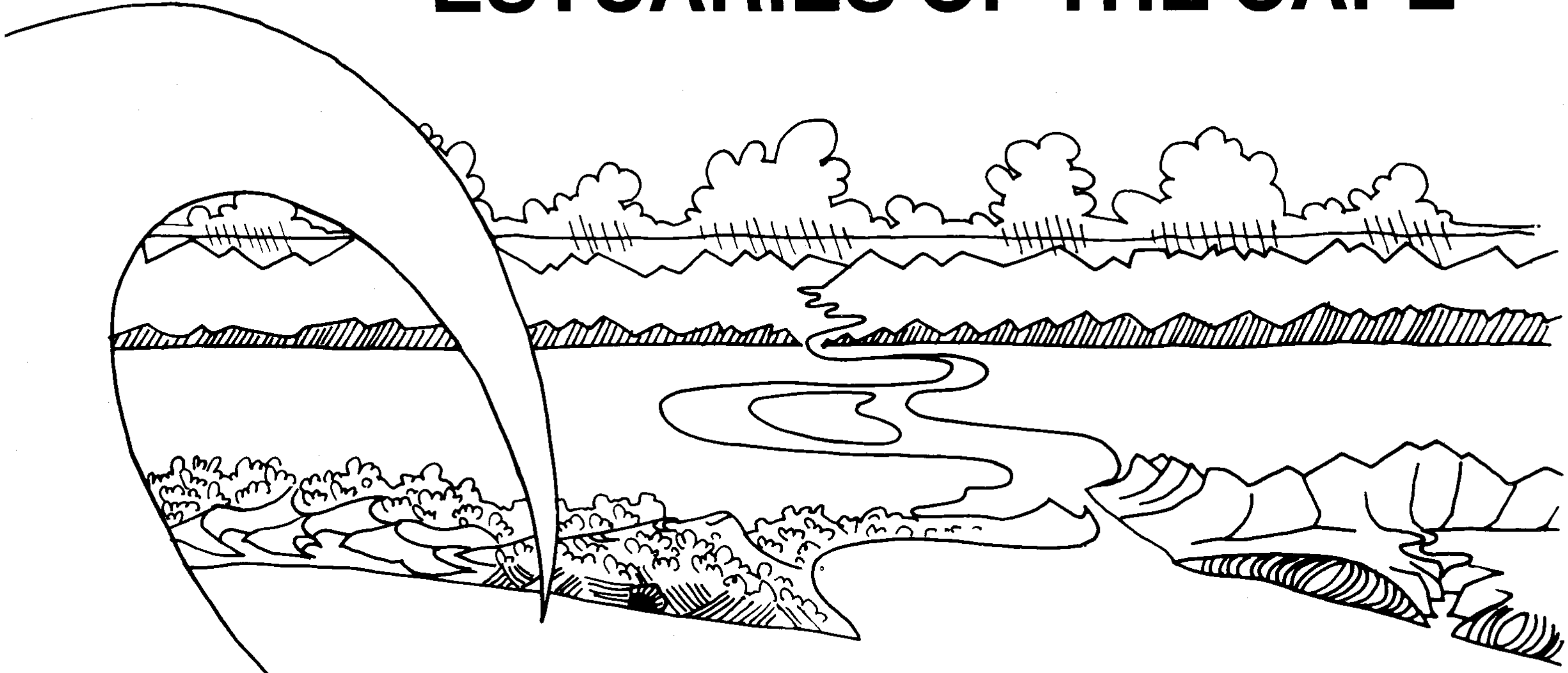
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
ESTUARINE AND COASTAL RESEARCH UNIT–ECRU

ESTUARIES OF THE CAPE



PART II
SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

REPORT NO. 30

KNYSNA (CMS 13)

CSIR RESEARCH REPORT 429

Stellenbosch, South Africa
March 1985

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PART II: SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

EDITORS:
A E F HEYDORN, National Research Institute of Oceanology, CSIR, Stellenbosch
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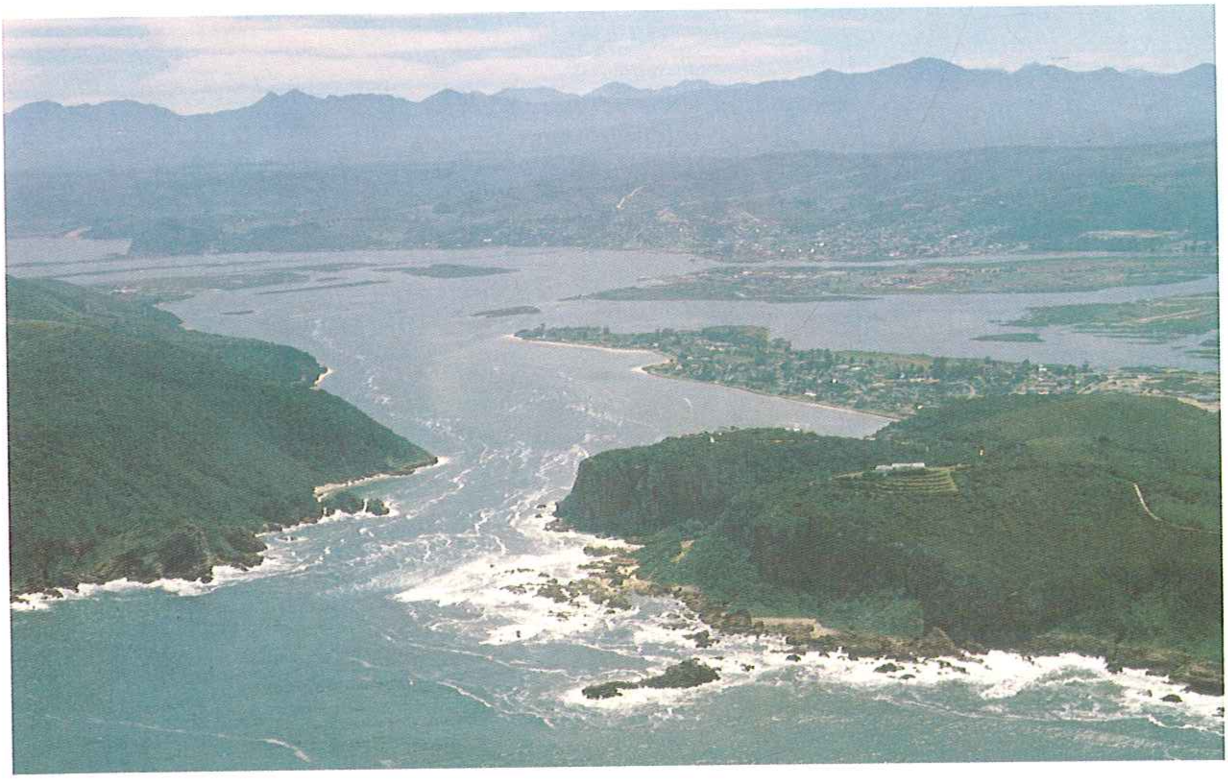

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REPORT NO. 30: KNYSNA (CMS 13)

(CMS 13 – CSIR Estuary Index Number)

BY: J R GRINDLEY

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PREFACE

The Estuarine and Coastal Research Unit (ECRU) was established by the National Research Institute for Oceanology (NRIO) 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 between the Kei and 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 contribute to *ad hoc* investigations carried out by NRIO 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). As the name of the report implies, it 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". In these reports all available information on individual estuaries is summarized and presented in a format similar to that used in a report on Natal estuaries which was published by the Natal Town and Regional Planning Commission in 1978. 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 usually carried out in collaboration with the Botanical Research Institute and frequently with individual scientists who have special interest in the systems concerned. One of these is Prof J R Grindley of the University of Cape Town who is co-editor of the Part II series.

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 Central Government levels can be met within a reasonable period of time.

Finally, the attempt has been made to write the Part II reports in language understandable to the layman. However it has been impossible to avoid technical terms altogether and a glossary explaining these is therefore included in each report.

F P ANDERSON
CHIEF DIRECTOR

National Research Institute for Oceanology, CSIR

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KNYSNA

1. HISTORICAL BACKGROUND

1.1 Synonyms and Derivations

KNYSNA ESTUARY (Day *et al.*, 1952)

KNYSNA LAGOON (Korringa, 1956)

The Knysna system is most commonly referred to as a lagoon but it may also correctly be called an estuary. The upper sections above the National Road Bridge are strictly estuarine and dependant on the flow of the Knysna river, but while the rest of the system is largely a marine embayment, it maintains estuarine characteristics including a predominantly estuarine biota. The name Knysna for the river and the estuary has been used by all sources consulted, but the system has been variously referred to as an Estuary, Lagoon or Embayment Estuary (Noble and Hemens, 1978). The appropriateness of terms for estuaries has been discussed by Day *et al.* (1952), Begg (1978), Grindley and Cooper (1979), Noble and Hemens (1978), Day (1980a), Reddering (1980), Day (1980b) and Day (1981). The origin of the name Knysna is uncertain but a name sounding like Knysna to Europeans was given to the river by the Hottentot term - 'place of wood', 'fern leaves' or simply 'straight down', which might refer to the two steep cliffs known as The Heads, which guard the mouth (Bulpin, 1978).

1.2 Historical Aspects

Before about 1760 the only human inhabitants of the Knysna area were the Khoikhoi (Hottentots) and the San (Bushman) people. They were hunter-gatherers and archaeological remains provide evidence of their way of life. Their depredations on natural systems were probably slight except perhaps for starting fires in order to drive out game. Exploitation of the forests started around 1763 with the coming of white settlers in the form of woodcutters, farmers and hunters. The white settlers had a major impact on the natural ecosystems. They exterminated the blue antelope *Hippotragus leucophaeus* and destroyed local populations of the larger buffalo herds from the forests. Carl Thunberg in 1772 reported on the lush forests in the Knysna area leading to an influx of woodcutters from the Cape where timber supplies were becoming exhausted (MacKay, 1983).

The estuary was one of the country's first harbours. In 1776 the Dutch East India Company established a lumber post at Knysna. A wharf from where timber was shipped to Cape Town was constructed at the site of the present yacht club (Reddering and Esterhuysen, 1984).

The founder of Knysna, George Rex, arrived from the Cape in 1803 and established a home. The land he purchased was situated between Knysna and Plettenberg Bay, a tract of forest and grass-land undulating to the sea, to which he gave the name Springfield. George Rex was widely claimed to have been an illegitimate son of King George III. This legend is discussed by Tapson (1961).

From the Dutch owners of the loan-right places adjacent to the river, Rex acquired Melkhout Kraal, Welbedacht, Sandkraal and De Poort. He retained the name of Melkhout Kraal for the farm on which he made his home, but changed the names of the other three to Eastford, Westford and Portland, respectively.

Eventually, by the purchase of all the land on the western bank of the river, Mr Rex became the owner of the whole Knysna basin. The part situated at the head of the lagoon on the western reaches immediately opposite Melkhout Kraal, he called Belvedere, and to the continuation of it towards the sea he gave the name of Brenton, in honour of the Admiral whose ship on a later visit lay at anchor in Featherbed Bay, (Metlerkamp, 1961). George Rex died in 1839 and his grave is at Old Place as Melkhout Kraal is known today (Tapson, 1961).

From 1817 onwards sailing ships called regularly at Knysna as a seaport. An experiment in ship-building was encouraged by Sir Jahleel Brenton, Commissioner for the Admiralty, who visited Melkhout Kraal. He was convinced that fine timber for the Navy could be obtained and shipped from Knysna. In 1820 the Admiralty established a naval dockyard on the lagoon foreshore where the village of Melville (named in honour of Viscount Melville, Treasurer of the Navy) remained the property of the Admiralty. In 1862 this was transferred to the Colonial Government. One morgen at The Heads was reserved for a pilot's residence and an area at the top of the Eastern Head for a flagstaff (Tapson, 1961).

By 1850 the village of Knysna consisted of about twenty-five homes. Then in 1876 gold was discovered at Ruigtevlei and later at Millwood to the north-west of Knysna, leading to the first gold rush in South Africa. There were over 1 000 permanent residents and five hotels at Millwood in 1890 but mining was shortlived and had collapsed by 1894. Gold mining, and more importantly the timber industry, turned Knysna into a flourishing seaport and about 70 or 80 sailing ships and steamers would enter the harbour in the course of the year. In 1882 Knysna was constituted a Municipality by the Governor, Sir Hercules Robinson, by proclamation No. 217 of 1882 (Kirsten, 1982).

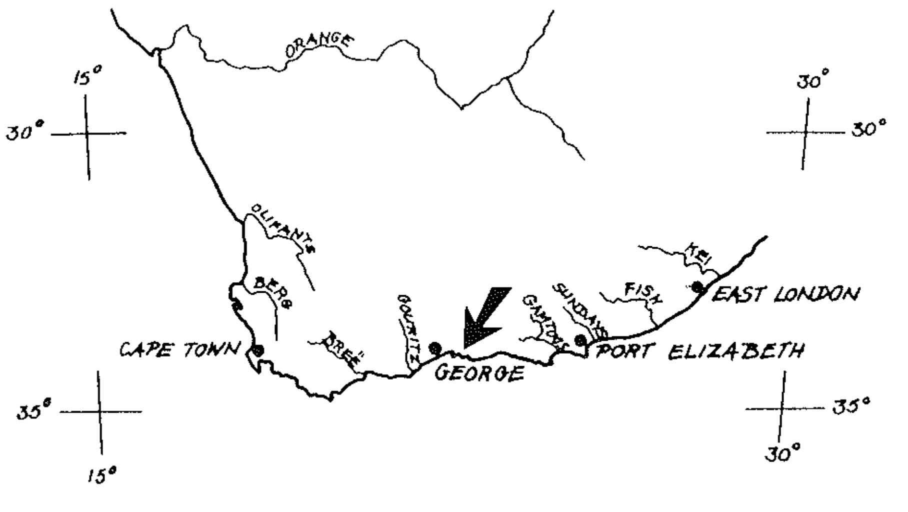
Knysna harbour was deproclaimed in 1959 (Reddering and Esterhuysen, 1984).

