence of industry along its banks and the limited development in its catchment area, the Palmiet River carries a very light pollution load. Furthermore, the fast flow regime of the estuary rapidly washes any pollutants out of the system. Nel (1980) reports that the estuary is practically unpolluted and is considered as one of the few coastal systems in South Africa that still exists in its natural condition. Levels of phosphates and nitrates entering the estuary are low (see Section 3.2.9 *Nutrients)* and retention times of surface waters are short (see Section 3.2.3). The potential for eutrophication in the estuary is thus low.

The Coastal Oil Spill Contingency Plan drawn up by the Department of Environment Affairs (South Africa, 1987) contains recommendations for the protection of individual estuaries in the event of a marine oil spill. In the case of the Palmiet Estuary it is recommended that the mouth be sealed by means of sandbags to prevent ingress of oil. In addition it is suggested that the beach berm be raised to prevent overtopping by high seas.

The extent to which power-boats pollute the water has not been investigated. Power-boats are, however, not used frequently and their contribution to the pollution load is probably small.

4. BIOTIC CHARACTERISTICS

4.1 Flora

4.1.1 Phytoplankton/Diatoms

Measurements of chlorophyll concentration taken along the entire length of the estuary indicate that phytoplankton is imported from both the river and the sea (Branch and Day, 1984). The riverine influence was greater in summer (December) and the sea influence greater in autumn (April). Presumably the riverine phytoplankton derives largely from a small dam behind the gauging weir upstream from the coastal road bridge, since there is little evidence of phytoplankton in the river above the weir (Branch and Day, 1984). Values are higher than might be expected in an estuary with such a fast flow regime. They range from 2,12 to 7,76 µg chlorophyll/l in December and from 1,48 to 4,82 ug chlorophyll/l in April. A rough estimate of the standing stock for the whole estuary is 232 kg (dry mass) (Appendix VII). Insignificant though this may appear, phytoplankton may turn over once every two days if nutrients are not limiting. Flushing times of surface waters vary with the strength of fluvial input but never exceed one tidal cycle (see Section 3.2.3). Thus retention times of surface waters and their phytoplankton content are extremely short, especially in winter where complete exchange of surface layers may occur during each ebb-tide. Even in December, when river flow was low, the high levels of phytoplankton coming in from the river are diluted fourfold within the estuary and most phytoplankton was eventually lost to the sea (Branch and Day, 1984).

Branch and Day (1984) have determined the standing stock of microflora, such as diatoms, in the sediment by measuring chlorophyll levels. Chlorophyll levels were low in the turbulent area at the mouth and at the head of the estuary, where the sediment is coarse. The highest levels were found on the sandflat just above the mid-tide level, decreasing down the shore and being very low subtidally. Cores taken to a depth of 30 cm showed that chlorophyll declined with depth into the sediment. Standing stock of benthic microflora is estimated at 7 000 kg (dry mass) for the whole estuary (Appendix VII).

4.1.2 Algae

The Palmiet Estuary is unusual in that there are practically no attached macrophytes in the system. This is due to the coarse nature and consequent instability of the sediment which prevents most attached macrophytes from settling and maintaining their position (Branch and Day, 1984). The exceptions are *Enteromorpha* and *Cladophora*. *Enteromorpha* grows on the rocky substrata near the mouth. *Cladophora* is most abundant in the deeper parts of the channel where salinities are high and water movement slow (Branch and Day, 1984). It is present in the estuary for only a short part of the year (December to April) after which it dies away completely until the following December. During April, when biomass was maximal, transects taken across the estuary revealed an absence of *Cladophora* in the mouth but an abundant presence in the channel at least up to the vicinity of station E (Figure 24). Biomasses in excess of 1 200 g dry mass per m^2 were found in the deeper parts of the channel in the vicinity of station E.

The total standing stock of *Cladophora* for the entire estuary was estimated at 30 360 kg (dry mass) (Appendix VII).

4.1.3 Production

Since nutrient levels in the estuary are moderate, they are unlikely to be limiting to plant growth. The current-driven nature and the low retention time of the estuary are probably the major factors restricting plant productivity (Branch and Day, 1984). The former factor influences the abundance of the macrophytes and benthic microflora. The high flow rate in winter makes it almost impossible for attached macrophytes to establish themselves. Only *Cladophora* thrives for a few months in summer when the flow is least. Benthic microflora are only abundant in the shallower, more stable sediments and are largely confined to the intertidal sandflat. The latter factor influences the abundance of phytoplankton. Phytoplankton values were fairly high relative to the sea, but retention times are short. Despite this, however, turnover rates may be high and the phytoplankton standing stock capable of significant productivity.

Humic substances in the water of the estuary limit light penetration, especially in winter when the river is flowing strongly. This is also likely to limit the productivity of the primary producers in the estuary (Nel, 1980).

Branch and Day (1984) have made very rough estimates of the productivity of the three major primary producer groups in the estuary. Values are listed in Appendix VII. Since *Cladophora* is so strongly seasonal, its annual production was conservatively estimated as being equal to the maximal standing stock, that is, 30 360 kg (dry mass) per annum for the entire estuary. Productivity of phytoplankton and benthic microflora was estimated at 8 000 kg (dry mass) per annum and 400 kg (dry mass) per annum respectively.

Production within the estuary should be viewed in relation to the import and export of organic material. Although the data are based on limited observations and must therefore be treated cautiously, they show quite clearly that a substantial amount of kelp, *Prionium* and particulate organic matter may be imported into the system (Appendix VII). If the sources of production within the estuary are compared with the net import of organic material, it is clear that import outweighs production *in situ* by a factor of about 3,6, since the net import is about 141 400 kg per annum, and the production of *in situ* *Cladophora*, benthic microflora and phytoplankton contributes only about 39 800 kg per annum (Branch and Day, 1984). This high import/production ratio stresses the importance of an almost permanently open mouth. Prolonged closure of the mouth would deprive the estuary of a high proportion of organic material. This in turn would have an adverse effect on the ecology of the system.

4.1.4 Aquatic and Semi-aquatic Vegetation

There are no records of any kind of aquatic vegetation in the Palmiet Estuary.

The most southerly distribution of the Palmiet reed *Prionium serratum* is in the vicinity of the weir, approximately 300 m upstream from the coastal road bridge. There are no records of the occurrence of *Prionium* below rocky sills which delineate the upper extremity of the estuary.

A small saltmarsh occurs on a sheltered region of the sandflat just south of the jetty (Figure 14). A remarkable range of species occurs here (see Appendix I). Steep banks and rapid water flow preclude the formation of saltmarshes in the rest of the system (Branch and Day, 1984).

4.1.5 Terrestrial Vegetation

The terrestrial vegetation that occurs in the immediate vicinity of the Palmiet Estuary can be divided into three categories, based on physiographic features (Boucher, 1978).

A. Coastal Plain Vegetation
B. Mountain Vegetation
C. Riparian Vegetation

Within these categories two main vegetation types can be distinguished: (i) Broad-leaved scrub (e.g. *Sideroxylon inerme* dune scrub) and (ii) Fynbos, which is the common vegetation in the area.

A. Coastal Plain Vegetation

The extreme lower reaches of the estuary are lined with two littoral dune communities: the *Ehrharta-Ficinia* Strand Pioneer community and the *Colpoon-Rhus* Dune Scrub Community. For mapping purposes these two communities have been combined (community A, Figure 27) because an active gradation from one to the other occurs (Boucher, 1978). Generally the hummock dunes have a sparse covering of Strand Pioneer species such as marram grass *(Ammophila arenaria)*, sea wheat *(Agropyron distichum)*, klappiesbrak *(Tetragonia decumbens)* and blombos *(Metalasia muricata)*. Behind the foredune area the more stable dune areas are vegetated with dune scrub species such as taaibos *(Rhus* spp.), bietou *(Chrysanthemoides monilifera)* and bruinsalie *(Salvia aurea)*. A further littoral dune community, the *Sideroxylon inerme* dune scrub (community B, Figure 27) is found in close

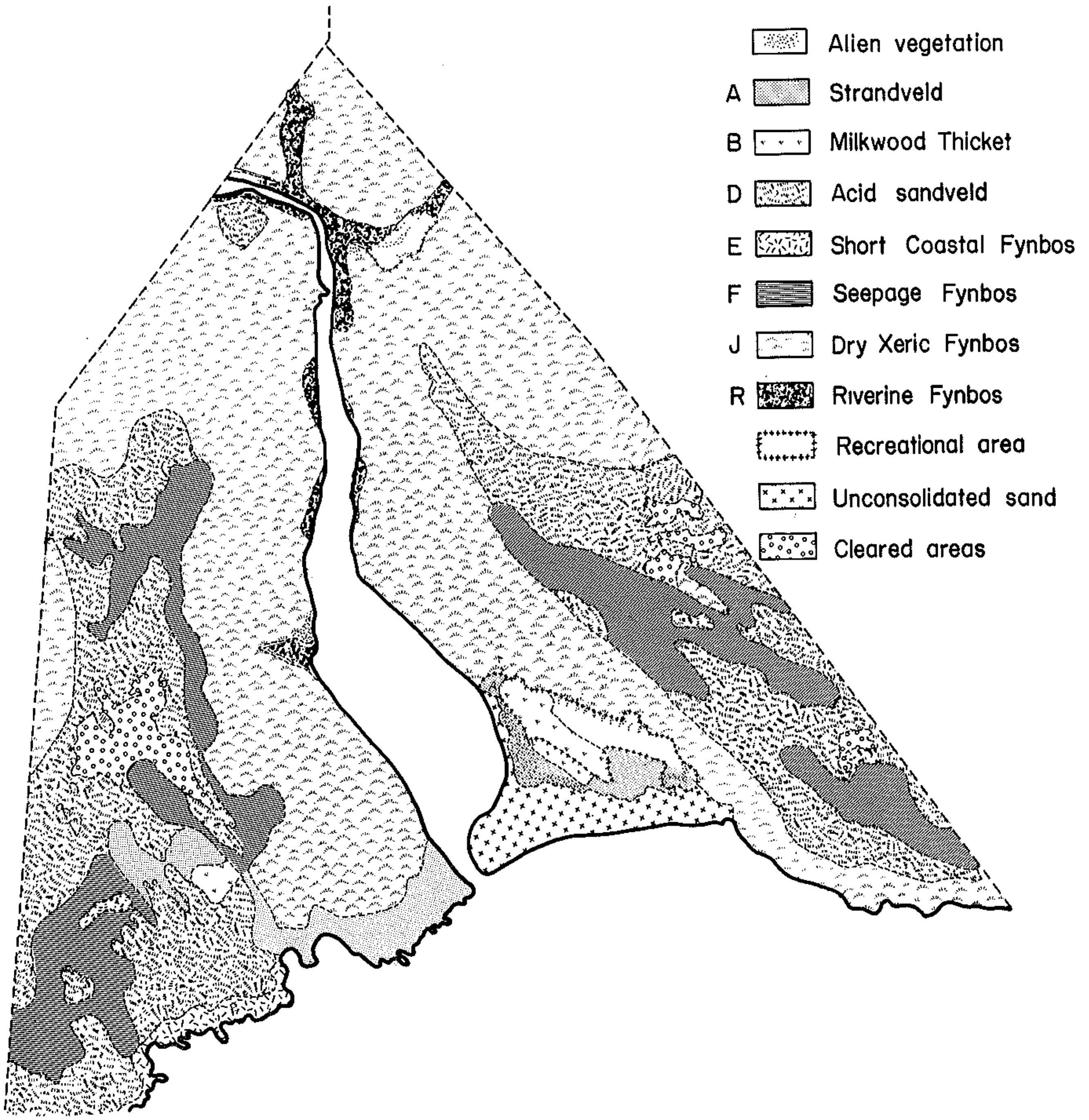


FIG 27: The terrestrial vegetation of the Palmiet Estuary (after Slingsby, 1983)

association with the above-mentioned two communities. This scrub appears to represent the climax vegetation on deep stabilized littoral sands (Boucher, 1978). Species that make up this community include white milkwood *(Sideroxylon inerme)*, coast cabbage tree *(Cussonia thyrsiflora)* and sea ghwarri *(Euclea racemosa)*.

Coleonema album Short Coastal Fynbos Communities (community type E, Figure 27) occur along the littoral rocky coastline adjacent to the littoral dune communities. This vegetation consists of a dwarf shrub layer, generally about 30-40 cm tall with prostrate succulents. Coastal dune scrub or strand pioneer elements are sometimes found in local deeper sand pockets (Boucher, 1978). Conspicuous species include the confetti bush *(Coleonema album)* and the blombos *(Metalasia muricata)*.

Substantial *Erica-Osmitopsis* Seepage Fynbos Communities (community type F, Figure 27) occur on the coastal plains around the estuary. The tall, ericoid-dominated shrub layer is about 2 m tall, while the lower shrub and herbaceous layer varies from 45-75 cm (Boucher, 1978). Common species include the swamp daisy *(Osmitopsis asteriscoides)*, Prince of Wales heath *(Erica perspicua)*, kolkol *(Berzelia lanuginosa)*, strawberry brunia *(Brunia alopecuroides)* and vlei mimetes *(Mimetes hirtus)*.

Acid Sandveld Series soils in the areas adjacent to the seepage fynbos support a diverse vegetation type, collectively known as the Acid Sand Flats Community (community D, Figure 27). The vegetation generally consists of two strata with species such as *Leucadendron xanthoconus* and *L. laureolum* forming the metre tall emergent, open shrub layer. The lower shrub and herbaceous layer is formed by a 15-30 cm tall mixture of ericoids and restioids (Boucher, 1978). The habitat of this community is well-suited to various types of developments. On both the eastern and western banks of the estuary, substantial areas within this community have been cleared for use as dumps and sandpits (Figure 14).

Extensive eradication ("hacking") efforts have substantially reduced the concentration of alien vegetation types in the vicinity of the estuary (P Slingsby, pers. comm.). At present the only large concentration occurs within the Littoral Dune Communities on the eastern bank of the lagoon (Figure 27). Alien species include Rooikrans *(Acacia cyclops)*, cluster pine *(Pinus pinaster)*, spider gum *(Eucalyptus lehmanii)* and Australian myrtle *(Leptospernum laevigatum)*. Certain aliens (e.g. *Pinus pinaster)* were introduced for the purpose of providing shade in the caravan park. Most of the aliens are, however, garden escapes. Small concentrations of aliens also occur along the upper banks of the estuary, along the coast to the west of the mouth, and in the picnic site at the head of the estuary (Figure 27).

B. Mountain Vegetation

The middle and upper reaches of the estuary are lined with vegetation of the mixed ericoid and restioid fynbos of the xeric slopes community (community J, Figure 27). This community is extremely diverse and extensive, covering over half the area covered by the vegetation study. Important species include *Erica plukenetii, Anthospermum aethiopicum, Thesium carinatum, Ficinia albicans, Lobelia capillifolia, Gnidia pinifolia,* olive leaved pin-cushion *(Leucospermum oleifolium)* and red everlasting *(Phaenocoma prolifera)*.

C. Riparian Vegetation

Brabejum-Rhus Riverine Scrub Communities line the banks along the upper reaches of the estuary (community R, Figure 27). This community forms a 3-4 m tall, dense scrub in which a number of tree, shrub and fynbos species (from adjacent communities) may be found. Examples include Cape Beech *(Rapanea melanophloeos)*, Kreupelhout *(Leucospermum conocarpodendron)*, Wild almond *(Brabejum stellatifolium)* and Lance leaf *(Metrosideros angustifolia)*.

4.2 Fauna

4.2.1 Zooplankton

Summer zooplankton population levels in the Palmiet Estuary are very low (Branch and Day, 1984). This is probably due to retention times of surface waters being so short. Short retention times of surface waters also explains why virtually all of the zooplankton is of marine rather than estuarine origin. The total summer standing stock of zooplankton for the estuary was estimated at 4,78 kg (dry mass).

No data on zooplankton population levels in winter are available.

4.2.2 Invertebrates

Macrofauna

The current-swept nature of the estuary, the annual flooding, the possibility of the mouth closing, the coarse sediment with its low organic content and interstitial salinity fluctuations are all factors militating against the establishment of invertebrate populations. Diversity is thus, not surprisingly, low (Branch and Day, 1984). Only 28 species have been recorded. This is lower than other estuaries (e.g. Klein River Estuary and Milnerton Estuary) which are closed more often and for longer periods than is the Palmiet (Branch and Day, 1984). Species that do occur in the estuary, however, are relatively abundant. The sand-prawn *Callianassa*, for example, achieves a density ($135/m^2$) that is exceeded only in the Langebaan Lagoon while the amphipod *Grandidierella* reaches a density of over $100\ 000/m^2$. The maximum biomass of invertebrates recorded ($35\ g/m^2$) equals that of many other estuaries, including such rich systems as Langebaan Lagoon (Branch and Day, 1984). The dense populations of *Callianassa* have an important influence on both abiotic and biotic components of the estuary. Their effect on the sediments and the concentration and turnover of organic material has been discussed in Section 3.2.9. This in turn influences the distribution and abundance of diatoms and meiofauna and possibly also microfauna and trace elements in the sediment (Byren, 1984).

A detailed account of the distribution and abundance of invertebrates in the Palmiet Estuary in summer is given in Branch and Day (1984). The 28 species recorded are listed in Appendix I. In summer, there were three major invertebrate zones in the estuary. The unstable mouth supported only a high-shore isopod fauna feeding in the water column at high tide and, subtidally, a few *Callianassa*. In the lagoon where conditions were more stable there were a large number of *Grandidierella* (over $100\ 000/m^2$), *Callianassa* ($135/m^2$), *Hydrobia* and *Cyathura*, together with a few other species. The highest diversity and abundance of invertebrates occurred within this zone on the sandflat. Towards the head of the estuary *Grandidierella* was replaced by *Corophium* and *Exosphaeroma hylecoetes* by *Pseudosphaeroma barnardi* but the rest of the fauna remained remarkably similar although it became sparser as the sediment became coarser. These three zones appear to reflect the stability of the substratum rather than changes in salinity since in summer, stratification maintains fairly constant salinities in channel bottom waters (Branch and Day, 1984). This is, however, probably not the case on the sandflat where wide salinity fluctuations in both bottom and interstitial waters have been recorded (Taljaard *et al.*, 1986; Fricke and Jensen, 1989). Further study is required to determine factors limiting the abundance and diversity of invertebrates in this region.

The mean biomass of invertebrates in summer was 5,7 g/m^2 to which an estimated 9 g/m^2 of *Callianassa* can be added (Appendix VII).

Little data are available on the distribution and abundance of invertebrates in the Palmiet Estuary during winter. Fricke and Jensen (1989) have demonstrated a marked decline in meiofaunal diversity in sandflat sediments during the winter months (see below). As macroinvertebrates essentially occupy the same niche, it is likely that a similar decline in diversity would occur. The abundance of *Callianassa* (which can tolerate wide salinity fluctuations) does not appear to be adversely affected by the low salinity conditions in winter (G M Branch, UCT, pers. comm.). It is, however, unlikely that many other invertebrates could tolerate these conditions. Interstitial salinities in the channel sediments appear to remain consistently high regardless of the salinity of the water flowing over them (Fricke and Jensen, 1989). It thus seems likely that invertebrates in the channel sediments would be less affected than those in sandflat sediments.

Fricke and Jensen (1989) have shown that a relatively low diversity and abundance of interstitial meiofauna exists in the sediments of the estuary. Eight taxa were distinguished with nematodes forming roughly 60 percent of organisms, which were concentrated in the top 100 mm of sediment (Appendix II).

Summer samples taken at nine sampling stations (Figure 24) indicate that diversity and abundance is higher in the channel than in the sandflat sediments. This is presumably due to more stable interstitial salinity conditions in the channel sediments (salinity fluctuations of up to 22 parts per thousand occurred in sandflat sediments during a single tidal cycle).

Summer and winter samples at station 7 (Figure 24) revealed that species composition changes and diversity and abundance declines in sandflat sediments during the winter months. This is presumably a reflection of seasonal salinity changes. During summer interstitial salinities ranged from 11-25 parts per thousand and meso-haline forms dominated. During winter interstitial salinities ranged from 0-6 parts per thousand and less abundant fresh water forms dominated. Salinity thus appears to be a major factor affecting the meiofauna in the Palmiet Estuary.

4.2.3 Fish

Nineteen species of fish have been collected in the estuary in a series of 29 samples spread throughout the year (Branch and Day, 1984). These are listed in Appendix III. Generally the number of fish caught was rather small and very variable. Only three species *(Liza richardsonii, Psammogobius knysnaensis* and *Myxus capensis)* occurred in the estuary throughout the year. The remaining sixteen species were present during various months but notably absent during winter. The number of species present increased from three in June and July to fifteen in March, declining rapidly during April and May. The decline in diversity during winter is thought to be due to a number of factors, including the export of juveniles by peak floods and the flood caused decline of temperature and salinities in the shallower, favoured fish habitats of the estuary (Bennett, 1981).

Fish in the Palmiet Estuary can be divided into three groups according to the degree of dependence on estuaries (Wallace *et al.*, 1984). The first group comprises three euryhaline species that are dependent on estuaries for their entire life cycle. Members of this group are *Caffrogobius multifasciatus*, *Psammogobius knysnaensis* and *Gilchristella aestuaria*. Individuals of all these species had reached adult size and were sexually mature. The second group comprises seven species dependent on estuaries during the juvenile phase of their life cycle. Members of this group include *Lichia amia*, *Lithognathus lithognathus*, *Mugil cephalus* and *Myxus capensis*. The species in this group were represented mainly by immature individuals. The third group comprises nine species whose juveniles occur in estuaries, but can also mature at sea. Members of this group include *Atherina breviceps*, *Liza dumerilii*, *L. tricuspidens* and *Pomatomus saltatrix*. This grouping shows quite clearly that ten out of the nineteen species of fish are either totally or partially dependent on estuaries for the successful completion of their life cycles.

Analysis of stomach contents reveal that most species in the estuary feed on small invertebrates and that the diets of these fish are all remarkably similar. Exceptions are *Lichia amia* which in this estuary feeds exclusively on small fish, and the five mullet species which feed mainly on detritus, micro organisms and attached diatoms (Bennett, 1981).

The Palmiet is the only estuary along some 350 km of coastline, between the Berg and Breë estuaries, which is normally open to the sea. Despite this it is unlikely to be of much importance as either a nursery or a breeding ground for estuary-dependent fish species. The almost complete lack of macrophyte vegetation cover and the hostile physical regime, particularly the prevalence of spates of cold acid river water negates its value as a breeding ground or nursery. As discussed in Section 3.2.3, the mouth is presently in a state of sensitive "dynamic equilibrium". Any further interference in the catchment (such as the proposed dam near the head of the estuary) of could have serious detrimental effects on this unique function.

4.2.4 Amphibians and Reptiles

A L de Villiers *(in litt.)* of the Cape Department of Nature and Environmental Conservation has produced a checklist of the amphibians and reptiles that occur and are likely to occur in the environs of the estuary and in the catchment area. These are listed in Appendix IV.

4.2.5 Birds

Twenty-three species of birds have been recorded at the Palmiet Estuary (Branch and Day, 1980; Underhill and Cooper, 1981, Summers *et al.* (1976), and ECRU survey (1986)). These are listed in Appendix V. The estuary does not appear to be a particularly important habitat for waterbirds. Diversity and abundance are generally low and variable throughout the year. This can probably be attributed to human disturbance (especially in summer) and the small size of suitable feeding grounds. Furthermore winter floods frequently result in the inundation of feeding grounds for prolonged periods and may cause a decline in potential sources of food (see Section 4.2.2). This probably renders the estuary unsuitable as a feeding ground for birds in the winter.

Very little data are available on the behaviour of the birds recorded at the estuary. Branch and Day (1980) report that with the exception of oystercatchers and sand martins, all the birds they observed appeared to be feeding on the shore or in the water.

4.2.6 Mammals

No systematic surveys of the mammals occurring in the immediate vicinity of the estuary have been undertaken. P Slingsby (pers. comm.) has, however, observed fifteen species near the estuary over the last 13 years. These are listed in Appendix VI. A list of species which are likely to occur in the vicinity of the estuary and which have been recorded or are likely to occur in the rest of the catchment area has been compiled by P H Lloyd of the Cape Department of Nature and Environmental Conservation. These are also listed in Appendix VI.

Of the species that have been recorded, the aardwolf, wildcat, serval, leopard, red musk shrew, Cape greater gerbil, Verreaux's rat and the black and white dormouse are listed as being threatened in the South African Red Data Book - Mammals (Smithers, 1986).

As most of the catchment area lies within the boundaries of State Forests and Nature Reserves, the fauna found there are afforded good protection.

5. SYNTHESIS

Present State of the System

The Palmiet Estuary is in a virtually pristine condition. This can be attributed largely to the limited human activity and development in its environs. Human activities in the catchment have had even less effect on the estuary than those in its immediate surroundings. This is surprising in view of the extensive damming and agricultural development that has taken place along the middle and upper reaches of the river (Sections 3.1.6 and 3.1.7). Impoundments attenuate river flow and alter downstream water quality while agricultural processes increase nutrient, pollution and silt levels in river water. In other local rivers this has had adverse effects on estuaries. Preliminary results of the Palmiet River Stream Regulation Programme (Zoology Department, University of Cape Town), however, show that the most southerly impoundment on the Palmiet River has no effect on the estuary - the river "recovers" completely, well above the estuary. Furthermore, the nearest development on the river is over 20 km from the head of the estuary. This appears to give natural processes adequate time to reduce the concentration of suspended substances which are harmful when in excess. Consequently concentrations of nitrates, phosphates, silt and pollution entering the estuary from the river approximate levels that would be encountered if the river was totally undisturbed. At present, flow is completely unobstructed and well supplemented by tributaries over the final 25 km of the river course. The estuary thus receives a permanent inflow of freshwater. This in turn maintains an almost permanently open mouth which is essential for the normal functioning of the system.

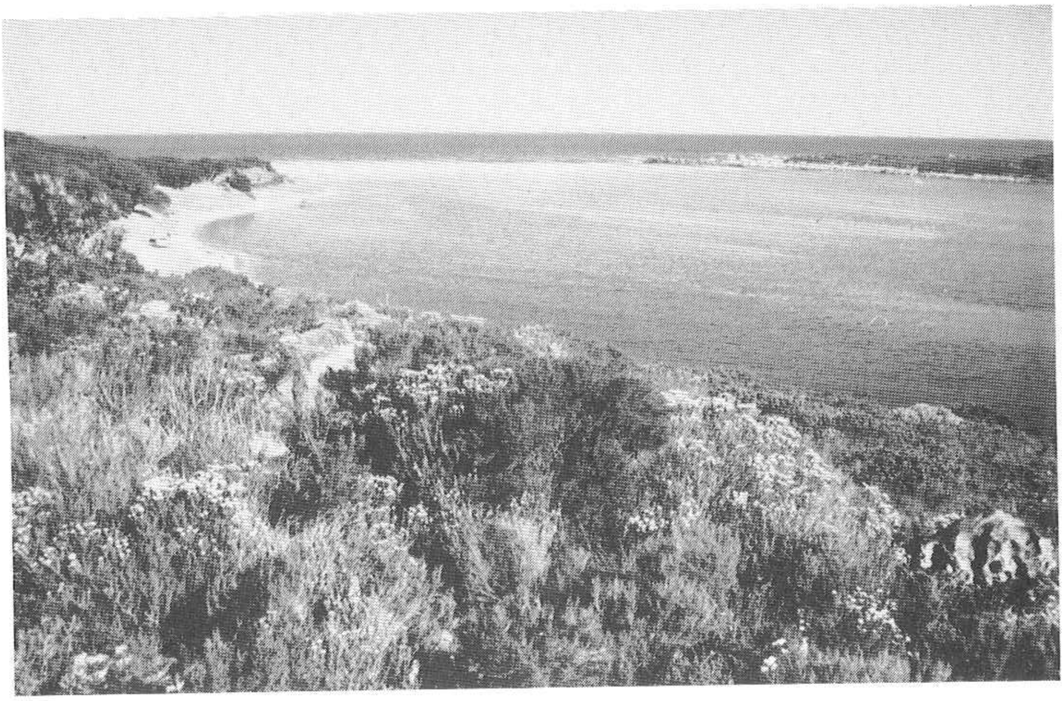


FIG 28: Palmiet Estuary at spring high tide. (Photo: ECRU, 86-08-20).