1.3 Archaeology

The only archaeological site at Knysna recorded by the South African Museum, is the Cave at the Western Head which included midden deposits (Van Ryssen, pers. comm.). FitzSimons (1928) provided an account of strandloper (sic) excavations about a mile from Knysna where excavations were made for filling material for the railway. This was an unusual burial site of flat open ground with no midden material. Acheulian artifacts have been reported by Mortelmans (1945) and Davies (1971) from reworked gravels of the Keurbooms Formation east of Knysna.

2. LOCATION

Position of mouth 34° 04′ 35″S, 23° 03′ 40″E.



2.1 Accessibility

Situated on National Road N2, 501 km east of Cape Town. Knysna is on the terminus of the branch railway line from George which in turn is on the main line between Cape Town and Port Elizabeth. It is accessible from the sea by moderately large vessels and provides a safe anchorage. Airstrips exist on Thesen's Island and Rex Island and there is a hangar on the latter. The airstrips are somewhat rough and there are no scheduled flights. The Department of Transport considers that neither strip is suitable for development because of the proximity of the hills to the north (Town Engineer, pers. comm.).

2.2 Local Authorities

(a) Knysna municipality. Control within the municipal area including residential areas, recreational facilities, sport facilities, boat-mooring facilities, services.

(b) Outeniqua Divisional Council. Control within the divisional council area including, residential areas, recreational facilities, services, and boat-mooring facilities.

Other controlling authorities include:

Sea Fisheries Institute, Department of Environment Affairs:

Most of the Knysna Lagoon is controlled in terms of the Sea Fisheries Act No. 58 of 1973. However, in terms of Provincial Proclamation No. 357 of 1972 that portion of the Knysna River situated upstream of the old Wagon Bridge up to an imaginary line between the beacons PA 100 on the left bank and PA 101 on the right bank is controlled by the Cape Provincial Department of Nature and Environmental Conservation. In this area referrred to as area 18 no person may use a fyke-net or bait trek net or a boat propelled by an engine of more than 8,9 kilowatts (unless specially permitted).

Cape Provincial Administration: various Provincial Ordinances. Control urban development, marine development, nature conservation above HWM and water area above National Road bridge. (There is a small overlap of responsibility here as the Sea Fisheries control extends to the old wagon bridge) (Geldenhuys, 1979).

Department of Constitutional Development and Planning: The Minister of Constitutional Development and Planning is responsible for the Knysna-Wilderness-Plettenberg Bay Guide Plan. The cardinal implications of this Guide Plan in terms of section 6A of the Physical Planning Act (Act 88 of 1967) relate to changes in the use of land. After a Guide Plan has been approved the Administrator concerned shall submit plans for this area to the Minister for his approval (Guide Plan Annexure B). The area concerned is defined by a full boundary description in Annexure A of the Guide Plan.

3. ABIOTIC CHARACTERISTICS

3.1 River Catchment

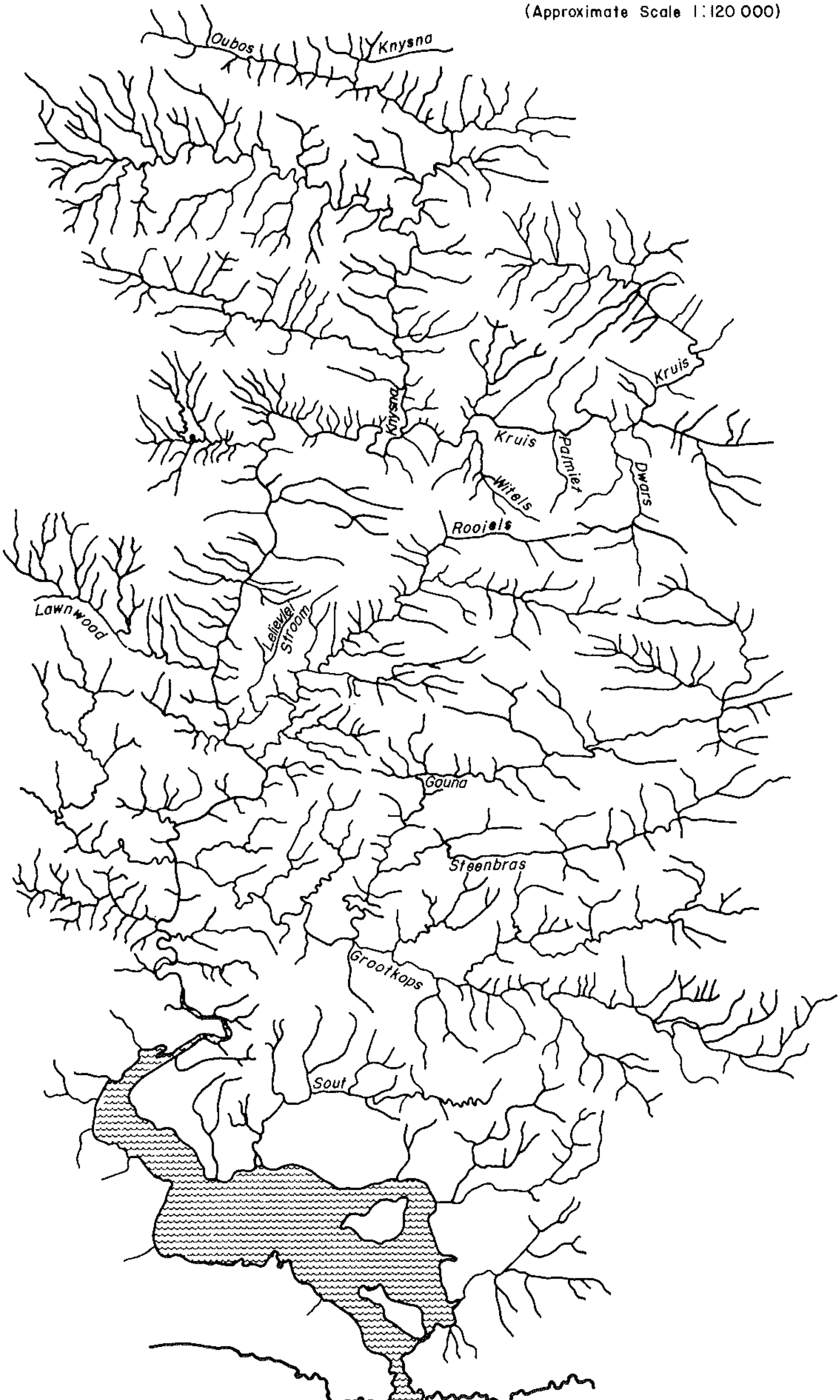
Area

Knysna River

337 km^2 (Ninham Shand, 1980) 362 km^2 (Zwamborn, 1980)
335 km^2 (the late P Haw, U.C.T., pers. comm.) 525 km^2 (Pitman *et al.*, 1981).
315 km2 (Reddering and Esterhuysen, 1984)

FIG. 1: Tributaries of the Knysna River.

(Approximate Scale 1:120 000)



Knysna Lagoon basin

About 250 square miles (400 km^2) (Day *et al.*, 1952)
214 060 ha (Department of Planning, 1970)
362 km^2 (140 square miles)(Proposed Braamekraal Marina, 1974)
526 km^2 (Noble and Hemens, 1978) 526 km^2 (Day, 1981)
525 km^2 for catchment K052 for Knysna Lagoon basin (Pitman *et al.*, 1981). About 100 km^2 of catchment K052 actually drains directly towards the sea.

River length

64 km (measured from Knysna Heads).
About 40 miles (64 km) (Day *et al.*, 1952).
59 km (J R Grindley from 1:50 000 map 3423 AA).

Tributaries

Anti-clockwise from the mouth of the Knysna River the tributaries are: Swartkops, Steenbras, Gouna, Rooiels, Lelievlei, Witels, Palmiet, Dwars, Kruis, Oubos and Lawnwood. The Gouna weir (K5M01) and Laerstreepbos weir (K5M02) measure sub-catchments. In addition the following streams enter Knysna Lagoon directly independently of the Knysna River. Anti-clockwise from the mouth: Hornlee stream, Hunters Home stream, Ouplaas stream, Salt river, Eastford stream, Westford stream and Brenton stream.

3.1.1 Climate and Run-off

Knysna has a warm climate and the average annual rainfall for the period 1936 to 1949 was 922 mm. Figures of seasonal and annual fluctuations in rainfall are published (Day *et al.*, 1952). Extensive reports on the climate of the area are included in the report on the Knysna Wilderness Lakes complex (Department of Planning, 1970) and further information appears in the Knysna-Wilderness-Plettenberg Bay Guide Plan (Department of Constitutional Development and Planning, 1983). The mean annual rainfall ranges from 700 mm at the coast to 1 161 mm (at Buffelsnek Stn 30/265). The pattern of rainfall distribution is shown by the mean annual isohyets based on all available data (Figure 2). Average monthly precipitation is given in Figure 3. The average yearly temperature for Knysna is 16,9°C (Mean maxima January 25°C, Mean maxima July 18,8°C, Department of Planning, 1970). The climate of the area is also described by Tyson (1971) who gives a table of rainfall for various stations including 722 mm for Knysna. The Knysna River rises in the Outeniqua Mountains where the rainfall exceeds 1 000 mm. As most of the catchment has natural vegetation, erosion is minimal (Day, 1981).

Mean annual run-off

110 x 16^6 m^3 (Noble and Hemens, 1978). 133 x 10^6 m^3 (Pitman *et al.*, 1981). 70 x 10^6 m^3 (Ninham Shand, 1980).

Flow

The river flow is usually not strong (Day *et al.*, 1952). In October 1974 flow velocity just above the drift at Charlesford was 0,5 m^3/s calculated on the basis of measurements at different positions across the river using an OTT current meter (Knysna Lagoon Model, 1976). Le Roi Le Riche and Hey (1947) described the current strength and river condition as excellent.

The Knysna River catchment area is Drainage Region 1050 (DWA code) (Zietsman and Schutte, 1980). The only hydrological gauging stations in the catchment area,

FIG. 2: Mean annual isohyets based on all available daily data since 1900.

(After Hughes and Görgens, 1981)