The estuary falls within the boundaries of the Kleinmond Coastal and Mountain Nature Reserve. In compliance with reserve legislation, development in the area has been restricted and damaging practices such as the use of the land for dumping grounds have been terminated (J J du Plessis, Town Clerk of Kleinmond, pers. comm.). The area surrounding the estuary is thus virtually unspoilt (Figure 28) and the system has suffered almost none of the ill effects associated with the indiscriminate use and management of land adjoining water bodies. An exception is the newly constructed ablution block on the eastern shore of the estuary which is an aesthetically displeasing sight. The estuary is, however, intensively used for recreation during the summer months (Section 3.2.7). The impact of activities such as swimming, fishing, bait collection and boating have not been assessed. Presumably, however, the utilization of the sandflat area by bathers, and the deeper channel waters by fishermen and power-boaters has an adverse effect on fauna such as invertebrates, fish and birds.

Despite fairly intensive recreation in summer the Palmiet Estuary is one of the few in South Africa still in a natural condition. Its present condition is considered to be 'good' and it has been recommended that the system be conserved but to permit some strictly controlled low intensity development (Heydorn (ed.), 1986).

Present State of Knowledge

As a result of the Palmiet River Water and Power Projects a considerable amount of research has been undertaken in both the catchment and the estuary. The prime motivation for this work has been the need to estimate the impact of the dams on the ecology of the river and estuary and on the dynamics of the estuary mouth. The Department of Water Affairs specifically commissioned two studies, namely an environmental impact assessment (Nel, 1980), and an assessment of the effect of the proposed Hangklip Dam on the Palmiet Estuary mouth (CSIR, 1980). River ecology studies are being undertaken by the University of Cape Town-based

Palmiet River Stream Regulation Programme. Studies of the estuarine chemistry have been made by Taljaard (1986, 1987a and 1987b), estuarine water circulation and mixing patterns by Largier (1986) and the ecology by Branch and Day (1980 and 1984).

The Palmiet is arguably the best studied blackwater (acid, tannin-stained) system in South Africa.

Problems: Present and Foreseeable

At present the Palmiet Estuary is little affected by the activities of man. In summer recreational activities are confined mainly to the eastern shore and the beach barrier adjacent to the mouth. Power boating, however, including water skiing, is permitted. These activities cannot be considered compatible with a small waterbody such as the Palmiet since the disturbance to the fauna, particularly birds, and to peace-seeking vacationers is considerable.

The only structures are the road bridge, presently being widened, across the head of the estuary and a boat-house and ablution block on the eastern shore. The bridge, a single clear span, has no effect on the river flow and is barely visible from the main recreation areas. The boat-house is discreetly sited and blends in well with its surrounding unlike the recently constructed ablution block which was erected with little or no consideration given to aesthetics. This displeasing structure is visible from the greater part of the estuary and its environs.

The house-boat moored against the west bank near the old pont landing appears to be little used and does not affect the estuary.

Currently four developments threaten to disturb the unspoilt nature of the Palmiet Estuary and its environs. The first two developments are related to the problems associated with the rapidly expanding population of Kleinmond. The town is approximately 40 percent developed and has a growth rate of about 7-9 percent per year (T Bokhorst, former Town Engineer of Kleinmond, pers. comm.). When the Kleinmond Coastal and Mountain Nature Reserve was expanded in 1979 little consideration was given to long-term management plans or the future needs of Kleinmond. Land is now urgently required to expand overloaded facilities. To purchase additional land outside the Reserve would not be economically viable and so attention has focussed on the use of land within the Reserve (T Bokhorst, pers. comm.).

The first development is the construction of a sewage works between the coastal road and the western bank of the estuary (J J du Plessis, pers. comm.). Expansion of existing facilities is necessary to cope with the increasing sanitary requirements of the expanding population of Kleinmond. Effluent from Kleinmond will be piped along the coastal road and, after treatment to General Standard, discharged into the sea. The outfall will, out of necessity, be near the mouth of the estuary. The nature and location of the outfall was decided after an investigation by the CSIR (Stellenbosch) on behalf of the Department of Water Affairs. The mouth of the outfall will be below the low-water spring tide mark to ensure rapid dilution and dispersion of the effluent thereby minimizing the risk of effluent entering the estuary. If, however, the discharge volumes are increased considerably there will be a commensurate increase in the risk of nutrient-rich water entering the estuary on the incoming tide. In such circumstances it is possible that growth of algae such as *Cladophora* may be enhanced resulting in aesthetically displeasing conditions.

The land for the sewage works has been excised from the Nature Reserve. As compensation, land from the proposed reserve extension will be proclaimed and added to the northern region of the reserve. Construction of the sewage works will consequently result in a spatial reduction in the lower region of the reserve and a potentially aesthetically displeasing visual disturbance (structures, security fences and lights) in the presently unspoilt environs of the estuary.

The second development, a pumping station, will probably have a negligible effect on the system provided that a suitable management policy is formulated and adhered to. The station has been constructed recently just above the coastal road bridge (Figure 29). Its function is to extract water from the river and pump it into storage reservoirs for use by Kleinmond (J J du Plessis, pers. comm.). The extraction policy for the pumping station falls under the control of the Kleinmond Municipality (G van Zyl, Department of Water Affairs, pers. comm.) and has been set at six megalitres per day. This is apparently 10-15 percent of the lowest flow rate recorded in the region of the river from which water will be extracted (T Bokhorst, pers. comm.). However, it must be remembered that this is an initial extraction figure. The volume extracted will probably be increased in years to come as the water requirements of Kleinmond increase. There is a close, positive correlation between fresh water input and the cross-sectional area of the mouth (Section 3.2.3). Therefore, if the volume of water allowed to bypass the pump intake is inadequate, mouth closure could result. This situation would then persist until the rainy season and have detrimental effects on the ecology of the estuary. It is thus strongly recommended that the fresh water input/mouth cross-sectional area data be used to formulate a long-term management policy for the pumping station. A further negative aspect of the pumping station is that construction requirements have necessitated the reopening of the old sandpits on the western bank of the estuary which were closed after the proclamation of the Nature Reserve (Figure 14).

The above-mentioned developments illustrate that nature reserves, especially those that are administered by municipalities, are seldom immune from the powerful and incessant hand of development. Until recently the Palmiet Estuary was protected by its reserve status. Now that developments are taking place around it, there is considerable reason for concern about preservation. It appears that the only way to assure the long-term conservation of the system is to revise the conditions under which developments are allowed to take place. Steps are, in fact, presently being undertaken to do this. The coastal plain between Rooiels and Botriviervlei (Figure 1) is to be given formal conservation status, as a "Nature Area" or "Protected Area". "Protected Area" is in terms of the terminology used in the revised Environmental Conservation Bill which is due to replace the Environmental Conservation Act No 100 of 1982. The area encompassed by the proposed Protected Area is scheduled to be proclaimed a Protected Natural Environment (PNE) in terms of the Environmental Conservation Bill now before Parliament (J Avis, CDNEC, pers. comm.). In terms of the bill, when enacted, the Administrator will be empowered to decide as to which authority will be appointed to manage the PNE. In addition, the Administrator will be able to appoint a management committee to guide the chosen authority in its tasks. It is strongly recommended that the CPA Chief Directorate of Nature and Environmental Conservation be given the responsibility for the management of the Betty's Bay Protected Natural Environment.

The remaining two developments which threaten to disturb the unspoilt nature of the Palmiet Estuary involve the construction of dams on the Palmiet River. The recently completed Kogelberg Dam, between the Applethwaite and Arieskraal dams, will probably have a negligible effect on the estuary (Section 3.1.5). It is possible, however, that the Kogelberg Dam may affect the estuary indirectly.

Once it is in operation, water supply to the Arieskraal Dam will be reduced. The Arieskraal Dam presently receives water from two major sources - the Palmiet and the Klein Palmiet rivers. The latter river actually bypasses the dam but water is pumped from it into the impoundment (B A Byren, Zoology Dept, UCT, pers. comm.). No control appears to be exercised over the amount of water extracted (G van Zyl, pers. comm.). The major tributaries of the Palmiet River downstream of the confluence of the Klein Palmiet are either extensively impounded (Huis and Kromme) or congested with vegetation (Dwars and Louws) (Figure 3 and Section 3.1.7). It thus follows that the Klein Palmiet probably contributes a fairly high percentage of the water entering the Palmiet River between the Arieskraal Dam and the estuary. If the Kogelberg Dam severely reduces the flow of water into the Arieskraal Dam, more water will probably be extracted from the Klein Palmiet as compensation. This, in turn, may have profound implications for the downstream ecology of the Palmiet and even the estuary at certain times of the year.

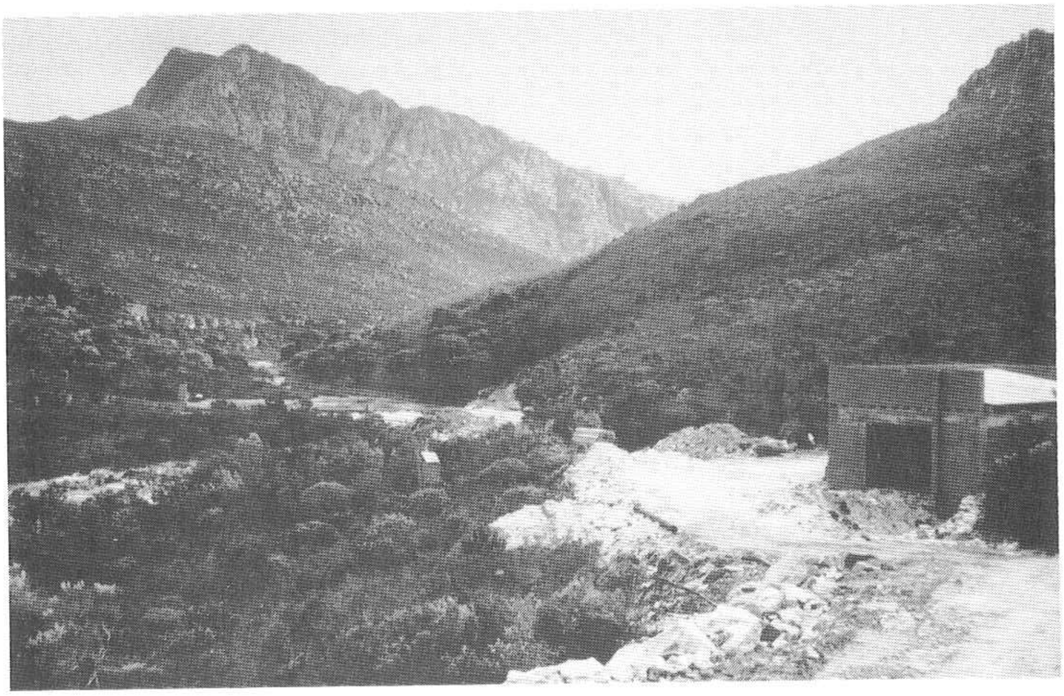


FIG. 29: Kleinmond pumping station just above the coastal road bridge. (Photo: ECRU, 86-08-20).

It is strongly recommended that all facets of the situation be analysed and, if necessary, the release policy of the Kogelberg Dam be designed so that the volume of compensatory water required from the Klein Palmiet is kept below the amount that, if extracted, will have adverse effects downstream.

The final development threatens to have a far greater direct impact on the estuary. This is the proposal to dam (the Hangklip Dam), the lower Palmiet River at one of three sites, the lowermost being very close to the head of the estuary (Figure 30). The proposal stems from the fact that existing sources of water will soon be inadequate to supply the rapidly expanding population of the

Greater Cape Town Region. The total dependable yield of present water resources belonging to the Cape Town Water Undertaking, local authorities and of allocated supplies from State controlled dams (including the Kogelberg Dam) is 298 x $10^6 m^3$ per annum (De Kock and Pretorius, 1981). Water demand predictions by the Unit for Futures Research of the Bureau of Economic Research, which assumes the gradual introduction of water recycling and reasonable conservation measures, indicate that existing resources will be inadequate by 1995 (Stauth and Lane, 1983). Unutilized potential water resources (besides the Palmiet) would satisfy projected demand until 2002. Thereafter it would be necessary to implement the Lower Palmiet damming proposal or an unconventional water resource scheme (namely, desalination). Even if the full potential water yield of the Lower Palmiet River is realised (104 x $10^6 m^3$ per annum), and all other potential conventional water resource schemes prove viable, further growth in water demand after the year 2012 would have to be met by unconventional sources (Stauth and Lane, 1983).

Though water from the Palmiet River will only be required in about 15 years time, it is essential that immediate decisions be made on two issues:

(i) What alternative water resource should be exploited once existing water resources become inadequate - should it be desalination or the Hangklip Dam project? As discussed above, unconventional sources will have to be sought in approximately 25 years time. Desalination is, however, relatively expensive and exploitation of the Palmiet River would keep the cost of water down until this measure is applied. A summary of the advantages and disadvantages of desalination relative to exploitation of the Palmiet is provided in Stauth and Lane (1983). A survey conducted by the Department of Environmental and Geographical Science, University of Cape Town, has revealed that the majority of households supplied by the Cape Town Water Undertaking would rather see increase water demands being met by desalination than by further exploitation of the Palmiet River (S Butcher, Department of Environmental and Geographical Science, UCT, pers. comm.). Households generally were prepared to contribute towards the increased cost of desalination. The additional amount they were prepared to pay for water was, however, substantially less than that which would be charged if water demands were met by desalination.

(ii) If the Palmiet is to be exploited, it must be decided to what degree this should be done. The Palmiet River Environmental Committee, commissioned by the Director General of the Department of Water Affairs in 1981 to assess the ecological implications of the proposed scheme, has formulated six alternatives for the exploitation of the Palmiet River. When compared, these alternatives generally engender a conflict of interests between water yield, the preservation of ecosystems (such as the estuary and unique fynbos communities) and the conservation of highly valuable agricultural land. Summaries of these conflicting interests and potential environmental impacts are provided in a variety of documents, including Environmental Conservation of the Proposed Palmiet River Water and Power Projects (1982), Stauth and Lane (1983), de Kock and Pretorius (1981) and Nel (1980).

A major consideration when deciding which alternative to implement is the impact that each alternative will have on the estuary. The damming of an area along the lower reaches of the river will have some effect on the estuary. On the basis of their year-long ecological survey, Branch and Day (1984) predicted what could happen to the estuary if a dam was constructed on the lower reaches of the river and fresh water flow was attenuated. Reduction in the flow of fresh water into the estuary would certainly result in closure of the mouth, either permanently or for longer periods than those that currently occur. Stagnation, a breakdown of stratification and greater long-term fluctuations in salinity would

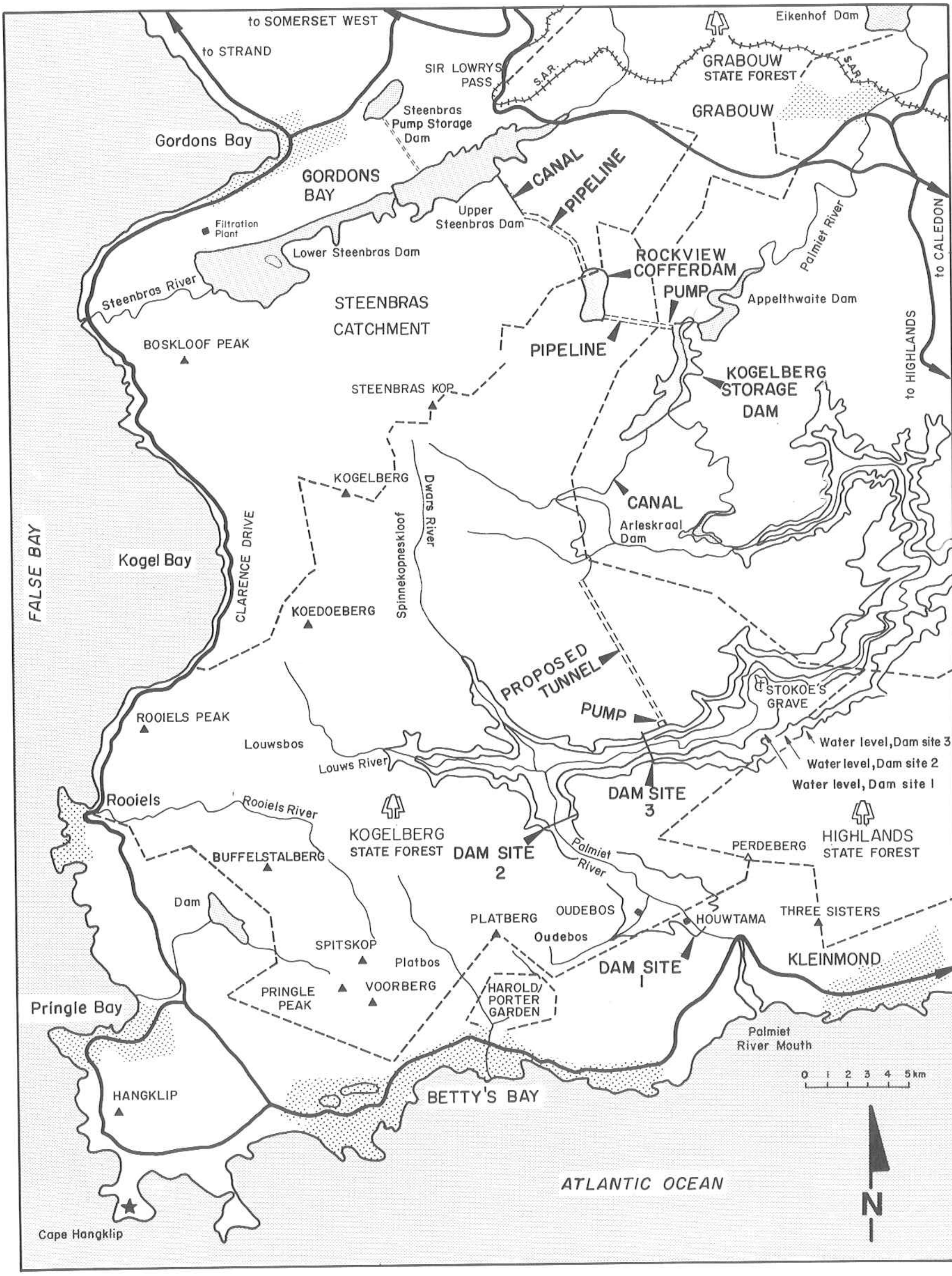


FIG 30: Proposed dam sites on the lower Palmiet River (after Boucher, 1982)

ensue. Recruitment of up to ten estuarine-dependent species of fish would be prevented or curtailed and algae such as *Cladophora* would bloom and choke the estuary. Almost all of the invertebrates are of marine origin and many of them thrive only in open estuaries, so that mouth closure would lead to a further impoverishment of fauna. Attenuation of water flow would also reduce the input of nutrients and organic particles to the estuary from the river. This problem would be compounded if the mouth closed since substantial amounts of organic material and nutrients enter the estuary from the sea (Section 3.2.9 *Nutrients)*. Import of organic material substantially outweighs production in the estuary (Section 4.1.3) and any reduction in supply would have profoundly adverse effects on the invertebrate and ultimately the fish fauna.

It goes without saying that such ecological changes would be of detriment to the recreational potential of the estuary - something which can be ill afforded during a time when the recreational demand upon all coastal recources is increasing rapidly.

The site chosen for the dam, its design and its release policy are the major factors to be considered if the impact on the estuary is to be minimized (Branch and Day, 1980; Environmental considerations of the proposed Palmiet River water and power projects, 1982). A dam situated high up on the river would have less effect on the estuary then a lower dam as released water would have more time to "recover" from the effects of the impoundment. The Palmiet River Stream Regulation Programme has been in operation since February 1986. Physico-chemical data are being collected from stations along the entire length of the river. A prime objective of this study is to determine river reset distances (the "recovery" distance following an impoundment). It is strongly urged that these findings be taken into account when a dam site is chosen. Furthermore, a dam situated upstream would allow water from several tributaries to flow naturally into the estuary and attenuation of flow would not be as severe.

The physico-chemical properties of water released from an impoundment are largely dependent on release depth. If the dam is situated high upstream, the depth of release is unlikely to affect the estuary as water characteristics will be modified within the river before reaching the estuary. If the dam is situated close to the estuary, however, depth of release should be varied so as to mimic the pre-impoundment characteristics of water entering the estuary as closely as possible. It is thus recommended that the dam have a multi-level outlet structure especially if it is situated near to the estuary. Substantial data on the physico-chemical characteristics of water entering the estuary at different times of the year have been collected (Branch and Day, 1984; Taljaard, *in litt.;* B A Byren *in litt.)* and should be used to formulate a depth of release management policy.

The water release management policy for the proposed dam should aim at maintaining the present state of the estuary mouth. A proposed policy for the release of compensation water from the dam has been formulated and is outlined in Section 3.1.5. The total volume of water required to ensure that the natural estuarine conditions are maintained as closely as possible throughout the year will vary between 3 and 8 x $10^6 m^3$ per annum. This corresponds to 1,4 - 4,4 percent of the mean annual run-off. Compensatory releases should not, therefore, have much effect on the potential water yield of the Palmiet River. It must be stressed that this recommended policy represents the best estimate of the required flow that can be made at present. It would probably need to be amended slightly to ensure optimum efficiency. This can only be done once the dam is in operation and should be based on the results of a regular monitoring programme. Currently the Kleinmond Municipality monitors the state of the estuary mouth on a weekly basis. This information will provide a valuable data-base for modification of the release policy once the dam has been constructed. A similar recommended release policy has been tested on the Hartenbos Estuary (D H Swart, EMA, CSIR pers. comm.). It is encouraging to note that predictions were accurate and the estuary has been restored to its original state.

During the construction of a dam there is an inevitable increase in sediment loads in the water. At the construction site every effort should be made to minimize the introduction of sediments into the river. A highy efficient silt trap procedure was utilized at the Kogelberg Dam site (Section 3.1.8). It is recommended that similar traps be used at the construction site should the proposed dam be built.

Finally, it should be noted that the estuary is not the only ecosystem threatened by the Hangklip and Kogelberg dams. If the Hangklip Dam is constructed within the Kogelberg State Forest (Figure 1), valuable components of the Cape Floral Kingdom will be inundated and destroyed (Figure 31). The Kingdom has already been extensively damaged outside major reserves. Sixty-one percent of its area has been lost to land users and the remainder is under strong pressures (Environmental considerations of the proposed Palmiet river water and power projects, 1982). Serious consideration should also be given to the conservation of this ecosystem before final decisions are made and dam construction commences. The compounded effect of the Applethwaite, Kogelberg and Arieskraal dams is undoubtedly having severe adverse effects on the downstream river ecology of the Palmiet River. However, there has been no apparent impact on the ecology of the Palmiet Estuary. Up to the end of 1985 no consideration was given to the collection of pre-impoundment data bases from which siting proposals and management policies could be formulated. This includes the recently constructed Kogelberg Dam which is often cited as a prime example of close liaison between impoundment constructors and environmentalists (B R Davies, Zoology Department, UCT, pers. comm.). Since the beginning of 1986, the Palmiet River Stream Regulation Programme has been gathering data which will be used to formulate management policies for existing dams and to determine the ecologically least disruptive sites for and designs of proposed dams. According to Mr G van Zyl (Department of Water Affairs, pers. comm.) no control is exercised over the amount of water released from the privately-owned dams on the Palmiet River. Water is not released from the dams in summer and only bypasses the impoundments via spillways in winter. It is strongly recommended that management policies formulated from this study be applied to existing and proposed impoundments.

Recommendations

The maintenance of the estuary in as near natural condition as possible should be the prime goal of any management policy (Sections 3.2.2 and 3.2.3). The single most important factor is the input of freshwater from the Palmiet River. An integrated water management policy is required to ensure that the needs of riparian owners, users outside the catchment e.g. Cape Town City Council and Kleinmond Municipality, and the natural environments are met.

The environs of the estuary require more formal protection than the present municipal reserve status. Urgent consideration should be given to the proclamation of the area as a Provincial Nature Reserve. In addition, the entire coast between Rooiels and Botriviervlei should be proclaimed a Protected Natural Area as soon as the revised Environmental Conservation Bill becomes law. This will ensure the protection of this almost unspoilt environment on a coast which is being developed on an ever-increasing scale.

Careful landscaping of the sewage works on the west side of the estuary should be undertaken to make them as unobtrusive as possible. At the planned discharge volumes it is extremely unlikely that measurable quantities of effluent-derived nutrients will enter the estuary. However, should the sewage works be expanded in the future a study should be undertaken to ensure that no enriched water enters the estuary. If necessary the outfall pipe should be extended further offshore to ensure thorough mixing of the treated effluent with seawater.

The unsightly ablution block on the eastern shore of the estuary should be demolished and a new more attractive structure should be erected well back from the estuary in the trees adjacent to the caravan park. All powercraft should be banned from the estuary. It is far too small to be used safely for water skiing simultaneously with other aquatic activities such as swimming, canoeing and boardsailng.

In conclusion, the opportunity exists to maintain the Palmiet Estuary in near-pristine condition. Immediate action is required to ensure that the estuary and the surrounding Kleinmond Nature Reserve is given the legal protection necessary to ensure its protection for the benefit and enjoyment of future generations.

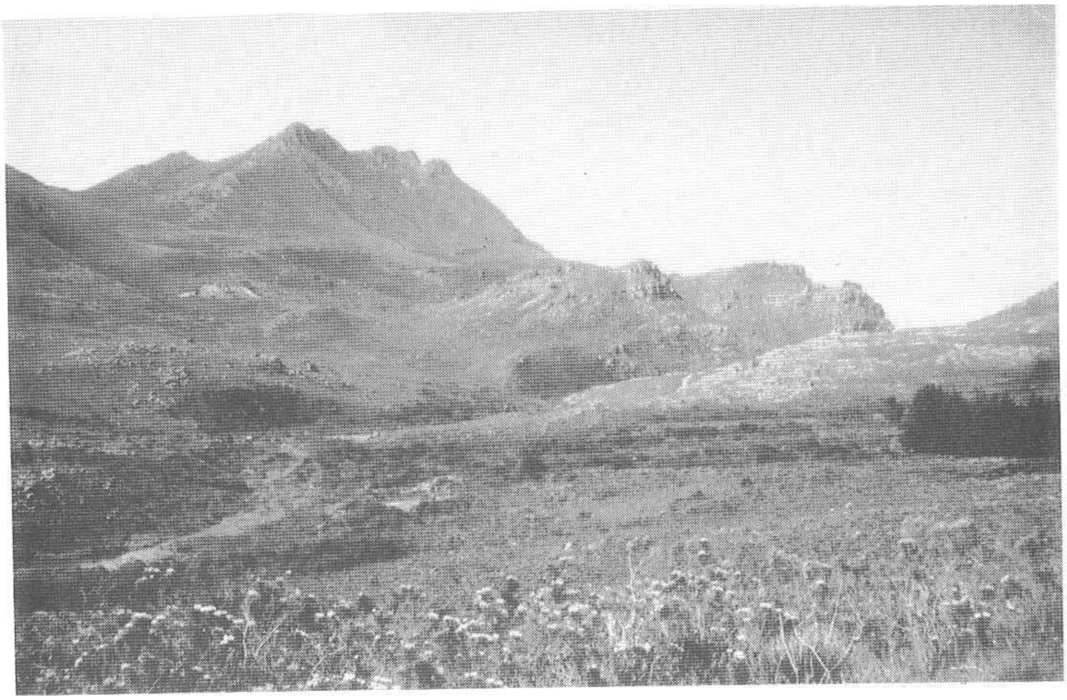


FIG. 31: Part of Kogelberg State forest which could be flooded by the proposed lower Hangklip Dam. (Photo: ECRU, 86-09-04).