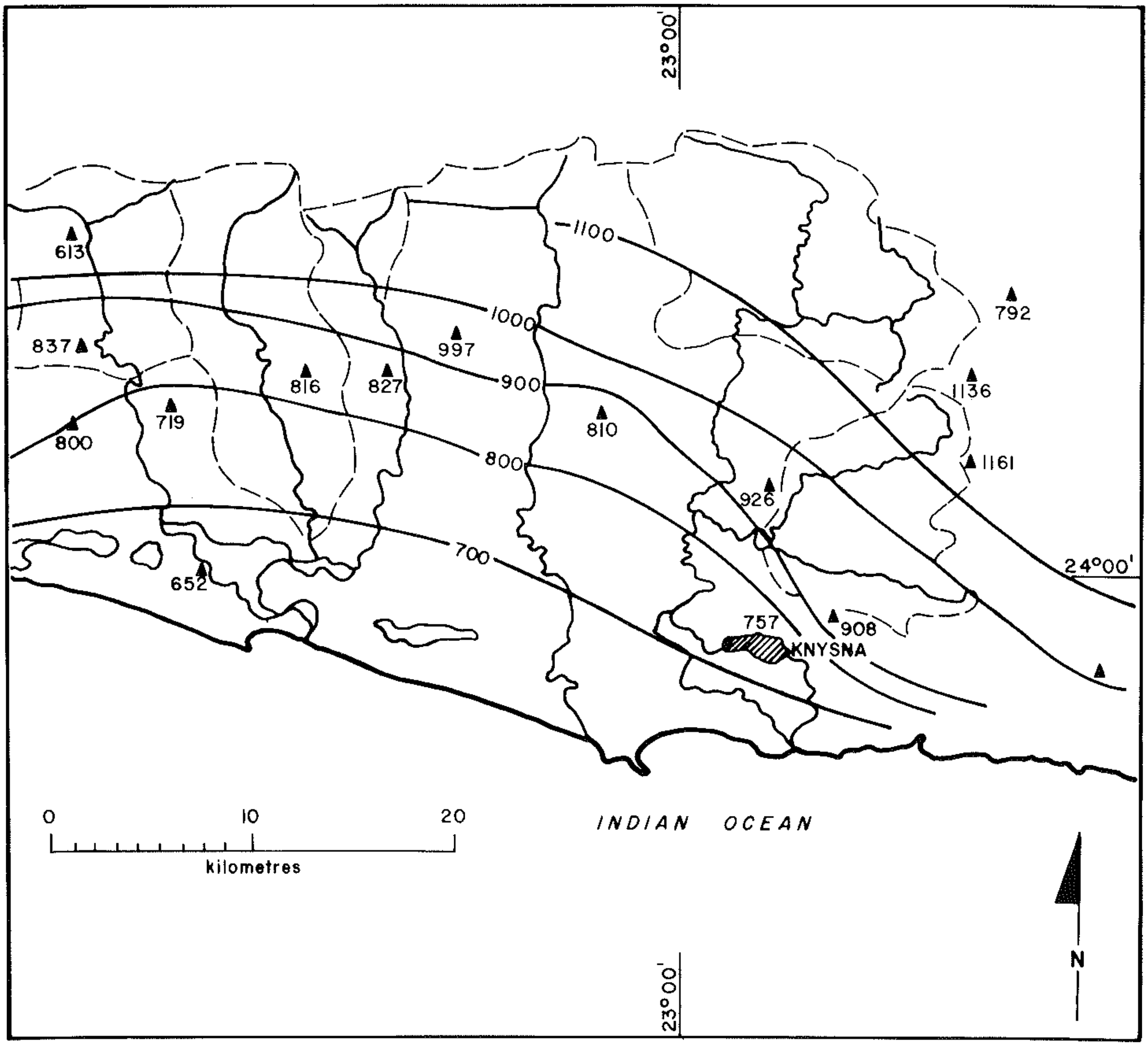
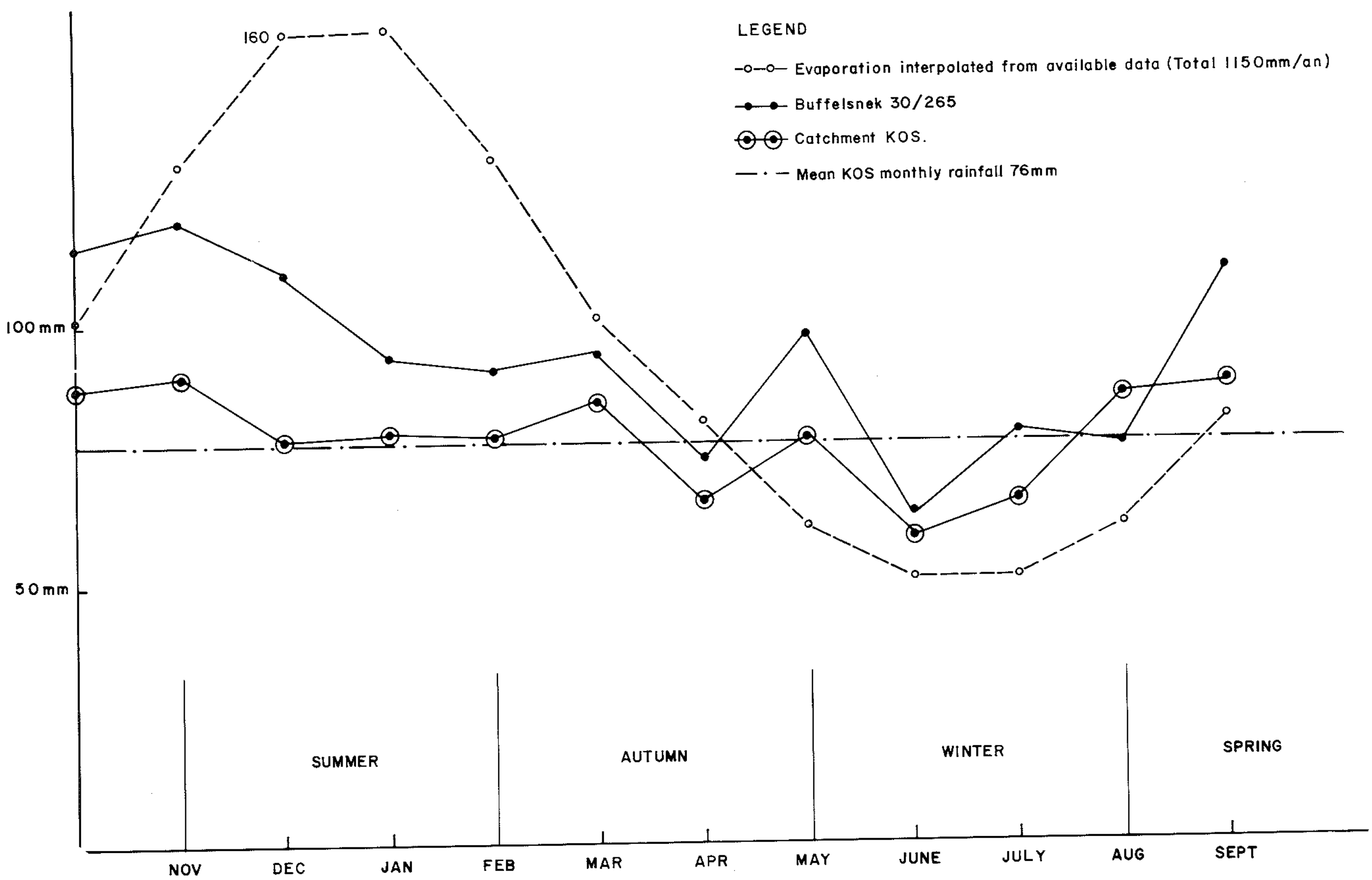


FIG. 3: Rainfall distribution for whole Knysna catchment KOS and Buffelsnek station 30/265.



is a continuous recorder at a causeway on the Gouna river in Concordia Plantation (Station K5M01, opened 16.11.1959, Catchment 91 km^2, 33° 59,50'S 23° 02,50'E) and a gauging weir on the Knysna River at Laer Streepbos (Station K5M02, opened 1.8.1961, Catchment 133 km^2, 33° 53,50'S 23° 01,75'E). River flow data for the period up to September 1960 is given in Monthly flow records of gauging stations Vol. II (1968):136. River flow data for the period October 1960 to September 1970 is given in River Flow Data (1978):326. More recent data are available from the Department of Water Affairs. Information on abnormal flow patterns affecting Knysna Lagoon are included in Section 3.1.6.

3.1.2 Geology, Geomorphology and Soils

The catchment of the Knysna River lies within the Cape Fold Belt with its long faults and folds that strike east-west. These old features provided a framework for the Mesozoic and Cenozoic fabric. Knysna is a true drowned valley, more or less silted up (Krige, 1927). The geology of the Knysna catchment is described by Toerien (1979). Tyson (1971), Butzer and Helgren (1972) and Helgren and Butzer (1977) provide accounts of the geomorphology and soils of this area. Dingle *et al.* (1983) discuss the Mesozoic and Tertiary geology of the area. Notes on the general geology of the coastal area are included in the Knysna-Wilderness-Plettenberg Bay Guide Plan (Department of Constitutional Development and Planning, 1983). The geology of the area is shown in Figure 4 derived from the 1:250 000 Geological Series (Map No. 3322 Oudtshoorn Sheet) of the Geological Survey. The sequence of major geological formations involved is indicated in the key to Figure 4.

The oldest rocks in the area (of late Precambrian age) are found south of the Outeniqua Mountains to the west of Knysna. They consist mainly of contorted bands of schist, phyllites and feldspathic quartzites of the Kaaimans Formation. They adjoin outcrops of intrusive gneissic granite further to the west, but these old rocks are not in the Knysna River catchment.

Most of the catchment lies in rocks of the Table Mountain Group, including the Peninsula, Cedarberg, Tchando and Kouga Formations. These rocks are supermature quartz sandstones which constitute the mountain ranges of the Cape Fold Belt and are believed to be mainly of marine origin. Geologists familiar with this area stress that this heavily faulted area is potentially seismically active and point out that this may be important when considering building developments on steep unstable slopes. The Baviaanskloof Formation, the youngest of the Table Mountain Group (TMG) and the overlying Gydo Formation of the Bokkeveld Group, lies beyond the Knysna catchment.

The Brenton Formation on the south-western shore of Knysna Lagoon is partly marine but there are differing opinions of its age. Microfossils from Brenton on the Knysna Lagoon correspond to fossils from the Sundays River Colchester Formation (Du Toit, 1966; Toerien, 1979; Dingle *et al.*, 1983). A detailed account of the Brenton Formation is provided by McLachlan *et al.* (1976). The relationship of the marine clays and sandstones of the Brenton Formation to the Enon Formation on the other side of the lagoon is not clear (Dingle *et al.*, 1983). The probable relationship is indicated in Figure 5.

Deposits that are believed to be Cretaceous or Early Tertiary age appear at Knysna (Miller, 1963; Du Toit, 1966; Butzer and Helgren, 1972; Toerien, 1979). The Enon pebble conglomerates represent torrential deposits in an arid climate under strongly oxidising conditions which give these deposits their characteristic reddish colour. These deposits are part of the Uitenhage Group with the terrestrial Enon conglomerates succeeded upwards by estuarine deposits. The conglomerates consist predominantly of rounded TMG quartzite clasts (fragments of pre-existing rock) set in a sandy matrix which laterally, interfinger with finer sandstones and mudstones.

A sequence of estuarine deposits occur in the Knysna Formation north of the town and contain lignites up to 1,5 m thick (Du Toit, 1966; Thiergart *et al.*, 1963). Plant fossils include *Podocarpus* and *Widdringtonia* and pollens indicate Knysna forest tree species but work by Thiergart *et al.* (1963) on Early Tertiary pollens reveals that the flora differed from that of the modern forest and include a palm.

Tertiary and Quaternary deposits, including fixed dunes and dune rock and colluvial slope deposits (weathered material transported by gravity) produced by sheet-wash are present on gently sloping surfaces away from the river channels. Recent marine terraces occasionally covered by pebbles and gravels occur at various altitudes up to 120 m along the coast (Butzer and Helgren, 1972). A littoral-marine sedimentary suite with a thickness of over 85 m called the Formosa Formation has been defined by Butzer and Helgren (1972). The geomorphic evolution of the southern Cape coast in late Tertiary and Early Pleistocene times included the planation of the 200 m coastal platform and the coeval accumulation of the thick Keurbooms Formation, followed by the regression of the sea to 140 m and the cutting of a planation surface at that level. Further regression of the sea to 120 m and the deposition of the Formosa Formation was followed by the cutting of beach platforms at that level. A further regression to about 100 m led to the development of beach barrier bars at that level with reworked material including land rubble (Butzer and Helgren, 1972).

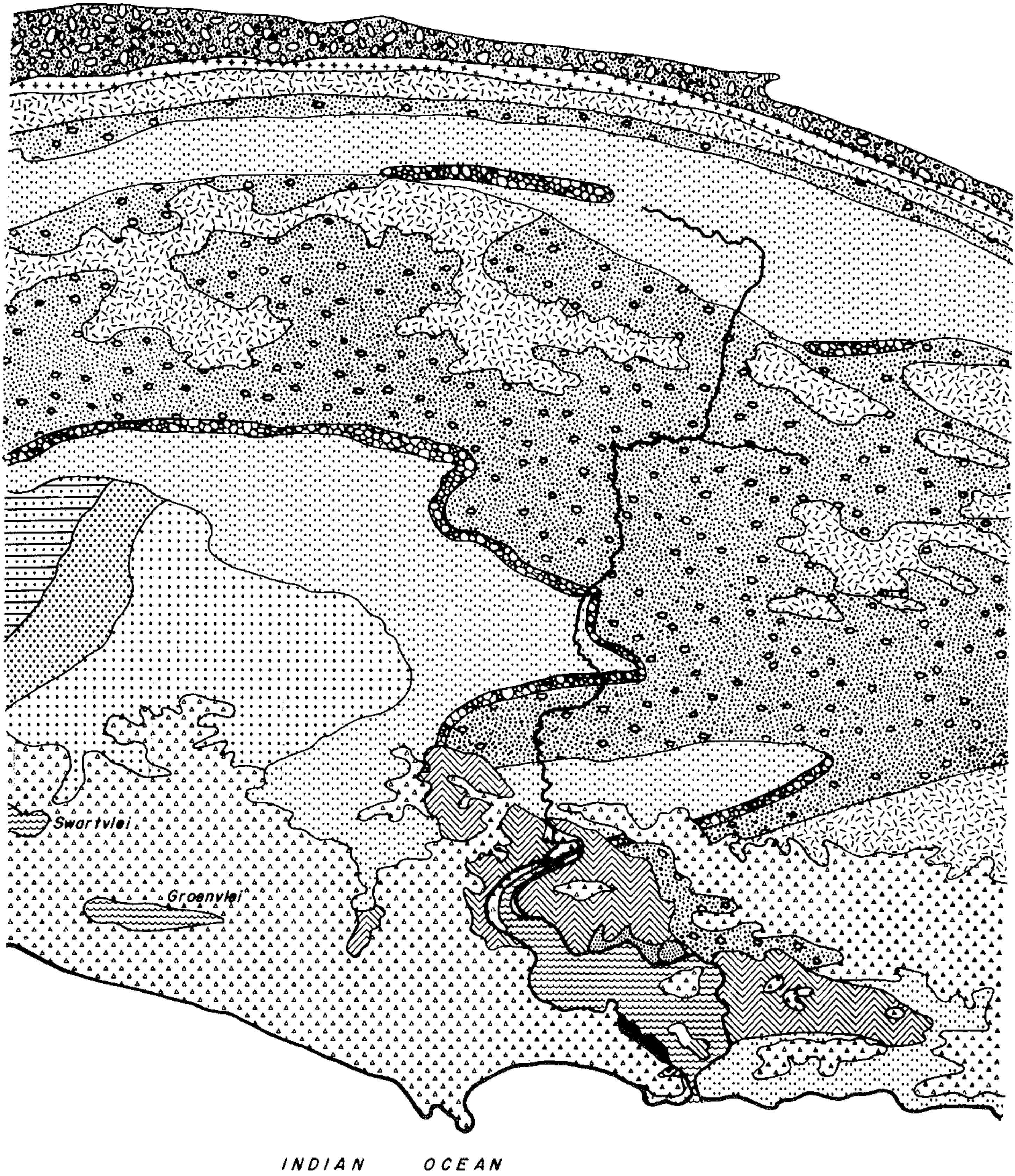
Aeolian sand was deposited on the coastal plain at various stages indicating drier conditions and aeolianites were formed at various sea levels and extend below the present sea level. The Quaternary deposits on land are largely overlain by younger vegetation-bound dunes which reach far inland on the Tertiary marine platform north and west of Knysna (Du Toit, 1966; Toerien, 1979). Aeolian sands younger than the Brenton soil are mainly unconsolidated.

Three ridges with elevations of 70-100 m run parallel to the coast between Brenton-on-Sea and Buffels Bay. The Knysna Heads and the cliffs and hills extending to the east are based on Table Mountain Rocks of the Peninsula Formation of Ordovician age. These rocks are quartz sandstone; medium to coarse grained; quartzitic and massive (Toerien, 1979). The hills west of The Heads and some of the hills north and east of Knysna are fixed dunes with dune rock of Tertiary to Quaternary Age. These areas are partly covered by recent vegetation-covered dunes.

The southern Cape coast preserves a Pleistocene sequence of high littoral terraces at heights ranging from 5 m above sea level to 60 m above present sea level. The oldest post-Formosa shoreline is at 57-63 m at the base of the Brakkloof Formation (Butzer and Helgren, 1972). Next, is the 30 m shoreline which is particularly prominent at Robberg. Distinctive traces of another shoreline at 15-20 m above the present are evident in a wide-spread estuarine terrace along the eastern side of the Knysna Estuary. A shoreline at 4 to 6 m above present including a rich warm water molluscan fauna appears on an erosional bench on the western side of the Knysna estuary (Miller, 1963; Butzer and Helgren, 1972). Carbon 14 dating of shells from this Swartkops horizon indicated an apparent age of 42 850 (±4 150 years) which must be regarded as a minimum value. This suggests that these beaches pertain to the last interglacial approximately 120 000 B.P. (Butzer and Helgren, 1972). Apparently post-glacial beaches younger than the Swartkops horizon and lacking Brenton soils profiles can be identified in the estuaries of this area at 1-2 m above high water.

FIG. 4: Geology of the Knysna area.

(from 1:250000 Geological Map No 3322 Oudtshoorn)



KEY to FIG. 4:

Various Tertiary and Quatenary formations
(Aeolian sand, Alluvial deposits & Aeolionite)

Brenton beds
(Marine clays and sandstone)

Enon and similar younger deposits
(Conglomerate, sandstone, Siltstone, Clay)

Bokkeveld Group

Gydo
(Shale, Siltstone)

Table Mountain Group

Baviaanskloof
(Feldspathic sandstone)

Kouga
(Whitish weathering quartz sandstone)

Tchando
(Brownish weathering sandstone)

Cederberg
(Shale, arenaceous shale)

Peninsula formation
(Whitish weathering quartz sandstone)

Kaaimans Formation

Homitini phyllite
(phyllite, feldspathic grit, quartzite)

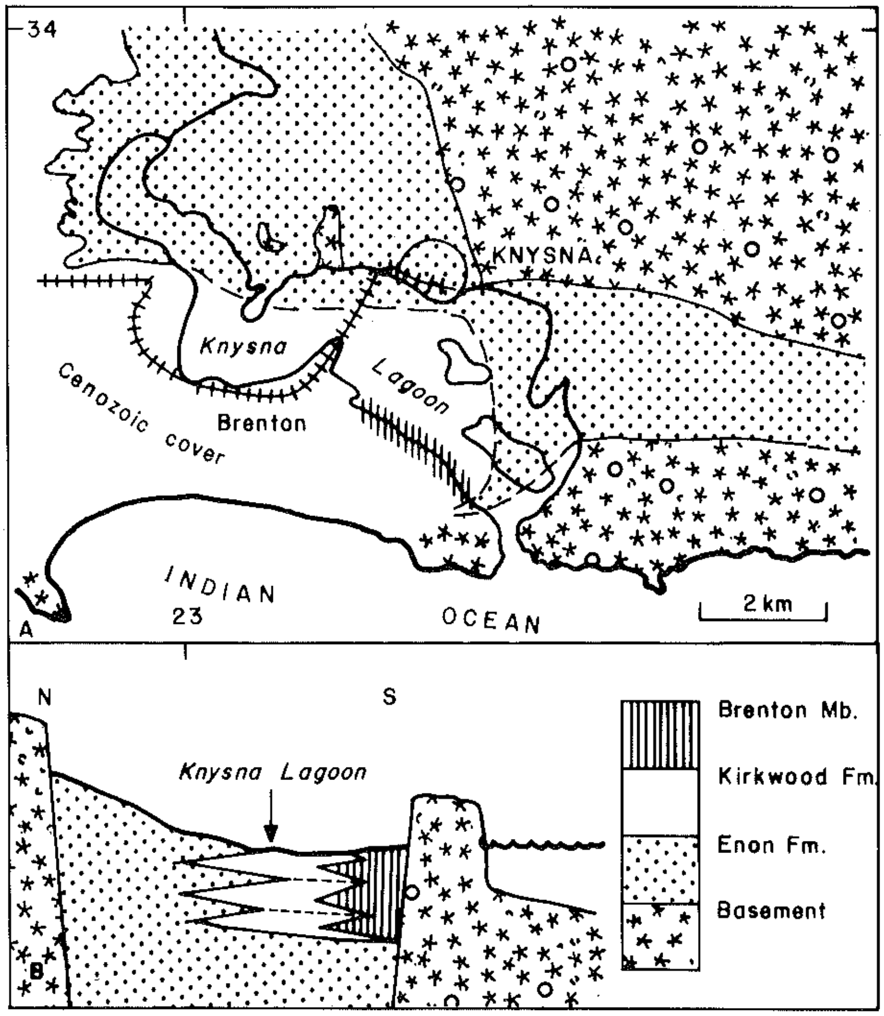
Victoria Bay
(Feldspathic quartzite)

Soetkraal
(Phyllite, schist, hornstone, quartzite)

Water

The town of Knysna and parts of Thesen's Island are formed of colluvial slope deposits of Tertiary to Quaternary Age. Tyson (1971) pointed out that in the Knysna area three categories of soil can be distinguished including youthful shallow azonal soils with imperfectly developed horizons, brown or grey soils forming under present day conditions and palaeosols (relict from the past) including laterites and soils with Terra Rossa affinities. Butzer and Helgren (1972), discuss these palaeosols in greater detail while Helgren and Butzer (1977) use their observations in this area to revise what is meant by the term laterite. The 'Formosa', 'Knysna' and 'Brakkloof' soils and their development are discussed. Soils are generally acid, pH 4,5-5,5, and podsolization is extensive.

FIG. 5: Geological sketch map and geological cross-section (from Dingle, Siesser and Newton, 1983)



Azonal soils are found on all steep slopes, on recent dunes and in wetlands. Except in areas liable to flooding where deep, dark, organic-rich soils develop with annual increments of silt, most azonal soils are shallow, rarely exceeding 30 m in depth and are sandy in texture. The brown and grey soils forming under present day conditions are most extensive on the forested interfluves of the foothills zone.

Lateritic palaeosols cover extensive areas over a wide variety of parent materials including on the 180-240 m surface. Laterites are considered to result from intensive leaching under seasonally warm wet conditions on level surfaces close to the water table. The bleached lower horizon is the product of reduction under saturated conditions and the mottled intermediate layer results from alternative oxidation and reduction under conditions of a fluctuating water table. Often it is only the presence of relict ironstone gravels which indicates the presence of the former soil processes. The deep lateritic soils on the coastal platform are indicative of a long period of weathering and leaching in a stable environment.

Soils of the coastal belt tend to reflect past climates more than that of the present, and consequently they vary considerably. Generally the topsoils are fine-medium sand, having originated from the TMG quartzites and sandstones, or being blown deposits from the littoral zone and coastal embayments. The A-horizons are generally humus rich and of low pH. Effective rooting depth varies widely from very shallow on the mountain midslopes to over a metre on some of the colluvial and plateau soils.

A good deal of deep depositional clays occur on the coastal platform creating strong duplex profiles. Groundwater fluctuations produce widespread gleying. Sandy-loam soils are associated with the granite plutons, as well as the Bokkeveld shales, and the pre-Cape schists and phyllites.

The foothills zone exhibits gravels and sands related to ancient alluvial fans and more recent colluviation. Shallow azonal A-C soils occur on rocky outcrops in the foothills and on the mountain mid-slopes. Sand dunes show recently formed soils, whilst the upper plateau comprises a relic land surface preserved by extensive ferricretes and silcretes. Laterisation is evident in many areas of the coastal Southern Cape.

Podzols are being increasingly recognised and appear to occur especially in the coastal sands, foothill colluvia, and in shallow mountain lithosols. They may also form the upper sequum in some of the deeper planosols of the coastal platform in the east. A-horizons under the indigenous forest tend to be thick and humus-rich whereas the heath-shrubland vegetation roots in shallower soils and a nutritionally poorer environment. Most soils in the area are found to be nutritionally deficient - applications of phosphorus and manganese being necessary for optimum timber growth.

Agriculture in this region was effectively prevented until the discovery of Copper, Molybdenum, and Cobalt trace element deficiencies in the soil, which were subsequently corrected.

In 1886 gold was found in several of the streams in the forestry area known as Goudveld. The town of Millwood north-west of Knysna grew up during the inevitable gold rush, only to be abandoned when none of the discoveries proved to be payable (Bulpin, 1978). The gold field was deproclaimed in 1924 (Reddering and Esterhuysen, 1984). Mining has also been attempted in the Tchando Formation of the Table Mountain Group just above its base (Toerien, 1979). The geology of lagoon sediments and their sources are described by Reddering and Esterhuysen (1984).

3.1.3 Land Ownership and Uses

The coastal belt is up to 30 km wide and often over 200 m high but intersected at intervals by deep, forest-clad ravines formed by rivers which rise in the Outeniquas and flow over a series of rapids to the sea (Day *et al.*, 1952).

Large areas of the land on the coastal plateau are owned by the Directorate of Forestry of the Department of Environment Affairs. There are extensive areas of conserved indigenous forests as well as plantations of conifers and eucalypts for timber production. The Outeniqua Trail, the Bosvark Trail and the Elephant Trail in the Knysna Forests have become popular for recreation. There are also privately-owned plantations in the Knysna area (Parks and Thesen's). There is some agriculture, mostly mixed farming, in the area behind Knysna. The State Forests are demarcated on the 1:50 000 topographic maps of the area.

Tyson (1971) in the South African Geographical Society study of Outeniqualand recognized five categories of land use in this area: settlement areas; agricultural lands; forest areas under management; unexploited indigenous forest and unproductive grassland and open scrub. With the exception of the perimeters of arable land holdings and exotic timber plantations, few boundaries are distinct. In particular it is difficult to distinguish, on the one hand, between indigenous forests managed for timber and those protected in reserves and, on the other, between waste land utilised for grazing and that abandoned after farming. The distribution of land use exhibits a close correlation with the physiographic regions and is clearly influenced by degree of slope (Tyson, 1971). The major land uses are indicated in Figure 10 of that publication.

Hughes and Görgens (1981) record that in the K5M02 catchment of the Knysna River being the 130 km^2 above Gouna, 11,4 percent is indigenous forest, 27,7 percent managed plantations and 58,9 percent natural veld. Recommendations for future land use in the Knysna area were made in Volume IV of *Riviermonde, Strandmere en Vleie* (Department of Planning, 1970). Constraints and guidelines for future land use are now presented in the Knysna-Wilderness-Plettenberg Bay Guide Plan (Department of Constitutional Development and Planning, 1983). Details of existing land uses in that part of the catchment are shown in the Guide Plan.

3.1.4 Obstructions

There are no major roads crossing the Knysna River beyond the lagoon. Forestry road causeways and the concrete causeway above the Charlesford Rapids are overtopped by flood waters and are thus not major obstructions. At Charlesford farm there is a series of shallow stony rapids and sandy pools between bushy banks (Day *et al.*, 1952).