6. ACKNOWLEDGEMENTS

Thanks are due to the following persons, institutions and organizations for the information and assistance received during the compilation of this report:

University of Cape Town (UCT):
Prof. G M Branch, Prof. B R Davies, Dr J A Day, Miss B A Byren and Miss A T Lombard, Zoology Department; Dr J Rogers, Marine Geoscience Unit; Mrs S Butcher, Department of Environmental and Geographical Science; Mr D A Gerneke, Electron Microscope Unit.

Department of Environment Affairs:
Mr T S Newby,
Department of Water Affairs:
Pretoria: Dr C P R Roberts and Mr W S Croucamp
Cape Town: Messrs G van Zyl and C Littlewort
Chief Directorate: Nature and Environmental Conservation (CDNEC):
Dr D Coetzee and Messr J Avis, P H Lloyd, A L de Villiers and C Burgers
Ekokonsult Incorporated:
Miss M V Anderson
ESKOM:
Mr C E Cooper
Weather Bureau, Department of Transport:
Mrs L Rademeyer
M J Mountain and Associates (Consulting Geologists):
Mr R A Bradshaw
University of Stellenbosch:
Dr C Boucher, Botany Department
Kleinmond
Mr J J du Plessis (Town Clerk), Mr P Slingsby (local resident) and Mr T Bokhorst (former Town Engineer)
Betty's Bay
Mr R I G Attwell
Division of Earth, Marine and Atmospheric Science and Technology, CSIR :
Miss S Taljaard, Dr J Largier, Mr A H Fricke and Mrs H Heydorn

The advice and assistance of all members of ECRU is acknowledged.

This survey was carried out at the request and with the financial support of the Department of Environment Affairs. The encouragement of this Department, the Steering Committee for Estuarine and Coastal Research and the SA National Committee for Oceanographic Research is gratefully acknowledged.

7. REFERENCES

Literature Cited

BARWELL, L (1988). Dynamics of the Palmiet River mouth. Stellenbosch. *CSIR Report* EMA/T 8802. 11p + Figs.

BENNETT, B (1981). Ecology of the fish in the Palmiet River Estuary. Zoology Department, University of Cape Town. *Unpublished Report.*

BOUCHER, C (1978). Cape Hangklip area II. The vegetation. *Bothalia* 12(3): 455-497.

BOUCHER, C (1982). The Kogelberg State Forest and environs - a paradise for Cape Flora. *Veld and Flora* 68(1): 9-11.

BRANCH, W R (1981). An annotated checklist of the lizards of the Cape Province, South Africa. *Ann. Cape Mus. (nat. Hist.)* 13(11): 141-167.

BRANCH, G M and DAY, J A (1980). The ecology of the Palmiet River Estuary. Zoology Department, University of Cape Town. *Unpublished Report.*

BRANCH, G M and DAY, J A (1984). Ecology of southern African estuaries: Part XIII. The Palmiet River Estuary in the south-western Cape. *S. Afr. J. Zool.* 19: 63-77.

BRANCH, G M and GRINDLEY, J R (1979). Ecology of southern African estuaries: Part X. Mngazana : a mangrove estuary in the Transkei. *S. Afr. J. Zool.* 14: 149-170.

BROADLEY, D G (1983). *FitzSimons' snakes of southern Africa.* Johannesburg. Delta Books, 376 pp.

BROADLEY, D G and GREER, A E (1969). A revision of the genus *Acontias* Cuvier (Sauria : Scincidae) *Arnoldia* 4(26): 1-29.

BROOKE, R K (1984). South African Red Data Book - Birds. Pretoria. *South Afr. Natl. Sci. Programmes Rep.* 97. 213 pp.

BULPIN, T V (1980). *Discovering Southern Africa.* Cape Town. T V Bulpin Publications. 899 pp.

BURMAN, J (1970). *Waters of the Western Cape.* Cape Town. Human and Rousseau. 176 pp.

BYREN, B A (1984). The effect of burrowing, by the sand prawn *Callianassa kraussi* Stebbing, on the sediment of the Palmiet River Estuary, Southern Cape. Zoology Department, University of Cape Town. *Unpublished Report.*

CSIR, (1980). Effect of proposed Hangklip Dam on Palmiet River mouth. Stellenbosch. *CSIR Report* C/SEA 8048. 26 pp + Figs.

DE GRAAF, G (1981). *The Rodents of Southern Africa.* Durban. Butterworths. 267 pp.

DE KOCK, F and PRETORIUS, P F (1981). Belangrikheid van die voorgestelde Hangklipskema as waterbron vir die stedelike gebied van Suidwes-Kaapland en die ekonomiese implikasies van alternatiewe uitlegte met 'n kleiner impak op die ekologie van die natuurlike omgewing. Direktoraat van Waterwese, Beplanningsafdeling, Junie 1981. *Unpublished Report.*

DE VILLIERS, J, JANSEN, H and MULDER, M P (1964). *Die Geologie van die gebied tussen Worcester en Hermanus.* Department of Mines. Pretoria. Government Printer. 69 pp.

DU PLESSIS, E J (1973). *'n Ondersoek na die oorsprong en betekenis van Suid-Afrikaanse berg- en riviername.* Cape Town. Tafelberg.

ENVIRONMENTAL CONSIDERATIONS OF THE PROPOSED PALMIET RIVER WATER AND POWER PROJECTS. INTERIM REPORT (1982). Pretoria. Department of Environmental Affairs. Palmiet River Environmental Committee. *Report* No. V/6400/04/E002.

FLINT, R F (1971). *Glacial and Quaternary geology.* New York. Wiley. 892 pp.

FRICKE, A H and JENSEN, P (1989). Meiofauna in coarse estuarine sediment exposed to short-term salinity changes. (In prep).

GREIG, J C and BURDETT, P D (1976). Patterns in the distribution of southern African terrestrial tortoises (Cryptodira :Testudinidae). *Zoologica Africana* 11(2): 249-273.

HEYDORN, A.E.F. (ed). (1986). An assessment of the state of the estuaries of the Cape and Natal in 1985/86. *South Afr. Natl. Sci. Programmes Rep.* 130. 30pp.

HEYDORN, A E F and TINLEY, K L (1980). Estuaries of the Cape, Part I. Synopsis of the Cape coast. Natural features, dynamics and utilization. Stellenbosch. *CSIR Research Report* 380. 96 pp.

HUIZINGA, P and SMITH, C J (in prep.). Palmiet Estuary - computation of flow through the estuary mouth. Stellenbosch. *NRIO Technical Report.*

JEZEWSKI, W A and ROBERTS, C P R (1986). Estuarine and lake freshwater requirements. Pretoria. Department of Water Affairs. *Technical Report* TR 129. 22pp.

KING, J M, DAY, J A and VAN DER ZEL, D W (1979). Hydrology and hydrobiology. In: *Fynbos ecology: a preliminary synthesis.* (Eds. Day, J, Siegfried, W E, Louw, G N and Jarman, M L). Pretoria. *South Afr. Natl. Sci. Programmes Report* 40: 27-42.

LARGIER, J (1986). Structure and mixing in the Palmiet Estuary, South Africa. *S. Afr. J. Mar. Sci.* 4: 139-152.

LARGIER, J and TALJAARD, S (1988). Winter intrusion and flushing in the Palmiet Estuary, South Africa. Submitted to *Est. Coastal and Shelf Science.*

MACLEAN, G L (1984). *Roberts birds of South Africa.* 5th edition. Cape Town. The Trustees of the John Voelcker Bird Book Fund. 660 pp.

McLACHLAN, G R (1978). South African Red Data Book - Amphibians and Reptiles. Pretoria. *South Afr. Natl. Sci., Programmes Rep.* 18. 59 pp.

MIDGLEY, D C and PITMAN, M V (1969). Surface water resources of South Africa. Johannesburg. Univ. of Witwatersrand. *Hydrological Research Unit Report* 2/69. 127 pp.

MOSSOP, E E (1927). *Old Cape Highways.* Cape Town. Maskew Millar. 202 pp.

NEL, A (1980). Palmietrivier ekologiese impakstudie. Vol I en II. Pretoria. Directorate of Water Affairs, Division of Special Tasks. *Unpublished Report.* (I)lv, (II). 445 pp.

NIENABER, G S (1963). *Hottentots.* Pretoria. J L van Schaik. 539 pp.

NOBLE, R G and HEMENS, J (1978). Inland water ecosystems in South Africa - a review of research needs. Pretoria. *S. Afr. Natl. Sci. Programmes Rep.* 34. 150 pp.

PASSMORE, N I and CARRUTHERS, V C (1979). *South African Frogs.* Johannesburg. Witwatersrand University Press. 270 pp.

PITMAN, W V, POTGIETER, D J, MIDDLETON, B J and MIDGLEY, D C (1982). Surface water resources of South Africa. Volume IV: Drainage regions EGHJKL - the Western Cape Part 2 (Appendices). Johannesburg. *Hydrological Research Unit Report* 13/81. 526 pp.

POYNTON, J C (1964). The Amphibia of southern Africa: a faunal study. *Ann. Natal Mus.* 17: 1-334.

RIVER FLOW DATA - MONTHLY SUMMARIES OCTOBER 1960 TO SEPTEMBER 1970 (1978). Pretoria. Department of Water Affairs. *Hydrological Information Publication* 10. 550 pp.

ROGERS, J (1985). Geomorphology, offshore bathymetry and Quaternary lithostratigraphy around the Bot River Estuary. *Trans. Roy. Soc. S. Afr.* **45, Part 3 & 4: 211-237.**

SCHULTZE, B R (1965). Climate of South Africa Part 8. General Survey. Pretoria. *Weather Bureau Publicaton* 28. 380 pp.

SIESSER, W G and DINGLE, R V (1981). Tertiary sea level movements around southern Africa. *J. Geol.* 89: 83-96.

SLINGSBY, P (1983). Kleinmond 1983. (Information accompanying map of Kleinmond). Kleinmond. Child and Family Welfare Society.

SLINGSBY, P (1984). *Fynbos.* (Newsletter of Kleinmond nature conservation Society). No. 21

SMITH, J L B and HEEMSTRA, P C H (eds.) (1986). *Smith's sea fishes.* Johannesburg. Macmillan. 1047pp.

SMITHERS, R H N (1986). South African red data book - Terrestrial mammals. Pretoria. *South Afr. Natl. Sci. Programmes Rep.* 125. 216 pp.

SOUTH AFRICA. DEPARTMENT OF ENVIRONMENT AFFAIRS (1982). Report on the proposed first phase of the Palmiet River government Water Scheme, 1982-83. Pretoria. W.P.K. -'82.

SOUTH AFRICA. DEPARTMENT OF ENVIRONMENT AFFAIRS. (1987). *Coastal Oil Spill Contingency Plan* No 4 Caledon Zone. lv.

STAUTH, R and LANE, S (1983). Alternative water supply schemes affecting the Palmiet Valley. A summary of potential environmental impacts. *Unpublished Report* School of Environmental Studies, University of Cape Town. 85 pp.

STUART, C T (1981). Notes on the mammalian carnivores of the Cape Province, South Africa. *Bontebok* Vol. 1: 1-58.

STUART, C T, LLOYD, P H and HERSELMAN, J C (1980). Preliminary distribution maps of mammals of the Cape Province (excluding Cetacea). CPA Department Nature and Environmental Conservation. *Unpublished Research Report.* Mammals. 176 pp.

SUMMERS, R W, PRINGLE, J S and COOPER, J (1976). *The Status of coastal waders in the South Western Cape, South Africa.* Cape Town. Western Cape Wader Study Group. 162 pp.

SWART, D H (1986). Prediction of wind-driven transport rates. *Proc.* 20th International Conference on Coastal Engineering, Taiwan: 1595-1611.

TALJAARD, S (1987a). Nutrient circulation in the Palmiet River estuary: A summer study. *M.Sc. thesis.* Department of Biochemistry, University of Port Elizabeth. 113 pp.

TALJAARD, S (1987b). Nutrient circulation in the Palmiet River estuary. A summer study. Stellenbosch. *CSIR Research Report* 633. lv.

TALJAARD, S, EAGLE, G and HENNIG, H F-K O (1986). The Palmiet Estuary: A model for circulation using salinity and temperature measurements over a tidal cycle. *Water SA* 12(3): 119-152.

UNDERHILL, L G and COOPER, J (1981). Counts of waterbirds at coastal wetlands in Southern Africa: Estuaries 1979-1981. *Unpublished Computer Printout.* Interim version UWETLD. Western Cape Wader Study Group and Percy FitzPatrick Institute of African Ornithology.

VAN DER MERWE, L (1988). River mouth surveys of the west and south west Cape coast (Orange, Olifants, Berg, Diep, Palmiet and the Klein River.) Data report no.1. *CSIR Report* EMA/D 8802. 31 pp and Figs.