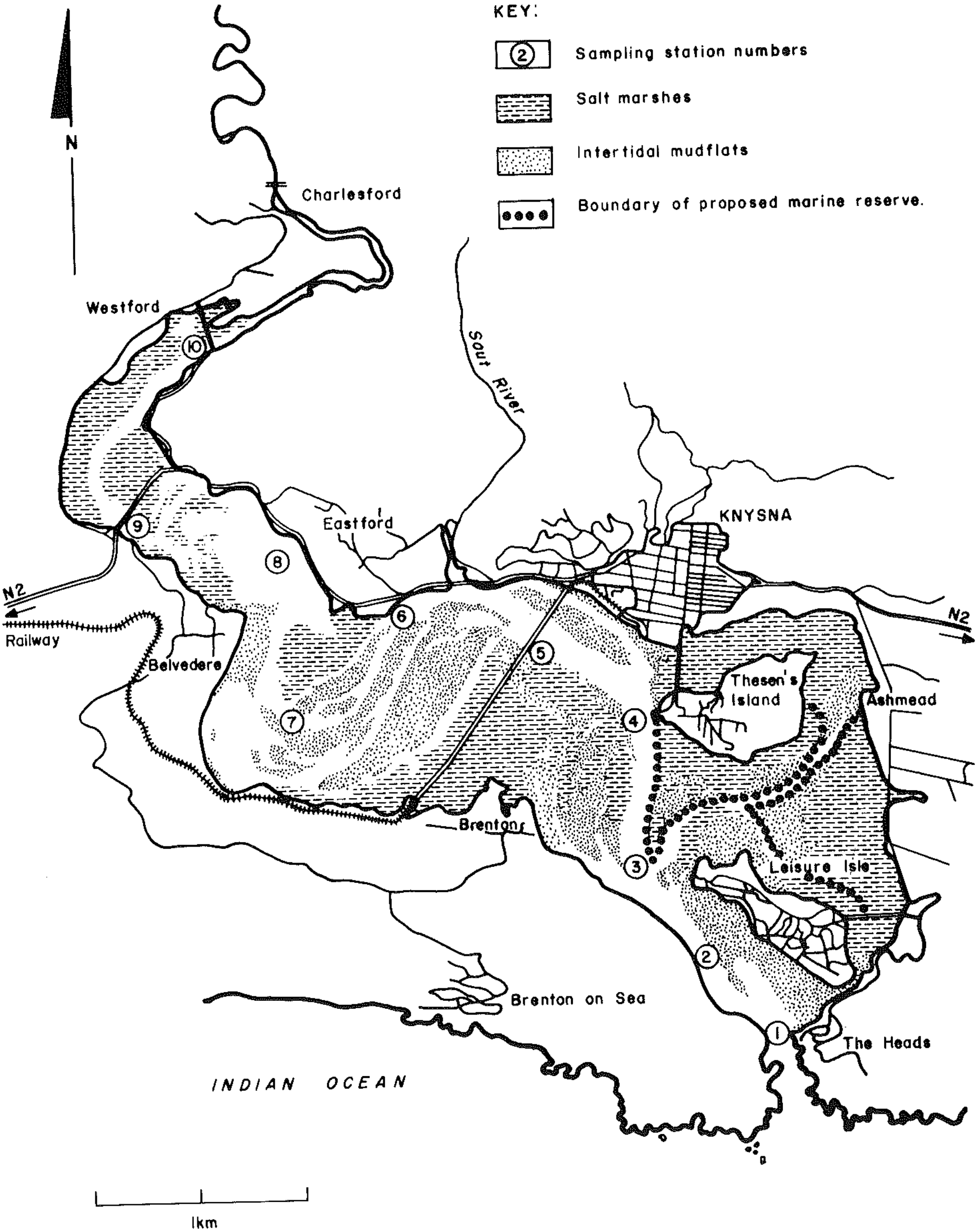
3.1.5 Siltation

Because of the well-vegetated catchment, largely controlled by the Directorate of Forestry, siltation is not a problem in the Knysna river. Quarrying activities above Charlesford Rapids tend to release fine silt but wash water is now routed via a well-vegetated silt trap area to minimize silt input into the lagoon. The Knysna River only becomes muddy during flood conditions. Soutrivier and the small creeks near Ashmead contain mud derived from their Mesozoic catchments (Reddering and Esterhuysen, 1984).

3.1.6 Abnormal Flow Patterns

Once in ten or twelve years the river is said to come down in flood, staining the whole estuary brown and killing much of the bottom-living fauna (Day *et al.*, 1952). This may be very significant in maintaining an estuarine rather than a marine fauna in the lagoon. Korringa (1956) notes that exceptional floods may occasionally occur in the lagoon after heavy rains in the Outeniqua Mountains. Large volumes of brown river water can even be seen entering the sea at ebb-tide. Octopus, *Octopus vulgaris, Sepia* and red-bait, *Pyura stolonifera,* may be killed in the upper lagoon. In November 1950 after prolonged heavy rains salinities at Thesen's wharf fell to 3 parts per thousand at low-tide on the surface and 14 parts per thousand in deeper layers (Korringa, 1956).

FIG. 6: Knysna Lagoon: physico-chemical sampling stations and proposed Marine Reserve boundaries.



In model investigations, the effects of simulated flood flows of 50 m^3/s and 850 m^3/s were studied under various tidal conditions and with modifications to the tidal basin including and excluding a causeway and a marina (Knysna Lagoon Model, 1976). In model studies the river flow resulting in the most correct reproduction of tidal levels was found to be 50 m^3/s (Proposed Braamekraal Marina, 1974). The floods used were a discharge of 640 m^3/s representing a 100-year flood. These floods are based on a catchment area of the river of 362 km^2 using the flood prediction method of Midgley and Pitman, 1969. The model study indicated increases of water level at Red Bridge with a 100-year flood of 0,50 m at HW and 1,78 m at LW. At The Heads the increases were only 0,17 m at HW and 0,5 m at LW (Proposed Braamekraal Marina, 1974). Abnormally high flows occurred in certain years but Hughes and Görgens (1981) note that records for K5M01 and K5M02 are not detailed enough to extract flood peaks. 1967 and 1971 appear to be highest.

Run-off frequency curves (based on daily mean flows) for catchments K5M01 and K5M02 are presented by Hughes and Görgens (1981). This indicates the percentage of time that run-off values presented as mm/day/km^2 are equalled or exceeded. The Gouna river (K5M01) generally has lower coefficients of variation than the others throughout the year as this catchment has lower slopes and less relief than mountain catchments.

The highest flood level during the past 20 years in Knysna Lagoon was MSL + 2,0 m. This was confirmed at three different sites (Pawson, of Van Waart, Pawson and Maree, land surveyors pers. comm.) The highest flood in the lagoon was MSL + 2,0 m in 1916 (Mr Schrecker, Scott and De Waal, consulting engineers, pers. comm.).

3.2 Estuary

3.2.1 Estuary Characteristics

Shape

Knysna Estuary is an S-shaped stretch of water with a channel about twelve miles long (Day *et al.*, 1952); 19 km long (Day, 1981). The tidal reach is about 10 km (Reddering and Esterhuysen, 1984).

There are two islands, Leisure Island (Steenbokeiland) and Thesen's Island (Paardeneiland) now connected by causeways to the mainland. A third low marshy island called Rex Island is now protected by dykes to prevent flooding of the airstrip on it. The area has unfortunately been artificially extended by encroaching on the saltmarshes.

Morphometry of the estuary

(See Figure 6)

Area

Over 3 km wide (Day, 1981).
4 515 acres (= 1 827 ha) (Cape Coastal Survey, 1973).
1,95 x 10^7 m^2 (Reddering and Esterhuysen, 1984).
12 km long and up to 3,2 km wide (Department of Planning, 1970).
19,2 km from Heads to Charlesford (Department of Planning, 1970).
Approximately 18 km^2 (Geldenhuys, 1979).
Approximately 1 350 ha (Underhill *et al.*, 1980).
Water area 1 633 ha (Duvenage, 1983).

Wandering sand banks considerably reduce the usable area bringing it down to approximately 2 500 acres (approximately 1 000 ha) (Cape Coastal Survey, 1973). 21 km^2 Reddering and Esterhuysen (1984).

Bathymetry

The maximum depth of the Knysna Lagoon is 40 feet (Krige, 1927). Below Leisure Island the lagoon narrows and the channel reaches a maximum depth of 51 feet (Day *et al.*, 1952). The bar between The Heads is charted as 13 feet deep (Day *et al.*, 1952). Day's map indicated depths from 4 to 48 feet and these depths were from the Admiralty Chart corrected in 1938 (Day *et al.*, 1952). Day (1981) indicated depths up to 6 m deep but this should be 16 m (15 m, A Genade, Fisheries Development Corporation, pers. comm.). An aerial survey of the lagoon was made in July 1970 and a contour map with 0,5 m vertical interval contours from low water (-0,5 GMSL) to +5,0 GMSL was made. Depth soundings in the lagoon were carried out in February 1971 and combined with the aerial survey. Twelve metres is the greatest depth shown (Figure 2, Proposed Braamekraal Marina, 1984). The average (sic) depth at the mouth is 4,59 m (Department of Planning, 1970).

On 1 October 1974 depth soundings were carried out in The Heads channel. Details of depth contours are given in Figure F1 of Knysna Lagoon Model, 1976. The greatest depth shown is more than 16,0 m below MSL. A survey of the Charlesford Rapids to Charlesford Drift is given in Figure E1 of Knysna Lagoon Model, 1976. This was a schematic plan for modelling purposes and should not be regarded as an accurate survey plan.

Nature of bottom materials

Day *et al.* (1952) described the bottom as follows:

"The substratum changes quite regularly along the length of the estuary in relation to the strength of the currents. As might be expected, the Charlesford Rapids run over pebbles and sand into a string of sandy pools. This condition continues as far down as the Old Drift, where a slight weir is formed by the rocky foundations of the drift. Below this the intertidal banks rapidly change to soft, black, oozy mud. Sand-spits are absent, and rocks only occur where they have been placed by human agencies as at the foundations of the bridge and along the road embankment. None the less it should be noted that a suitable substratum exists for a rock fauna. Dredging proved that the channel bed along this stretch is soft mud. This muddy substratum continues with little change from Westford Bridge down to Belvedere. Here the first banks of muddy sand are found on the sides of the main channels, and soft mud is restricted to the backwaters. At The Point the proportion of sand increases, and the first mid-channel sand-bank is found slightly lower down opposite Salt river. As before, stone is still restricted to the road embankment and the foundations of the rail bridge. Below the rail bridge, the channel bottom and most of the intertidal banks are muddy sand. Clean, loose sands are first found along the sides and on the bed of the main channel at Leisure Isle; the only rocks in this stretch are those built into the foundations of Thesen's Wharf and the causeway to Leisure Isle; the first natural rocky outcrops are below Leisure Isle. At first they alternate with patches of sand but at Fountain Point the whole shore is rocky and sand is limited to tiny coves."

Clean loose sand can be found in the main channel nearly up to Belvedere with dune-like shifting sand patches even in the so-called 'donkey bridjes channel' (A Genade, pers. comm.).

Day *et al.* (1952) noted that recent borings for the new rail bridge failed to find bedrock at 80 feet.

Day *et al.* (1952) presented further details of the main types of substratum describing the bottom materials as rock (Fountain Point), muddy sand (Brenton, Paarden Island, Rail Bridge and The Point), mud (Westford Bridge), sand and rock (Old Drift) and sand and stone (Charlesford Rapids). Grindley (1976a) and Grindley and Eagle (1978) present an analysis of sediments on the east and west side of Thesen's Causeway. The percentage of subsieve particles east of the causeway is 45,8 percent, while it is 18,6 percent west of the causeway. The higher percentage of organic material east of the causeway may be seen by comparing the nitrogen contents 0,12 percent (east) 0,04 percent (west). The figures indicate that the area east of the causeway is accumulating fine sediments with a high organic content. The mud in this area is exceptionally soft and glutinous and very difficult to work in. It is deoxygenated to near the surface. Particle size distribution of the substrate in three zones of the salt marsh near the sewerage outfall and in the area east of Thesen's Causeway are given in Grindley and Eagle (1978). Further details are given in Grindley and Snow (1983).

Substrate analyses at a series of diving survey stations are given in Grindley (1976a). Sediment from the lagoon has a mean grain size of 200 micron while material from the sea is coarser with grain size in the order of 1 000 micron and larger (Proposed Braamekraal Marina, 1974).

3.2.2 Mouth Dynamics and Tidal Currents

Knysna Lagoon has a deep rocky mouth and the estuary channel passes between two massive headlands into the sea (Day *et al.*, 1952). As a result of the constant wave action and the depth of the rocky channel between The Heads, the formation of a sand-bar is not possible (Department of Planning, 1970). The mean low-tide cross-sectional flow area is 1 737 m^2 (Proposed Braamekraal Marina, 1974). The mouth is 229,5 m wide (Department of Planning, 1970). Wave action is strong on the rocky shores at the mouth, but as one passes in between The Heads the seas rapidly diminish, and at Fountain Point the swells are very gentle. Further upstream, where the estuary widens into a lagoon, they disappear entirely. On the other hand this broad stretch of water is easily affected by winds blowing up and down the river. The waves so formed rapidly stir up the soft mud in the shallows but have no obvious effect on the fauna (Day *et al.*, 1952).

Tides

The tidal rise and fall at the mouth at spring-tide is about six feet (1,8 m) and the mouth is sufficiently wide and deep to allow this tidal range to be maintained right up to Westford Bridge, where a maximum range of 6 feet 4 inches was recorded on 13 April 1949. At the Old Drift a mile further upstream the range had fallen to 5 feet 7 inches, but above this there is a steep rise over a series of rapids. At Charlesford above the rapids the tidal rise was only one foot (Day *et al.*, 1952).

The time of high water at the Knysna Heads is 37 minutes after high water in Table Bay. South African tide tables (1980) issued by the Hydrographer, South African Navy give the following tidal levels for Knysna:

Lowest Astronomical Tide	0,11
Mean Low Water Spring	0,36
Mean Low Water Neaps	0,90
Mean Level (as defined)	1,16
Mean High Water Neaps	1,43
Mean High Water Spring	1,96
Highest Astronomical Tide	2,29

These levels are referred to the Chart Datum which is -0,900 m relative to the Land Levelling Datum in the Republic of South Africa. The Land Levelling Datum is the datum adopted by the Director General of Surveys for the Precise Levelling of the Republic of South Africa. It is commonly called Mean Sea Level by most land surveyors. In an erratum slip to the 1980 tide tables it is noted that the height of chart datum relative to land levelling datum in South Africa used up to 1978 for Knysna is -0,625 m (South African tide tables, 1980).

"The spring-tide range on the coast is 1,8 m and although there is some reduction in the broad lagoon, the maximum of 1,8 persists at Belvedere and even increases slightly at the Charlesford Rapids which mark the head of the estuary" (Day, 1981).

Tide recorders were established at Thesen's Jetty, on a tripod in The Point area and at Red Bridge. The data obtained from these recorders over nine months together with data from the Navy tide recorder at The Heads were used for model studies. Maximum and minimum values of tide level recordings are given in Proposed Braamekraal Marina (1974).

Tide levels in metres to geodetic mean sea level(GMSL)

The Heads	Thesen's Island	Channel behind Thesen's Island	Red Bridge
+1,03-0,56	+1,04-0,56	+1,05-0,28	+1,18-0,18

(From Proposed Braamekraal Marina, 1974)

Tidal Currents

Current measurements have been made at The Heads, at the Railway Bridge and at the National Road Bridge. The measurements were done at various depths on each cross-section throughout a full tidal cycle (Proposed Braamekraal Marina, 1974.)