VISSER, J D (1984). Akkedisse van Suider-Afrika. *Landbouweekblad* reeks 65(319) - 66(359).

WALLACE, J H, KOK, H M, BECKLEY, L E, BENNETT, B, BLABER, S J M and WHITFIELD, A K (1984). South African estuaries and their importance to fishes. *S. Afr. J. Sci.* 80(5): 203-207.

WILLIS, J P (1981). Geochemistry and size analysis of sediments from estuaries in the southern Cape. *Unpublished Report* University of Cape Town, Department Geochemistry.

Maps

SOUTH AFRICA 1:50 000 Sheet 3318BB Somerset West, 3rd edition. Pretoria. Government Printer. 1981.

SOUTH AFRICA 1:50 000 Sheet 3318BD Hangklip, 3rd edition. Pretoria. Government Printer. 1981.

SOUTH AFRICA 1:50 000 Sheet 3419AA Grabouw, 2nd edition. Pretoria. Government Printer. 1979.

SOUTH AFRICA 1:50 000 Sheet 3419AC Hermanus, 3rd edition. Pretoria. Government Printer. 1982.

SOUTH AFRICA 1:250 000 Topocadastral Sheet 3318 Cape Town, 5th edition. Pretoria. Government Printer. 1981.

SOUTH AFRICA 1:250 000 Topocadastral Sheet 3319 Worcester, 3rd edition. Pretoria. Government Printer. 1980.

KLEINMOND 1:12 500 Map Cartography by P Slingsby. Kleinmond. Child and Family Welfare Society. 1983.

Aerial Photographs

Date	Job	Number	Scale 1:	Type	Source
1938	12638	12831-35,36	25 000	B&W	Trig. Survey
1961	719	1792	40-50 000	B&W	Trig. Survey
1973	461	8721	36 000	B&W	Trig. Survey
1980	374	250	20 000	B&W	Univ. of Natal
79-04-21	326	349, 350/3	10 000	Col.	Univ. of Natal
Dec. 1981	391	351, 352/3	20 000	Col.	Univ. of Natal
Feb. 1987	-	347-350	10 000	Col.	ECRU/EMA

8. GLOSSARY OF TERMS USED IN PART II REPORTS

ABIOTIC: non-living (characteristics).

AEOLIAN (deposits): materials transported and laid down on the earth's surface by wind.

ALIEN: plants or animals introduced from one environment to another, where they had not occurred previously.

ALLUVIUM: unconsolidated fragmental material laid down by a river or stream as a cone or fan, in its bed, on its floodplain and in lakes or estuaries, usually comprised of silt, sand or gravel.

ANAEROBIC: lacking or devoid of oxygen.

ANOXIC: the condition of not having enough oxygen.

AQUATIC: growing or living in or upon water.

ARCUATE: curved symmetrically like a bow.

BARCHANOID (dune): crescent-shaped and moving forward continually, the horns of the crescent pointing downwind.

BATHYMETRY: measurement of depth of a water body.

BENTHIC: bottom-living.

BERM: a natural or artificially constructed narrow terrace, shelf or ledge of sediment.

BIMODAL: having two peaks.

BIOGENIC: orginating from living organisms.

BIOMASS: a quantitative estimation of the total weight of living material found in a particular area or volume.

BIOME: major ecological regions (life zones) identified by the type of vegetation in a landscape.

BIOTIC: living (characteristics).

BREACHING: making a gap or breaking through (a sandbar).

CALCAREOUS: containing an appreciable proportion of calcium carbonate.

CALCRETE: a sedimentary deposit derived from coarse fragments of other rocks cemented by calcium carbonate.

CHART DATUM: this is the datum of soundings on the latest edition of the largest scale navigational chart of the area. It is -0,900 m relative to the land levelling datum which is commonly called Mean Sea Level by most land surveyors.

COLIFORMS: members of a particularly large, widespread group of bacteria normally present in the gastro-intestinal tract.

COMMUNITY: a well defined assemblage of plants and/or animals clearly distinguishable from other such assemblages.

CONGLOMERATE: a rock composed of rounded, waterworn pebbles 'cemented' in a matrix of calcium carbonate, silica or iron oxide.

CUSP: a sand spit or beach ridge usually at right angles to the beach formed by sets of constructive waves.

"D" NET: a small net attached to a "D" shaped frame riding on skids and pulled along the bottom of the estuary, used for sampling animals on or near the bottom.

DETRITUS: organic debris from decomposing plants and animals.

DIATOMS: a class of algae with distinct pigments and siliceous cell walls. They are important components of phytoplankton.

DYNAMIC: relating to ongoing and natural change.

ECOLOGY: the study of the structure and functions of ecosystems, particularly the dynamic co-evolutionary relationships of organisms, communities and habitats.

ECOSYSTEM: an interacting and interdependent natural system of organisms, biotic communities and their habitats.

EDDY: a movement of a fluid substance, particularly air or water, within a larger body of that substance.

ENDEMIC: confined to and evolved under the unique conditions of a particular region or site and found nowhere else in the world.

EPIFAUNA: animal life found on the surface of any substrate such as plants, rocks or even other animals.

EPIPHYTE: a plant living on the surface of another plant without deriving water or nourishment from it.

EPISODIC: sporadic and tending to be extreme.

ESTUARY: a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage (Day, 1981).

EUTROPHICATION: the process by which a body of water is greatly enriched by the natural or artificial addition of nutrients. This may result in both beneficial (increased productivity) and adverse effects (smothering by dominant plant types).

FLOCCULATION (as used in these reports): the settlement or coagulation of river borne silt particles when they come in contact with sea water.

FLUVIAL (deposits): originating from rivers.

FOOD WEB: a chain of organisms through which energy is transferred. Each "link" in a chain feeds on and obtains energy from the preceding one.

FYNBOS: literally fine-leaved heath-shrub. Heathlands of the south and south-western Cape of Africa.

GEOMORPHOLOGY: the study of land form or topography.

GILL NET: a vertically placed net left in the water into which fish swim and become enmeshed, usually behind the gills.

HABITAT: area or natural environment in which the requirements of a specific animal or plant are met.

HALOPHYTES: plants which can tolerate saline conditions.

HAT (Highest Astronomical Tide) and LAT (Lowest Astronomical Tide): HAT and LAT are the highest and lowest levels respectively, which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; these levels will not be reached every year. HAT and LAT are not the extreme levels which can be reached, as storm surges may cause considerably higher and lower levels to occur (South African Tide Tables, 1980).

HUMMOCK (dune): a low rounded hillock or mound of sand.

HYDROGRAPHY: the description, surveying and charting of oceans, seas and coastlines together with the study of water masses (flow, floods, tides, etc.).

HYDROLOGY: the study of water, including its physical characteristics, distribution and movement.

INDIGENOUS: belonging to the locality; not imported.

INTERTIDAL: generally the area which is inundated during high tides and exposed during low tides.

ISOBATH: a line joining points of equal depth of a horizon below the surface.

ISOHYETS: lines on maps connecting points having equal amounts of rainfall.

ISOTHERMS: lines on maps joining places having the same temperature at a particular instant, or having the same average, extremes or ranges of temperature over a certain period.

LAGOON: an expanse of sheltered, tranquil water. (Thus Langebaan lagoon is a sheltered arm of the sea with a normal marine salinity; Knysna lagoon is an expanded part of a normal estuary and Hermanus lagoon is a temporarily closed estuary (Day 1981)).

LIMPID: clear or transparent.

LITTORAL: applied generally to the seashore. Used more specifically, it is the zone between high- and low-water marks.

LONGSHORE DRIFT: a drift of material along a beach as a result of waves breaking at an angle to the shore.

MACROPHYTE: any large plant as opposed to small ones. Aquatic macrophytes may float at the surface or be submerged and/or rooted on the bottom.

MARLS: crumbly mixture of clay, sand and limestone, usually with shell fragments.

MEIOFAUNA: microscopic or semi-microscopic animals that inhabit sediments but live quite independently of the benthic macrofauna.

METAMORPHIC: changes brought about in rocks within the earth's crust by the agencies of heat, pressure and chemically active substances.

MHWS (Mean High Water Springs) and MLWS (Mean Low Water Springs): the height of MHWS is the average, throughout a year when the average maximum declination of the moon is 23°, of the height of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is greatest. The height of MLWS is the average height obtained by the two successive low waters during the same periods (South African Tide Tables 1980).

MORPHOMETRY: physical dimensions such as shape, depth, width, length etc.

OLIGOTROPHIC: poor in nutrients and hence having a paucity of living organisms.

OSMOREGULATION: the regulation in animals of the osmotic pressure in the body by controlling the amount of water and/or salts in the body.

PATHOGENIC: disease producing.

PERIPHYTON: plants and animals adhering to parts of rooted aquatic plants.

PHOTOSYNTHESIS: the synthesis of carbohydrates in green plants from carbon dioxide and water, using sunlight energy.

PHYTOPLANKTON: plant component of plankton.

PISCIVOROUS: fish eating.

PLANKTON: microscopic animals and plants which float or drift passively in the water.

QUARTZITE: rock composed almost entirely of quartz recemented by silica. Quartzite is hard, resistant and impermeable.

RIPARIAN: adjacent to or living on the banks of rivers, streams or lakes.

RIP CURRENT: the return flow of water which has been piled up on the shore by waves, especially when they break obliquely across a longshore current.

SALINITY: the proportion of salts in pure water, in parts per thousand by mass. The mean figure for the sea is 34,5 parts per thousand.

SECCHI DISC: a simple instrument used to measure the transparency of water.

SHEET FLOW: water flowing in thin continuous sheets rather than concentrated into individual channels.

SLIPFACE: the sheltered leeward side of a sand-dune, steeper than the windward side.

TELEOST: modern day bony fishes (as distinct from cartilaginous fishes).

TROPHIC LEVEL: a division of a food chain defined by the method of obtaining food either as primary producers, or as primary, secondary or tertiary consumers.

TROUGH: a crescent shaped section of beach between two cusps.

WAVE HEIGHT (average energy wave height): an index which reflects the distribution of average incident wave energy at inshore sites along the coast presented as a wave height.

WETLANDS: areas that are inundated or saturated by surface or ground water frequently enough to support vegetation adapted to life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

ZOOPLANKTON: animal component of plankton.

References:

DAY, J.H. (ed.)(1981). Estuarine ecology with particular reference to Southern Africa. Cape Town, A.A. Balkema.

SOUTH AFRICAN TIDE TABLES (1980). Retreat C.P. The Hydrographer. South African Navy.

APPENDIX I: Species list of the macro invertebrates and plants (algae, aquatic and semi-aquatic vegetation) collected from the Palmiet Estuary (from Branch and Day, 1984). Station locations are shown in Figure 24. Symbols indicate the relative abundance of invertebrates (number of specimens per m^2)/percentage cover of plants.

For invertebrates	For plants
R = 1- 2 (rare)	R = 0- 5% (rare)
P = 3- 20 (present)	P = 5-20% (present)
C = 21-100 (common)	C = 21-50% (common)
A = > 100 (abundant)	A = > 100% (abundant)

Habitat types are rock (Ro), sand (Sa), saltmarsh (SM) or river bank (Rb).

Species	Abundance at stations A-F						Habitat
	A	B	C	D	E	F	
Invertebrates							
Polychaeta							
Ceratonereis keiskamma	P	A	A	A	A		Sa
Prionospio cf. *tenuis*	C	A					Sa
Ostracoda	A	A	A				Sa
Copepoda	A						Sa
Amphipoda							
Corophium triaeonyx	R			P	A	P	Sa
Grandidierella bonnieroides	A	A	A	A	P		Sa
Melita zeylanica	P	P	R				Sa
Orchestia rectipalma			C				Sa
Talorchestia quadrispinosa	A	A					Sa
Isopoda							
Cyathura estuaria	P	A	A	P	P		Sa
Eurydice longicornis	R	P					Sa
Excirolana natalensis	P						Sa
Exosphaeroma hylecoetes	R	P	P	P			Ro
Pseudosphaeroma barnardi					P	P	Ro
Tanaidacea							
Tanais philetaerus	A				C		Sa, Ro
Decapoda							
Betaeus jucundus		P	P				Sa
Callianassa kraussi	C	A	A	A	A		Sa
Cleistostoma edwardsii		P					Sa
Hymenosoma orbiculare		P	C	P			Sa
Ocypode ceratophthalmus	R						Sa
Thaumastoplax spiralis		R				R	Sa
Insecta							
Chironomid larvae (Diptera)	C	A					Sa
Coelopea africana (Diptera)	C	A					Sa
Pachyphaleria capensis (Coleoptera)	C	A					Sa
Staphylinid (Coleoptera)	A	C					Sa

APPENDIX I: (Cont.)

Species	Abundance at stations A-F						Habitat
	A	B	C	D	E	F	
Gastropoda							
Assiminea globulus			A				SM
Hydrobia sp.	A	A	A	A	A		Sa
Natica tecta	R						Ro
Oxytele sinensis				R			Ro
Oxytele variegata	P						Ro
Bivalvia							
Choromytilus meridionalis	P						Ro
Plants							
Algae							
Enteromorpha sp.	C						
Cladophora sp.		C	P	C	A		Sa
Angiospermae							
Arctotheca calendula			R				SM
Cotula coronopifolia			C				SM
Crassula sp.			R				SM
Chenopodium sp.			R				SM
Ficinia sp.			R				SM
Juncus kraussii kraussii			C				SM
Orphium fructescens			P				SM
Plantago crassifolia var. crassifolia			R				SM
Prionium serratum						P	R
Samolus porosus			C				SM
Isolepis verrucosula			P				SM
Sporobolus virginicus			P				SM
Triglochin striata			P				SM

APPENDIX II: Meiofauna taxa collected from the Palmiet Estuary (Fricke and Jensen, 1989).