Average tidal flow through The Heads is approximately 1 000 m^3/s and the maximum tidal flow about 2 000 m^3/s. Mean flow velocities at The Heads are 0,9 m/s, 0,0-1,6 m/s. The tidal prism is 19,0 x 10^6 m^3 (Proposed Braamekraal Marina, 1974).

Tidal currents were measured at The Heads on four days in October 1974 with velocities measured 2 m below the surface and 2 m above the bottom in all cases. The current measurements are shown in Knysna Lagoon Model Investigation (1976). Current velocities of up to 1,27 m/s are recorded in this series. Tidal flow patterns in the lagoon were obtained by tracking drogue floats in October 1974 by means of range finders at two stations. Data on flow patterns are presented as figures in Knysna Lagoon Model Investigation (1976). In addition to these diagrams and those in Proposed Braamekraal Marina (1974) black and white photographs and ciné films of the flow patterns in the Knysna model at NRIO were made in 1976 by members of the staff of NRIO.

Observations of tidal currents are described and records of the movement of drift bottles are presented by Korringa (1956). He showed that ocean water penetrates well beyond the railway bridge on a flood tide. The tidal current velocity exceeded one nautical mile per hour.

Tidal lag

The delay in the low-tide from the mouth to the Old Drift is approximately two hours at spring-tide. The delay in the high-tide is very much less. This means that, as usual, the ebb is of considerably longer duration than the flow (Day *et al.,* 1952).

Records of tidal lag at the following positions were:

	The Heads	Thesen's Island	Channel behind Thesen's Island	Red Bridge
HW	0h00	0h15	0h35	0h25
LW	0h00	0h00	1h55	1h30

(Proposed Braamekraal Marina, 1974)

Surf Zone Currents

The mouth of the estuary opens between two impressive rocky headlands (see Frontispiece and Plate I) which prevent longshore drift of sand so that marine sediments do not enter the lagoon (Day, 1981). Chunnett (1965) concludes that there has been little or no influx of sediments over the last 100 years.

3.2.3 Land Ownership/Uses

The Knysna-Wilderness-Plettenberg Bay Guide Plan (Department of Constitutional Development and Planning, 1983), depicts existing land use around the estuary. Most of the land around the estuary is privately owned. Urban residential areas demarcated for White, Coloured and Black use are indicated. A white rural residential area is indicated at Eastford but the other rural residential areas at Belvedere, Brenton-on-Lake and on the eastern Head, etc. are not shown. The industrial areas of Thesen's Island and the new industrial area are demarcated. A number of quarries and gravel pits for construction materials are indicated. Recreational resorts including hotels, caravan parks and camp sites are indicated.

Knysna Lagoon is very beautiful and a popular tourist resort with excellent yachting and angling facilities (Day, 1981). Bulpin (1978) lists angling, canoeing, diving, camping and caravanning, swimming and walking, as activities. Estuary uses that have been observed include yachting, water-skiing, motor-boating, rowing, bathing, angling, oyster cultivation, bird-watching. This diversity of activities leads to problems, as certain activities clash, so that the same area cannot be used for them all. It is therefore necessary to plan some zonation of activities such as was proposed by the Department of Nature and Environmental Conservation of the Cape Provincial Administration (Department of Planning, 1970).

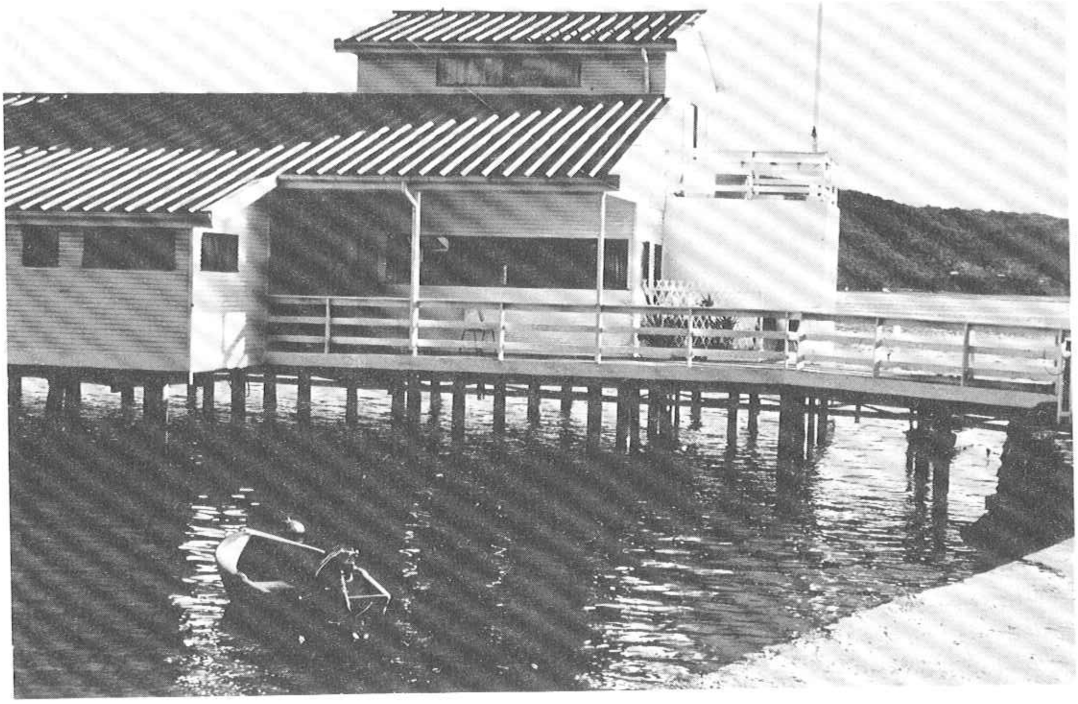


FIG. 7: Knysna Yacht Club built on pilings adjoining the major anchorage in the main channel of the lagoon. (Photo: J R Grindley, September 1984).

Other uses of the estuary include:

(i) Fisheries Development Corporation - experimental and commercial cultivation of oysters. Approximately 30 ha water area reserved for the purposes in the area west of the railway bridge. At present 6 ha are utilised by the two companies accommodated (A Genade, pers. comm.).

The areas of the lagoon allocated for oyster cultivation in the Guide Plan have been deemed adequate for the future so no further areas are being reserved for this purpose. Thus the question of the relative importance of recreational water use and commercial oyster production is not an immediate issue. However, the great problems that have been encountered in other countries, e.g. south east Australia in regard to conflicts between recreational water use and oyster production need to be considered.

(ii) Knysna Yacht Club - mooring facilities and other services for its members, approximately 150 boats of various types presently registered with the club.

(iii) Aircraft Landing Strip, situated near Ashmead, on Rex Island.

(iv) Railway line over the estuary.

(v) Timber industry, situated on Thesen's Island. (Geldenhuys, 1979).

FIG. 8: The middle reaches of Knysna Lagoon at Belvedere. Two areas of racks for Oyster culture can be seen adjoining the main channel. (Photo: J R Grindley, July 1983).

FIG. 9: Thesen's Island connected by Thesen's causeway to the town of Knysna. The causeway is now pierced by culverts to allow tidal flow. (Photo: J R Grindley, December 1982).

A feasibility investigation for a Knysna pleasure-boat harbour has been carried out (NRIO and VISKOR, 1980) but this has not yet been developed. The necessity for this is realised by private enterprise and the local authority (A Genade, pers. comm.). However, a small residential marina is presently under construction at Ashmead.

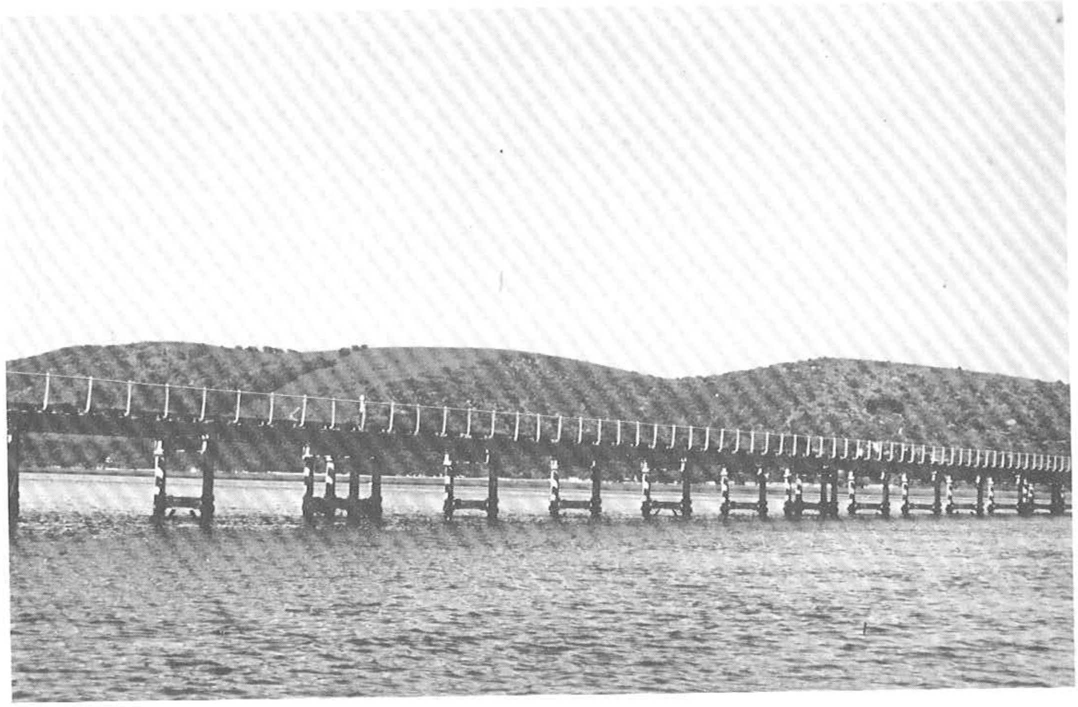


FIG 10: The steel railway bridge across Knysna Lagoon includes a 1 700 m long causeway across the marshes on the west bank and a 700 m long causeway along the east bank. (Photo: J R Grindley, September 1984).

3.2.4 Obstructions

Old Drift: Below Charlesford there was once a stony ford or drift. This has long since been abandoned but rubble remains; now known as the Old Drift (Day *et al.*, 1952).

Red Bridge: This old steel girder road bridge which is now abandoned is referred to as Westford Road Bridge by Day *et al.*, (1952). A causeway 400 m long crosses the marshes on the west bank.

National Road Bridge: This concrete bridge carrying the N2 across the estuary has a 750 m long causeway on the east bank and a 100 m long causeway on the west bank. The bridge has five spans with vertical clearances of between 5,6 and 7,1 m above MSL (that is, minimum of 3,6 m above maximum flood level) (Schrecker, Scott and De Waal, pers. comm.).

Railway Bridge: This steel bridge has a 1 700 m long causeway across the marshes on the west bank and a 700 m long causeway along the west bank.

All three bridges have solid embankments which restrict tidal flow and encourage the deposition of sediments (Day, 1981).

Thesen's Causeway: The road from Thesen's wharf crosses a narrow side channel (Day *et al.*, 1952). A rubble causeway approximately 420 m long carrying a narrow tarred road links Long Street to Thesen's Island. There are no culverts but on the flood-tide water flows through the rubble to the west while on an ebb-tide the flow is reversed. It has been recommended that part of this causeway be replaced by a bridge (Grindley and Eagle, 1978). Grindley and Snow (1983) recommended that large box culverts be introduced and this is being done (installed May 1984, A Genade, pers. comm.). A proposal for a small boat harbour adjoining this causeway on the west side has been prepared (Research Group for Ocean Engineering of Stellenbosch University, 1980).

Leisure Island Causeway: This is a long narrow causeway across saltmarshes (Day, *et al.*, 1952). This 500 m long causeway had nine culvert pipes under it to allow a limited tidal flow beneath the road. Concern was expressed about the adequacy of the flow because of excessive sand accumulation in the 'Green Hole' area (Town Engineer, pers. comm.). To improve the flow large culverts were introduced in the early 1980s but such measures are inadequate for the removal of the accumulated sand. The film record of the NRIO physical model indicates a net inflow into the Green Hole area over a tidal cycle.

Woodbourne Causeway: The concrete main road to the Eastern Head traverses a causeway which cuts off a permanently flooded area to the east of the road. This area which receives drainage from the Hornlee stream and from the golf course has variable intermediate salinities. This shallow sheltered area with varying range of salinity is perhaps the most important bird habitat adjoining Knysna Lagoon and requires conservation. The range of salinities varies with the season but in March 1984 salinities of 0, 2, 22 and 25 parts per thousand were recorded (P Haw, pers. comm.). A new culvert has increased tidal exchange to this area.

Moored boats can be an obstruction in the open waters of the lagoon so the following guide-lines were proposed in the Guide Plan:

1. No boats should be allowed to moor in the main flow channels.

2. Specific localities for mooring and landing sites should be properly designated.

The Guide Plan did not identify such localities but the following areas, shown in Figure 6 of this report, were considered for this purpose:

(a) An area from The Point to Thesen's Island landward of the main channel.

(b) The north-eastern corner of the lagoon, adjoining the caravan camp site.

(c) The existing anchorage at The Heads.

(d) The existing anchorages around Leisure Island.

(e) The southern end of Leisure Island for riparian owners only.

(f) The area opposite Brenton-on-Lake.

(g) The area south-east of Brenton-on-Lake.

(h) The existing areas at Belvedere seaward of the bridge.

(i) The two areas north of The Point.

The development of a harbour for small craft with appropriate facilities in the planned locality adjoining Thesen's Causeway is desirable.