Nematoda

Thoracostomopsidae
- *Mesacanthion*

Oxystominidae
- *Oxystomina*
- *Halalaimus*

Oncholaimidae
- *Oncholaimus*
- *Viscosia*

Enchelidiidae
- *Polygastrophora*

Tripiloididae
- *Bathylaimus*
- *Tripyloides*

Axonolaimidae
- *Axonolaimus*

Dorylaimidae
- *Dorylaimus*

Monhysteridae
- *Daptonema*

Crustacea

Harpacticoid copepoda
Interstitial amphipoda
Caprellids

APPENDIX II: (Cont.)

Chromadoridae
Chromadorella
Ptycholaimellus
Prochromadorella
Cyatholaimidae
Paralongicyatholaimus
Paracyatholaimus
Selachinematidae
Halichoanolaimus
Comesomatidae
Dorylaimopsis
Desmodoridae
Desmodora

Annelida

Archiannelida
Oligochaeta
Polychaeta

Platyhelminthes

Turbellaria

Kinorhyncha

APPENDIX III: Fish species list for the Palmiet River Estuary and numbers caught in 12 monthly samples between May 1980 and April 1981 (from Branch and Day, 1984). Nomenclature after Smith and Heemstra (1986).

Species	Common name	Number caught	Seasonal occurrence
Galeichthys feliceps	White sea catfish	24	Late summer
Gobius multifasciatus	Prison goby	96	Spring to summer
Gilchristella aestuaria	Estuarine round herring	78	Summer
Atherina breviceps	Cape silverside	7 887	Spring & autumn
Lichia amia	Leervis	5	Summer
Lithognathus lithognathus	White steenbras	384	Summer
Liza dumerilii	Groovy mullet	81	Autumn
Liza richardsonii	Southern mullet	8 729	Year round
Liza tricuspidens	Striped mullet	1	-
Monodactylus falciformis	Cape moony	4	-
Mugil cephalus	Flathead mullet	10	-
Myxus capensis	Freshwater mullet	88	Year round
Pomatomus saltatrix	Elf	5	Summer
Psammogobius knysnaensis	Knysna sandgoby	464	Year round
Rhabdosargus globiceps	White stumpnose	23	Summer
Rhabdosargus holubi	Cape stumpnose	27	Late summer
Solea bleekeri	Blackhand sole	3	-
Syngnathus acus	Longsnout pipefish	1	-
Terapon jarbua	Thornfish	1	-

APPENDIX IV: Checklist of Amphibians and Reptiles that have been recorded (X) or, on the basis of preferred habitats, are likely to occur (L) in the environs of the Palmiet Estuary and in the area covered by the 1:50 000 Topocadastral Sheets 3318 BB Somerset West, 3318 BD Hangklip, 3319 AA Grabouw and 3319 AC Hermanus, in which the catchment area is centrally situated (A L de Villiers, CDNEC *in litt.*). Data from Poynton (1964), Broadley and Greer (1969), Greig and Burdett (1976), Passmore and Carruthers (1979), Branch (1981), Broadley (1983), Visser (1984) and P Slingsby, (pers. comm.). Threatened species listed in the South African Red Data Book (McLachlan, 1978) are indicated with an asterisk.

Common name	Species	Estuary	Catchment area
FROGS			
Common platanna	*Xenopus laevis*	L	X
*Cape platanna	*Xenopus gilli*	-	X
Cape ghost frog	*Heleophryne purcelli*	-	X
Sand toad	*Bufo angusticeps*	L	X
Cape mountain toad	*Capensibufo rosei*	-	X
Raucous toad	*Bufo rangeri*	L	X
Leopard toad	*Bufo pardalis*	L	X
Strawberry rain frog	*Breviceps acutirostris*	-	X
Cape rain frog	*Breviceps gibbosus*	-	X
Cape mountain rain frog	*Breviceps montanus*	L	X
Sand rain frog	*Breviceps rosei*	-	L
Cape sand frog	*Tomopterna delalandii*	L	L
Cape river frog	*Rana fuscigula*	L	X
Spotted rana	*Rana grayii*	L	X
Cape grass frog	*Rana montana*	L	X
Common caco	*Cacosternum boettgeri*	L	X
*Micro frog	*Microbatrachella capensis*	-	X
*Cape caco	*Cacosternum capense*	-	X
Cape chirping frog	*Arthroleptella lightfooti*	L	X
Rattling kassina	*Kassina wealii*	L	X
*Arum lily frog	*Hyperolius horstockii*	L	X
LIZARDS			
Ocellated gecko	*Pachydactylus geitje*	L	X
Marbelled gecko	*Phyllodactylus porphyreus*	L	X
Cape dwarf chameleon	*Bradypodion pumilum*	L	X
Rock agama	*Agama atra*	L	X
Green-striped mountain lizard	*Topidosaura montana*	-	L
Yellow-striped mountain lizard	*Topidosaura gularis*	-	L
Silver sand lizard	*Scelotes bipes*	L	L
Golden sand lizard	*Acontias meleagris*	L	X
Three-striped skink	*Mabuya capensis*	L	X
Cape speckled skink	*Mabuya homalocephala*	L	X
Yellow-throated plated lizard	*Gerrhosaurus flavigularis*	L	X
Ocellated sand lizard	*Eremias lineoocellata*	-	X
Common girdled lizard	*Cordylus cordylus*	L	X
Crag lizard	*Pseudocordylus microlepidotus*	-	X

APPENDIX IV: (Cont.)

Common name	Species	Estuary	Catchment area
Smith's girdled lizard	*Pseudocordylus capensis*	-	X
Cape snake lizard	*Chamaesaura anguina*	L	X
Long-tailed seps	*Tetradactylus tetradactylus*	L	X
Short-legged plated lizard	*Tetradactylus seps*	L	X
TORTOISES/TERRAPINS			
Angulate tortoise	*Chersina angulata*	X	X
Southern padloper	*Homopus areolatus*	X	X
Cape terrapin	*Pelomedusa subrufa*	L	L
SNAKES			
Delalandės blind snake	*Leptotyphlops nigricans*	L	L
Common brown water snake	*Lycodonomorphus rufulus*	L	L
Yellow-bellied house snake	*Lamprophis fuscus*	L	L
Aurora house snake	*Lamprophis aurora*	L	X
Olive house snake	*Lamprophis inornatus*	L	X
Spotted house snake	*Lamprophis guttatus*	L	X
Southern slugeater	*Duberria lutrix*	L	X
Mole snake	*Pseudaspis cana*	L	X
Cape many-spotted reed snake	*Amplorhinus multimaculatus*	L	L
Spotted grass snake	*Psammophylax rhombeatus*	L	X
Whip snake	*Psammophis notostictus*	L	X
Cross-marked grass snake	*Psammophis crucifer*	L	X
Spotted harlequin snake	*Homoroselaps lacteus*	L	X
Herald snake	*Crotaphopeltis hotamboeia*	L	X
Boomslang	*Dispholidus typus*	X	X
Common eggeater	*Dasypeltis scabra*	L	L
Rinkhals	*Hemachatus haemachatus*	L	X
Cape cobra	*Naja nivea*	X	X
Cape mountain adder	*Bitis atropos*	L	X
Puff adder	*Bitis arietans*	X	X

APPENDIX V: Bird species recorded at the Palmiet Estuary (after Branch and Day, 1980; Underhill and Cooper, 1981; Summers *et al.*, 1976; ECRU Survey, 1986; Grindley *in litt.*, 1979).

Roberts No. (Maclean 1984)	Species	Roberts No. (Maclean 1984)	Species
3	Jackass Penguin*	102	Egyptian Goose
55	Whitebreasted cormorant	170	Osprey
56	Cape Cormorant	244	Black Oystercatcher
58	Reed Cormorant	246	Whitefronted Sandplover
60	Darter	281	Sanderling
67	Little Egret	264	Common Sandpiper
95	African Spoonbill	270	Greenshank

APPENDIX V: (Cont.)

Roberts No. (Maclean 1984)	Species	Roberts No. (Maclean 1984)	Species
312	Kelp Gull	324	Swift Tern
316	Hartlaub's Gull	428	Pied Kingfisher
327	Common Tern	533	African Sand Martin
328	Arctic Tern	713	Cape Wagtail
326	Sandwich Tern		

* Threatened species as listed in the South African Red Data Book - birds (Brooke, 1984)

APPENDIX VI: Checklist of mammals (compiled by P H Lloyd, CDNEC) that have been recorded (X), are likely to occur (L) or are possibly present (P) in the environs of the Palmiet Estuary and the area covered by the 1:50 000 Topocadastral Sheets 3318 BB Somerset West, 3318 BD Hangklip, 3319 AA Grabouw and 3319 AC Hermanus, in which the catchment area is centrally situated. Data taken from Stuart (1981), Stuart *et al.* (1980), De Graaf (1981), CDNEC mammal records, P H Lloyd *(in litt.)*. P Slingsby, (pers. comm.), M van der Merwe, (EMA, pers. comm.). Where known, records are marked
1 - specimen records
2 - sight records
Threatened species listed in the South African Red Data Book-Mammals (Smithers, 1986) are indicated with an asterisk.

NOTE:
"Likely to occur" refers to animals which may occur but have not yet been recorded. "Possibly present" refers to animals which have been recorded from or are likely to occur in areas adjacent to the study area.

Common name	Scientific name	Estuary	Catchment area
ORDER CARNIVORA			
Cape grey mongoose	*Galerella pulverulentus*	X_2	X_2
Egyptian mongoose	*Herpestes ichneumon*	-	X_1
Water mongoose	*Atilax paludinosus*	X_2	X_2
Small spotted genet	*Genetta genetta*	L	X_1
Large spotted genet	*Genetta tigrina*	X_2	X_1
Striped polecat	*Ictonyx striatus*	-	X_2
Cape fox	*Vulpes chama*	-	X_2
*Aardwolf	*Proteles cristatus*	-	X_2
*Wildcat	*Felis lybica*	L	X_1
*Serval+	*Felis serval*	-	X_1
Caracal	*Felis caracal*	X_2	X_2
*Leopard	*Panthera pardus*	X_1	X_2
Cape clawless otter	*Aonyx capensis*	X_2	-
*Honey badger	*Mellivora capensis*	-	P

\+ historical recording (1898), possible recent sighting.

APPENDIX VI: (Cont.)

Common name	Scientific name	Estuary	Catchment area
ORDER CHIROPTERA			
Melck's house bat	*Eptesicus melckorum*	-	X_2
Geoffroy's horseshoe bat	*Rhinolophus clivosus*	-	X_2
Egyptian fruit bat	*Rousettus aegyptiacus*	-	X_2
Natal long-fingered bat	*Miniopterus schreibersii*	-	P
Cape serotine	*Eptesicus capensis*	-	P
Temminck's hairy bat	*Myotis tricolor*	-	L
*Lesueur's hairy bat	*Myotis lesueuri*	-	L
Egyptian free-tailed bat	*Tadarida aegyptiaca*	-	L
Cape horseshoe bat	*Rhinolophus capensis*	-	P
ORDER INSECTIVORA			
Dwarf shrew	*Suncus varilla*	-	X_1
*Red musk shrew	*Crocidura flavescens*	-	X_1
Cape golden mole	*Chrysochloris asiatica*	L	X_1
Forest shrew	*Mysorex varius*	-	P
Reddish grey musk shrew	*Crocidura cyanea*	L	P
Hottentot golden mole	*Amblysomus hottentotus*	-	P
Rock elephant shrew	*Elephantulus rupestris*	-	L
ORDER PRIMATES			
Chacma baboon	*Papio ursinus*	-	X_2
ORDER PINNEPEDIA			
Southern elephant seal	*Mirounga leonina*	X_2	-
Cape fur seal	*Arctocephalus pusillus*	L	P
ORDER ARTIODACTYLA			
Common duiker	*Sylvicapra grimmia*	X_2	X_2
Grysbok	*Raphicerus melanotis*	X_2	X_2
Eland	*Taurotragus oryx*	-	X_2
Vaalribbok	*Pelea capreolus*	-	X_2
Klipspringer	*Oreotragus oreotragus*	X_2	X_2
Steenbok	*Raphicerus campestris*	-	L
ORDER HYRACOIDA			
Rock dassie	*Procavia capensis*	X_2	X_2
ORDER TUBULIDENTATA			
*Antbear	*Orycteropus afer*	-	L
ORDER LAGOMORPHA			
Scrub hare	*Lepus saxatilis*	L	L
Cape hare	*Lepus capensis*	-	P
Red rock hare	*Pronolagus rupestris*	X_2	X_2
ORDER RODENTIA			
Cape greater gerbil	*Tatera afra*	-	X_1
Verreaux's rat	*Praomys verreauxi*	-	X_1
*Black & white doormouse	*Graphiurus ocularis*	-	X_1
Vlei rat	*Otomys irroratus*	X_2	X
Bush karoo rat	*Otomys unisulcatus*	-	X

APPENDIX VI: (Cont.)

Common name	Scientific name	Estuary	Catchment area
Grey pygmy climbing mouse	*Dendromus melanotis*	-	X
Kreb's fat mouse	*Steatomys krebsii*	-	X
Hairy-footed gerbil	*Gerbillurus paeba*	-	X
Striped mouse	*Rhabdomys pumilio*	X_2	X
Black house rat	*Rattus rattus* (alien)	L	X
House mouse	*Mus musculus* (alien)	L	X
Pygmy mouse	*Mus minutoides*	-	X
Common hottentot molerat	*Cryptomys hottentotus*	L	X
Grey squirrel	*Sciurus carolinensis* (alien)	-	X
Cape dune-mole rat	*Bathyergus suillus*	-	X_2
Saunder's vlei rat	*Otomys saundersae*	-	L
Laminate vlei rat	*Otomys laminatus*	-	L
*White-tailed rat	*Mystromys albicandatus*	-	P
Brant's climbing mouse	*Dendromus mesomelas*	-	P
Large-eared mouse	*Malacothrix typica*	-	P
Cape spiny mouse	*Acomys subspinosus*	-	P
Namaqua rock mouse	*Aethomys namaquensis*	X_2	X_2
*African water rat	*Dasymus incomtus*	-	P
Brown house rat	*Rattus norvegicus* (alien)	L	P
Cape porcupine	*Hystrix africaeaustralis*	X_2	X_2
Cape mole rat	*Georychus capensis*	L	P

APPENDIX VII: Standing stocks and estimated rates of turnover of various sources of organic material in the Palmiet Estuary. Mean standing stocks are derived from actual measurements whereas total standing stocks and turnover rates have been estimated (Branch and Day, 1984)

Source	Mean standing stock	Total standing stock for estuary kg (dry mass)	Estimated turnover per year kg (dry mass)
Kelp[a]	1,17 g/m^2	270	1 400
Cladophora[a]	132 g/m^2 [f]	30 360	30 360
Detritus[b]	390 g/m^2	89 764	?
Callianassa faeces[a]	84 g/m^2	19 347	>235 000
Particulate organic matter[c]	2,40 g/m^3	715,6	140 000
Phytoplankton[c]	2,7-5,1 mg Chl/m^3	232	? 8 000
Zooplankton[c]	16 mg/m^3	4,78	?
Benthic diatoms[d]	0,305 g Chl/m^2	7 000	348
Organics in sediments[d]	899 g/m^2	206 963	?
Callianassa[e]	9,0 g/m^2	2 070	4 140[g]
Invertebrates other than *Callianassa*[d]	5,7 g/m^2	1 329	4 784[h]

a = measured from surface collections; b = measured from surface collection and top 10 cm of sediment; c = measured from water samples; d = measured in top 10 cm of sediment; e = estimated from number of holes and average mass; f = maximum for the year: taken as being equal to production; g = assuming a production; biomass ratio of 2,0; h = assuming a mean P:B ratio of 3,6.

APPENDIX VIII: Guide to available information.

ESTUARY / RIVERMOUTH / LAGOON: PALMIET

		Guide to available information / Sources of information	Barwell	Bennet	Boucher	Boucher	Branch	Branch and Day	Branch and Day	Branch and Grindley	Broadley	Broadley and Greer	Brooke	Bulpin	Bürman	Byren	CSIR	De Graaf	De Kok and Pretorius	De Villiers **et al**
YEAR (DATE OF INFORMATION)			1988	1981	1978	1982	1981	1980	1984	1979	1983	1969	1984	1980	1970	1984	1980	1981	1981	1964
MANAGEMENT		Historical				*									*					
		Conservation/Utilization						*	*					*	*		*		*	
		Management/Planning						*	*								*		*	
		Legislation																		
		Water						*	*								*		*	
BIOTIC		Food webs/Ecosystems							*											
	Fauna	Mammals																*		
		Birds							*				*							
		Reptiles					*				*	*								
		Amphibians																		
		Fish		*					*											
		Molluscs							*											
		Crustaceans							*							*				
		Other aquatic invertebrates							*							*				
		Terrestrial invertebrates							*											
		Zooplankton							*											
	Flora	Terrestrial vegetation			*															
		Semi-aquatic vegetation							*											
		Aquatic vegetation																		
		Algae							*											
		Phytoplankton							*											
		Microbiology														*				
ABIOTIC	Chemistry	Pollution																		
		Eutrophication																		
		General Chemistry							*											
		Salinity							*											
	Physics	Circulation and mixing	*																	
		Hydrology / Flood regime	*						*								*			
		Oceanography																		
		Climate			*				*								*			
	Geology	Sedimentology							*	*						*				
		Palaeoenvironment																		
		Geology																		*
	Physiography	Morphology							*											
		Dams/Obstructions			*										*					
		Catchment characteristics							*											

APPENDIX VIII: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: PALMIET

Guide to available information

		Sources of information	Du Plessis	Environmental considerations ...	Flint	Fricke and Jensen	Greig and Burdett	Heydorn and Tinley	Huizinga and Smith	Jezewski	King et al	Largier	Largier and Taljaard	Maclean	McLachlan	Midgley and Pitman	Mossop	Nel	Nienaber	Noble and Hemens
		YEAR (DATE OF INFORMATION)	1973	1982	1971	1989	1976	1980	in prep.	1986	1979	1986	1988	1984	1978	1969	1927	1980	1963	1978
MANAGEMENT		Historical	*														*		*	
MANAGEMENT		Conservation/Utilization		*														*		
MANAGEMENT		Management/Planning		*														*		
MANAGEMENT		Legislation																		
MANAGEMENT		Water		*														*		
BIOTIC		Food webs/Ecosystems																		
BIOTIC	Fauna	Mammals																		
BIOTIC	Fauna	Birds												*						
BIOTIC	Fauna	Reptiles					*								*					
BIOTIC	Fauna	Amphibians													*					
BIOTIC	Fauna	Fish																		
BIOTIC	Fauna	Molluscs																		
BIOTIC	Fauna	Crustaceans																		
BIOTIC	Fauna	Other aquatic invertebrates				*														
BIOTIC	Fauna	Terrestrial invertebrates																		
BIOTIC	Fauna	Zooplankton																		
BIOTIC	Flora	Terrestrial vegetation									*									
BIOTIC	Flora	Semi-aquatic vegetation																		
BIOTIC	Flora	Aquatic vegetation																		
BIOTIC	Flora	Algae																		
BIOTIC	Flora	Phytoplankton																		
BIOTIC		Microbiology																		
ABIOTIC	Chemistry	Pollution																*		
ABIOTIC	Chemistry	Eutrophication																		
ABIOTIC	Chemistry	General Chemistry									*							*		
ABIOTIC		Salinity				*						*	*							
ABIOTIC	Physics	Circulation and mixing							*			*	*					*		
ABIOTIC	Physics	Hydrology / Flood regime							*	*	*	*	*			*		*		*
ABIOTIC	Physics	Oceanography																		
ABIOTIC	Physics	Climate																*		
ABIOTIC	Geology	Sedimentology				*												*		
ABIOTIC	Geology	Palaeoenvironment			*															
ABIOTIC	Geology	Geology																*		
ABIOTIC	Physiography	Morphology						*										*		
ABIOTIC	Physiography	Dams/Obstructions																*		
ABIOTIC	Physiography	Catchment characteristics						*								*		*		*

APPENDIX VIII: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: PALMIET

Guide to available information			Passmore and Carruthers	Pitman et al	Poynton	River Flow Data	Rogers	Schultze	Siesser and Dingle	Slingsby	Slingsby	Smith	Smithers	South Africa Dept. Env. Aff.	South Africa Dept. Env. Aff.	Stauth and Lane	Stuart	Stuart et al	Summers et al	Swart
YEAR (DATE OF INFORMATION)			1979	1981	1964	1978	1985	1965	1981	1983	1984	1975	1986	1982	1987	1983	1981	1981	1976	1985
MANAGEMENT		Historical								*										
		Conservation / Utilization								*						*				
		Management / Planning												*		*				
		Legislation								*				*						
		Water														*				
BIOTIC		Food webs / Ecosystems																		
	Fauna	Mammals											*				*	*		
		Birds																	*	
		Reptiles																		
		Amphibians	*		*															
		Fish										*								
		Molluscs																		
		Crustaceans																		
		Other aquatic invertebrates																		
		Terrestrial invertebrates																		
		Zooplankton																		
	Flora	Terrestrial vegetation								*	*									
		Semi-aquatic vegetation																		
		Aquatic vegetation																		
		Algae																		
		Phytoplankton																		
		Microbiology																		
ABIOTIC	Chemistry	Pollution													*					
		Eutrophication																		
		General Chemistry																		
		Salinity																		*
	Physics	Circulation and mixing																		*
		Hydrology / Flood regime				*														
		Oceanography		*																
		Climate		*				*												
	Geology	Sedimentology																		
		Palaeoenvironment					*		*											
		Geology					*													
	Physiography	Morphology								*										
		Dams/Obstructions		*						*				*						
		Catchment characteristics		*																

APPENDIX VIII: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: PALMIET

		Sources of information	Taljaard a	Taljaard b	Taljaard et al	Underhill and Cooper	Van der Merwe	Visser	Wallace et al	Willis	B A Byren (in litt.)	A L de Villiers (in litt.)	J R Grindley (in litt.)	P H Lloyd (in litt.)	S Taljaard (in litt.)
YEAR (DATE OF INFORMATION)			1987	1987	1986	1981	1988	1984	1984	1981					
MANAGE - MENT		Historical													
		Conservation/Utilization													
		Management/Planning													
		Legislation													
		Water													
BIOTIC	Food webs/Ecosystems														
	Fauna	Mammals												*	
		Birds				*							*		
		Reptiles						*				*			
		Amphibians										*			
		Fish							*						
		Molluscs													
		Crustaceans													
		Other aquatic invertebrates													
		Terrestrial invertebrates													
		Zooplankton													
	Flora	Terrestrial vegetation													
		Semi-aquatic vegetation													
		Aquatic vegetation													
		Algae													
		Phytoplankton													
	Microbiology														
ABIOTIC	Chemistry	Pollution													
		Eutrophication													
		General Chemistry	*	*	*						*				*
	Salinity		*	*	*										
	Physics	Circulation and mixing	*	*	*										*
		Hydrology / Flood regime	*	*	*										*
		Oceanography													
		Climate													
	Geology	Sedimentology					*				*				*
		Palaeoenvironment								*					
		Geology													
	Physiography	Morphology	*	*	*		*								
		Dams/Obstructions													
		Catchment characteristics													

Guide to available information

PLATE I:

A series of obstructions on the Palmiet River: the Kogelberg Dam wall (background), a farm road bridge, a drift (causeway) and the Applethwaite gauging weir (foreground). (Photo: ECRU, 86-09-04).

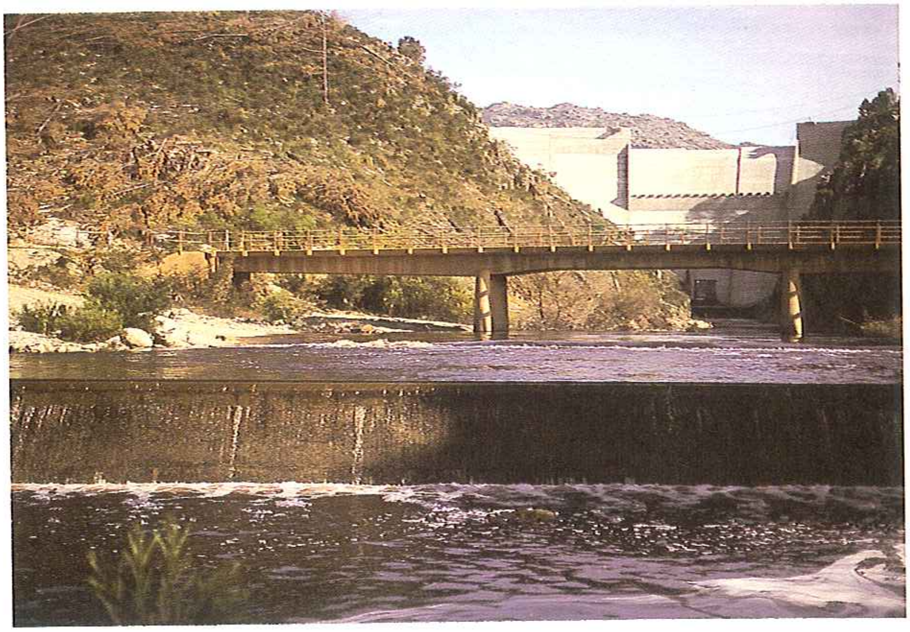


PLATE II:

The lower reaches and mouth of the Palmiet Estuary. Note the brown freshwater plume in the sea. (Photo: ECRU, 86-08-20).

PLATE III:

The Palmiet Estuary mouth showing the rocky promontory on the west bank and the sandspit on the east bank (foreground). Note the sharp barrier between the dark brown river water (right) and the blue green sea-water (left). (Photo: ECRU, 86-08-20).

LIST OF REPORTS PUBLISHED BY ECRU TO DATE

Estuaries of the Cape Part I. Synopsis of the Cape Coast. Natural features, dynamics and utilization. A E F Heydorn and K L Tinley. *CSIR Research Report* 380.

Estuaries of the Cape Part II. Synopses of available information on individual systems.

Report No.	Estuary Name	CSIR Research Report No.
1	*Spoeg	400
2	*Buffels	401
3	*Groen	402
4	*Swartlintjies	403
5	*Holgat	404
6	Bitter	405
7	*Gamtoos	406
8	*Rooiels	407
9	*Uilkraals	408
10	*Kowie	409
11	Hartenbos	410
12	*(Buffels Wes, Elsies, Sir Lowry's Pass) (Steenbras, Buffels Oos)	411
13	*Silvermine	412
14	Sand	413
15	Zeekoe	414
16	Eerste	415
17	Lourens	416
18	*Bot	417
19	*Groot (Wes), Sout	418
20	*Groot Brak	419
21	*Breë	420
22	*Swartvlei	421
23	Swartkops	422
24	Onrus	423
25	*Heuningnes	424
26	Olifants	425
27	Wildevoëlvlei	426
28	Riet/Diep	427
29	Houtbay	428
30	Knysna	429
31	Keurbooms/Bitou and Piesang	430
32	Verlorenvlei	431
33	Krom, Seekoei, Kabeljous	432
34	Duiwenhoks, Kafferkuils (in prep.)	433
35	Boknes, Boesmans, Kariega, Kasuka (in prep.)	434
36	Rufane, Riet, Kleinemondes (in prep.)	435
37	Palmiet	436
38	Gourits	437
39	Quko	438
40	Klein (in prep.)	439
41	Groot Berg (in prep.)	440

* Out of print.