FIG. 11: Knysna Lagoon from the air with The Heads and Leisure Island in the background. Large numbers of boats can be seen moored in the main channel near the Yacht Club. Thesen's Island Quay lies beyond the moored boats. (Photo: ECRU).

3.2.5 Siltation

It is widely recognized that the siltation of certain areas in Knysna Lagoon is related to obstructions caused by structures. Day *et al.*, (1952) pointed out that since the completion of the rail bridge, the silting in the upper reaches had been accelerated. The depths of the upper channels are less than those marked on the Admiralty chart drawn in 1924 and the mud banks are more extensive.

Siltation in the Knysna Lagoon is discussed by Reddering (University of Port Elizabeth) in an unpublished manuscript and is now the subject of further research by him. The question of siltation is reviewed in the Department of Planning report on Knysna largely with reference to the earlier report by Chunnett (Department of Planning, 1970). Chunnett (1965) published the results of a CSIR study of siltation problems in the Knysna Lagoon. Opinions expressed on the siltation problems in the Knysna Lagoon had varied greatly. People felt that since the construction of the rail bridge silting had been accelerated and that depths are less than marked on earlier charts but others felt that the lagoon had not changed at all. After the CSIR study it was possible to define the siltation problem with certainty and to consider the specific problems which arose from it.

Chunnett states that all evidence for at least 100 years, if not 150 years, points to virtual absence of siltation from external sources, either from the river or from the sea. The essential siltation problem in the Knysna Lagoon is one of internal movement of material. In the majority of situations this movement has no fixed direction, merely fluctuating about a mean location and, at the worst, causing only some temporary inconvenience by cutting off or changing the position, width or depth of a channel. In a few specific areas, however, there is a tendency for permanent accumulation of material to occur and this can be attributed to the erection of artificial structures. The rate of accretion is very slow and the areas affected are mainly in the immediate vicinity of the structures. While structures have had little, if any, overall effect on tidal flow in the estuary, they have undoubtedly resulted in substantial local accumulations of sediment. Two sorts of effects can be classified:

(a) Stabilisation of channels and banks by bridge structures.

(b) Creation of dead water areas by causeways and approach embankments.

Among the specific problem areas were the Paarden (Thesen's) Island Causeway. The survey indicated that the causeway had resulted in the original channel being filled in completely in the vicinity of the causeway and to have narrowed and probably to have become shallower over much of the reach north of the island. The cause lies in the creation of dead or back water conditions, with suspended material being carried into the area by tides but not all taken out again on the ebb. The nature of these sediments is discussed in the section on bottom materials (Section 3.2.1).

The situation at the causeway to Leisure Island has certain similarities with that at Paarden Island. However, the dead water area created is far less extensive due to the culverts (which although small in size and placed rather high in relation to the requirements for free flow of the tides) do nevertheless permit some degree of flow and consequent flushing of the channel. The fact that the causeway is situated considerably nearer the original null point of the tides probably limited local sediment accumulation but apparently favoured the accumulation of marine sand south of Leisure Island. The area to the east of The Heads road (where it is built on an embankment) tends to be stagnant but attracts remarkable numbers of birds.

In general Chunnett (1965) concluded that the investigation of Knysna Lagoon had shown that siltation from external sources is virtually absent but that, where artificial structures have been erected, the internal movement of sediment is interfered with and has created problems in specific areas. There has been little change in the main tidal flow conditions. Chunnett's suggestion that areas already partly silted up be reclaimed by filling, to permit township development is clearly invalid in the light of modern ecological knowledge. The importance to the overall ecology of the estuary of these intertidal areas was not recognized at that time.

3.2.6 Physico-chemical Characteristics

pH

Day *et al.* (1952) recorded pH values of 8,1 to 8,5 in the upper reaches and 6,6 to 8,2 in the lower reaches of the estuary.

Values are high up to the Rail Bridge but at the Old Drift the pH drops to 7,4 and at the Charlesford Rapids the pH is 6,6 to 6,8. Above the rapids the fresh water is reported to be acid (Day *et al.*, 1952). Grindley and Eagle (1978) give pH values ranging from 7,8 (at the sewage outfall) to 8,8. Grindley and Snow (1983) give values ranging from 7,6 (at the sewage outfall) to 8,9. Le Roi Le Riche and Hey (1947) give the pH of the river as 5.

Temperature

Maximum and minimum temperatures recorded at the top of the estuary are 12,2°C (winter), 29,0°C (summer); the range at the mouth is 13,9°C (winter) to 21,8°C (summer) (Day *et al.*, 1952).

The mean annual sea temperature at Knysna Heads is 16,8°C, the maximum monthly temperature 19,9°C (February) and the minimum 13,5°C (August) (Isaac, 1937). Day (1981)reports a sea temperature range of 15,3° to 22,4°C .

During periods of cold upwelling sea temperatures may be very low (e.g. 11,0°C on 1950.01.05.) According to local residents these low temperatures are due to a very cold inshore current which appears after a south-east onshore wind has been blowing for a few days (Day *et al.*, 1952).

The sea has an average summer temperature of about 18°C, but a large body of water of only 10°C may suddenly appear. Such upwelling is fairly common at Knysna (Smith, 1949). When summer upwelling along the coast causes a sudden drop to 11,5°C at the mouth marine fish are either numbed or take refuge in the estuary (Day *et al.*, 1981). Spotted grunter are especially affected (A Genade, pers. comm.).

Cold water occasionally enters the lagoon in summer (January and February). The temperature of inshore water drops abruptly to values much lower than those recorded in winter. Cold water of between 10°C and 15°C then penetrates far into the lagoon with the flood-tide. As a rule the phenomenon lasts for a few days only and appears after a strong south-easterly wind has been blowing for several days (Korringa, 1956). This can last for weeks if the wind persists. A westerly or south-westerly wind causes a reversal of the situation. A minimum temperature of 9°C has been recorded by the Fisheries Development Corporation (A Genade, pers. comm.).

Transparency

A feature of the estuary is the clarity of the water (Day *et al.*, 1952). The river water is clear, though peat-stained, and the estuary itself is sufficiently clear for a Secchi disc to be visible at a depth of six feet in the mixing basin (Day, 1967). Once in ten or twelve years the river is said to flood, staining the whole estuary brown (Day *et al.*, 1952). Although the river water is peat-stained and turbidity increases in the upper reaches of the estuary, the water in the lagoon is sufficiently clear for the bottom to be visible at a depth of 2-3 m (Day, 1981). River water is dark red-brown and the Secchi disc was visible at a depth of 4 feet (1,22 m) (Le Roi Le Riche and Hey, 1947).

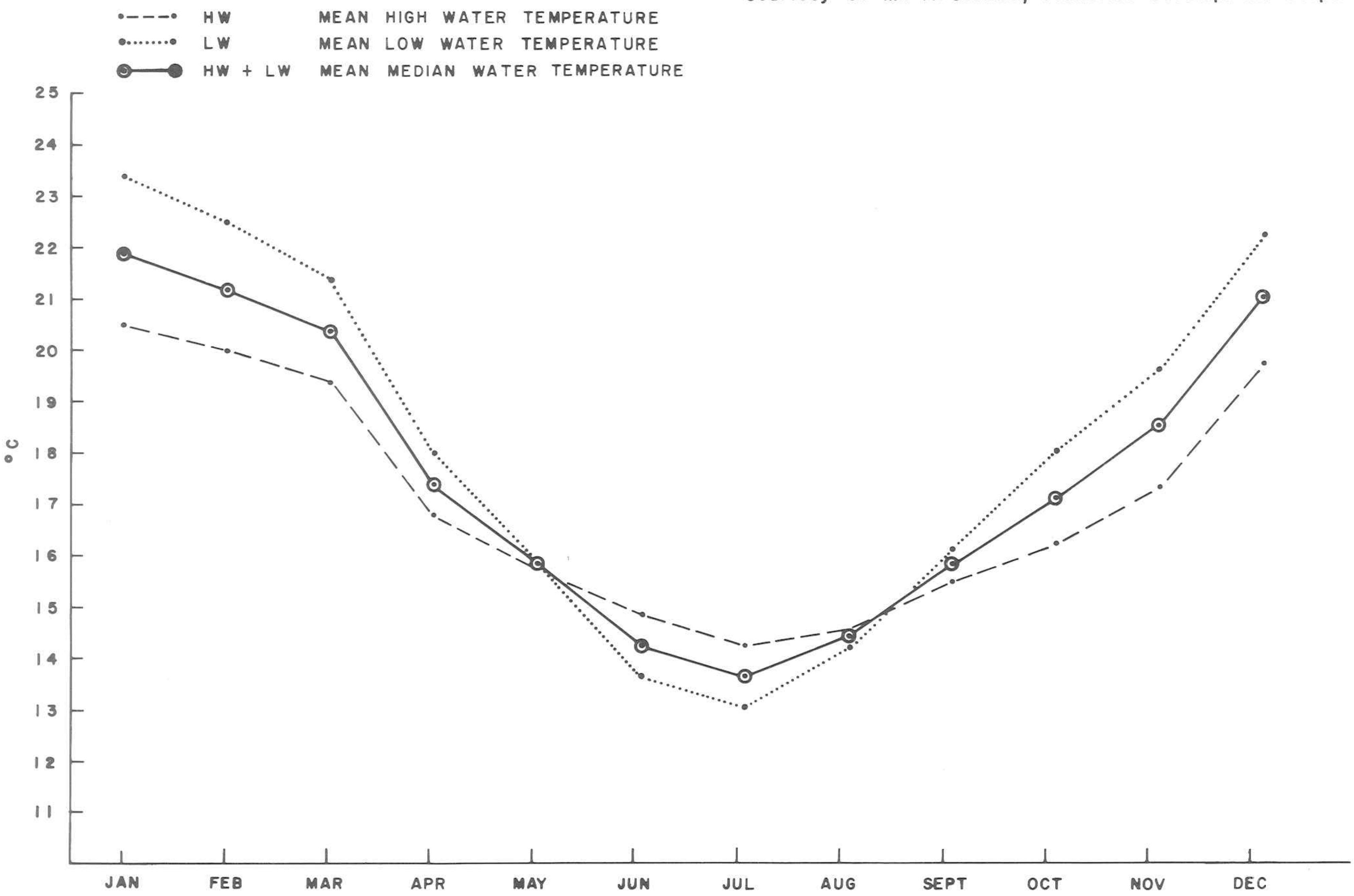
Salinity

Salinities range from fresh water (0 parts per thousand) to slightly hypersaline conditions (36,7 parts per thousand) (Day *et al.*, 1952).

	Day *et al.*, 1952	Day, 1967	Day, 1981	Grindley & Eagle 1978 Grindley & Snow, 1983
Mouth	34,2-36,7	34,5-35,7		35,29-35,36
Lagoon	22,0-36,1	29,1-34,8	30-35	29,60-37,50
Middle reaches	04,5-28,6	18,9-26,5		23,48-30,40
Head	00,3-20,4	01,1-14,0	0,4-5,1	-

FIG. 12: Seasonal Variations of Water temperature at Thesen's Island Quay.

Courtesy of Mr. A. Genade, Fisheries Development Corporation.



Salinities decrease gradually from the mouth (approximately 35,3 parts per thousand) falling below 30 parts per thousand near Westford Bridge and to 0 parts per thousand above Charlesford Rapids. Tables of values presented by Day indicate considerable seasonal variation (Day *et al.*, 1952).

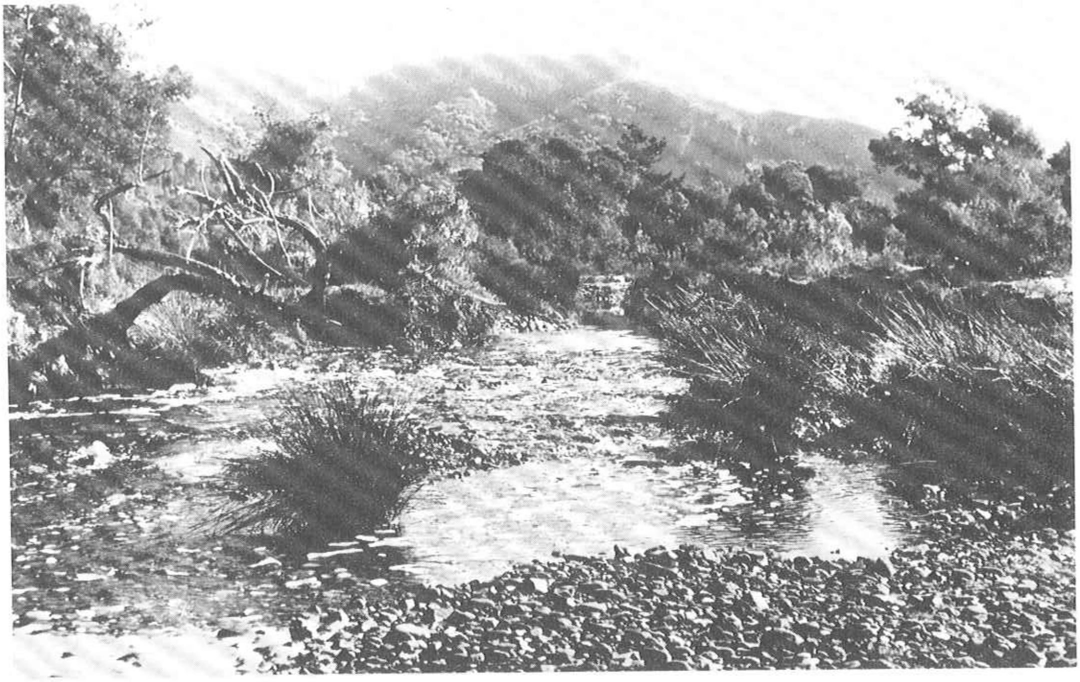


FIG. 13: Charlesford Rapids where the Knysna River enters the estuary. (Photo: J R Grindley, August 1983).

Salinity Stratification

At the Charlesford Rapids which mark the head of the estuary the water is well-stratified with salinities of about 0,4 parts per thousand on the surface and 5,1 parts per thousand on the bottom. However, the river discharge is minute compared with the tidal exchange at the mouth so that the isohalines rapidly become steeper. Salinities of 30-35 parts per thousand are recorded at the Rail Bridge and seaward of this point there is little indication of vertical gradients and normally no salinity gradient at the mouth.

Dissolved Oxygen

Oxygen concentrations are high except near the sewage outfall in the narrow channel north of Thesen's Island (Day, 1981). Values ranging from 3,77 to 6,76 ml/l are reported by Grindley and Snow (1983).

In the Knysna River (Le Roi Le Riche and Hey, 1947) recorded 6 parts per million. Fluctuations in dissolved oxygen concentrations from under 6 µg/g to 10 µg/g have been recorded near the Thesen's Island Causeway (Grindley and Eagle, 1978). 4,0 to 15,0 parts per million were recorded in this area by Grindley and Snow (1983).

Nutrients

In the channel north of Thesen's Island nutrient concentrations are high and the marginal vegetation is lush as might be expected. Elsewhere in the estuary nitrate nitrogen decreases from about 2,5 µg of NO_3-N/l at the mouth to about

0,9 μg per l in the upper reaches during the winter. In the autumn the reverse is true and the nitrate concentration increases through the same range from the mouth to the upper reaches. The reason for these seasonal changes requires further investigation. Dissolved phosphate values remain more or less constant at about 1,2 μg atoms PO_4-P/l throughout the estuary. This may be due to the buffering action of the bottom sediments (Day, 1981).

Korringa (1956) made studies of the fertility of the Knysna Lagoon including phosphate analyses. Phosphate values as P mg. atom/m^3 ranged from 0,17 in the river above Charlesford Rapids to 0,35-0,39 at Belvedere, 0,70 at Thesen's Jetty, 0,31-0,70 at Knysna Heads and 0,23-0,39 2,5 miles offshore (mg atom/m^3 = μg atom/l).

Tables 1 and 2 detailing chemical observations in Knysna Lagoon made by the Sea Fisheries Branch in August 1976 and April 1977 are taken from Grindley and Eagle (1978). The positions of the sampling stations are indicated in Figure 6.

3.2.7 Pollution

Some forms of pollution which are a potential hazard to estuaries are listed by Chmelik *et al.* (1975), including trace metals, hydrocarbons, pesticides, organic wastes including sewage and solid wastes and other pollutants.

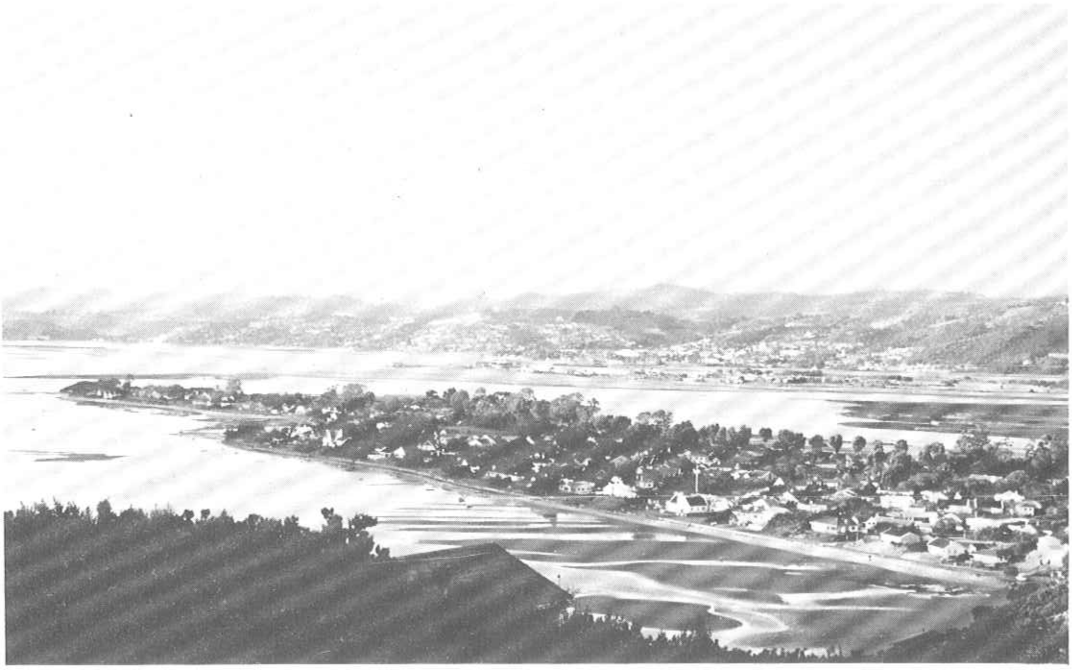


FIG 14: Residential development on Leisure Island as seen from the Eastern Head. Thesen's Island and the town of Knysna behind it lie in the background. (Photo: J R Grindley, February 1983).

Sewage

Model tests on sewage pollution levels in Knysna Lagoon based on introducing a fluorescein solution into the NRIO model at the sewage outlet position have been carried out. Samples were taken at various positions in the model and the concentration of pollutant determined. (Proposed Braamekraal Marina, 1974, Knysna Lagoon Model, 1976).

TABLE 1: CHEMICAL OBSERVATIONS IN KNYSNA LAGOON MADE BY THE SEA FISHERIES BRANCH ON 18TH AUGUST 1976

Station (no.)	Depth (m)	Salinity (o/oo)	Oxygen (ml/L)	Nitrate (mg at/m^3)	Phosphate (mg at/m^3)	Total-P (mg at/m^3)	Silica (mg at/m^3)	Chlorophyll -A (mg at/m^3)	Chlorophyll -B (mg at/m^3)	Chlorophyll -C (mg at/m^3)	Total (mg/m^3)	COD (mg/L)	OA (mg/L)
1	0	35,32	5,72	2,4	1,2	1,2	5,2	1,2	1,1	2,9	5,2	5,8	0,5
	5	35,36	5,98	2,5	1,1	1,2	5,2					8,3	0,6
	10	35,32	6,05	2,4	1,2	1,2	3,7					8,1	0,6
	14	35,32	6,02	2,6	1,2	1,2	6,0					5,6	0,6
2	0	35,00	5,62	2,1	1,2	1,2	6,0	1,3	0,5	2,2	4,0	7,7	0,7
	5	35,06	5,73	2,5	1,2	1,2	6,7					7,7	0,9
	10	35,14	5,80	2,2	1,2	1,2	6,0					6,9	0,6
	16	35,12	5,83	2,1	1,2	1,2	6,0					8,1	0,7
3	0	34,44	5,63	2,2	1,2	1,2	7,5	1,2	0,6	1,8	3,6	15,4	1,0
	5	34,75	5,98	2,4	1,2	1,2	6,0					8,7	1,2
4	0	34,20	5,56	1,9	1,0	1,2	7,5	2,0	0,8	3,0	5,8	7,1	0,9
	5	34,27	5,57	1,8	1,1	1,2	9,0					7,5	1,0
	8	34,25	5,61	2,0	1,2	1,2	9,0					6,9	1,1
5	0	32,41	5,92	1,3	1,1	1,3	13,4	3,5	0,8	3,0	7,3	14,8	1,4
	4	32,89	5,92	1,5	1,1	1,3	11,2					9,6	1,3
6	0	32,68	5,62	1,5	1,1	1,2	13,4	2,8	0,0	0,6	3,4	11,0	-
	5	32,82	5,60	1,4	1,2	1,2	13,4					11,6	1,6
7	0	32,17	5,62	1,3	1,0	1,1	12,7	1,8	0,0	0,6	2,4	11,2	-
8	0	29,60	5,68	0,9	1,1	1,2	14,9	3,4	0,6	1,1	5,1	14,6	2,4
	5	31,43	5,45	0,6	1,2	1,2	14,2					11,0	2,6
9	0	27,19	5,43	0,9	0,9	0,9	17,2	2,3	1,1	4,6	8,0	17,9	4,1
	5	30,40	5,33	1,1	1,2	-	14,2					14,5	2,8
10	0	26,64	4,75	0,8	0,6	0,7	23,9	2,4	1,4	5,3	9,1	19,5	6,6

TABLE 2: CHEMICAL OBSERVATIONS IN KNYSNA LAGOON MADE BY THE SEA FISHERIES BRANCH ON 19TH APRIL 1977

Station (no.)	Depth (m)	Salinity ($^{o}/oo$)	Oxygen (ml/L)	Nitrate (mg at/m^3)	Silica (mg at/m^3)	Ammonia (mg at/m^3)	Phosphate (mg at/m^3)	Chlorophyll -A (mg at/m^3)	Chlorophyll -B (mg at/m^3)	Chlorophyll -C (mg at/m^3)	Total (mg/m^3)	COD (mg/L)	OA (mg/L)
1	0	35,29	5,60	1,1	4,2	12,4	1,3	1,1	0,2	0,0	1,3	4,9	0,8
	5	35,30	5,31	1,0	4,2	3,7	1,2					4,8	
	10	35,29	5,55	0,8	4,2	13,3	1,1					4,8	
2	0	35,29	5,22	1,0	4,2	4,6	1,1	1,2	0,0	0,0	1,2	1,3	0,8
	5	35,29	6,76	1,1	4,2	4,6	1,1					5,8	0,7
	10	35,28	6,39	0,1	4,2	6,6	1,2					4,8	0,8
	13	35,28	5,66	1,1	4,2	3,7	1,2					4,7	0,7
3	0	35,29	5,78	1,0	5,4	20,4	1,1	1,3	0,0	0,0	1,3	4,2	0,8
	6	35,29	5,36	1,0	3,6	4,0	1,2					5,9	0,8
4	0	33,68	4,73	2,0	16,7	7,5	1,6	1,5	0,0	0,0	1,5	0,9	1,4
	4	33,80	4,11	2,1	16,1	7,5	1,6					2,2	1,2
5	0	35,25	4,99	1,0	6,0	5,8	1,1	0,9	0,0	0,1	1,0	3,4	0,6
	4	35,26	5,26	1,2	5,4	9,4	1,1					4,6	0,7
6	0	33,14	4,63	2,2	19,6	8,4	1,5	3,8	2,6	5,9	12,3	1,7	2,4
7	0	32,92	4,74	2,5	21,4	5,7	1,5	2,7	0,0	0,1	2,8	0,0	1,9
8	0	31,16	3,99	2,8	25,6	6,3	1,4	2,1	0,5	1,2	3,8	1,9	2,7
	3	32,53	4,24	2,6	22,6	7,0	1,5						
9	0	28,02	4,08	2,8	31,6	70,4	1,2	1,6	0,0	0,0	1,6	4,9	3,2
	4	29,38	4,12	3,0	29,2	4,7	1,3					10,2	10,4
10	0	23,48	3,77	2,1	37,5	4,0	0,8	2,2	1,5	3,4	7,1	4,5	4,0

Grindley and Eagle (1978) reported on the environmental effects of the discharge of sewage effluent into Knysna Estuary. While a further study (Grindley and Snow, 1983), concluded that the position of the sewage outfall is unfortunate, in that it opens into a blind ending arm of the estuary, in the midst of a series of public recreation facilities. It was noted that while the effects of the present discharge of effluent on water chemistry, substratum, flora and fauna in the area around the outfall did not appear to be serious, increased discharges would have greater effects. The high recorded coliform and in particular *Escherichia coli* counts obtained in this area are obviously undesirable in view of the popularity of swimming in this area. However, Ninham Shand and Partners Inc. have stated that the chlorination unit will "ensure a zero *E. coli* discharge." The aesthetic implications of this discharge are nonetheless questionable.

It would seem that the limited tidal exchange in the area east of Thesen's Causeway causes stagnation in that area and that the effects of pollution are worse there than near the sewage outfall where there is a better tidal circulation. A number of effects in the area east of Thesen's Causeway gave cause for concern. The fluctuations in dissolved oxygen are evidence of high organic production. The high percentage of sub-sieve particles (< 75 μ) and the high total Kjehldahl nitrogen values indicate that this area is accumulating fine sediments with a high organic content in constrast to the unaffected area west of the causeway. The abundance of *Ulva* and *Enteromorpha* in this area is probably related to the raised nutrient levels. The fauna of this area is apparently impoverished at the lowest intertidal level as the biomass is lowest here at the level where it is normally highest. It would seem that the limited tidal exchange in this area causes the effects of pollution to be worse here than near the sewage outfall. Studies of tidal movement have shown that the exchange of water in the channel between Thesen's Island and the mainland is poor. Studies using a hydraulic model showed that the situation could be improved by opening a section of Thesen's Causeway. The removal of this section of the causeway caused a 98 percent reduction in pollution levels with spring-tides and a 71 percent improvement on neap-tides (Grindley and Eagle, 1978). A further study carried out by Grindley and Snow (1983) again stressed that the limited tidal exchange in the area of Thesen's Causeway caused the effects of pollution to be worse there than near the sewage outfall. It is hoped that the opening of the causeway will alleviate this problem. The value of the reed marsh below the sewage works as a nutrient uptake mechanism must not be neglected and probably deserves further study (Grindley and Snow, 1983).

On the basis of the abovementioned findings it was recommended that the discharge of a large volume of effluent from an outfall in the present position is undesirable. The possibility of discharging the treated sewage effluent into the main channel south of Thesen's Island should be investigated. It might be possible to lay the required pipeline in the bed of the channel east of Thesen's Island, but such a development should not be contemplated without thorough foregoing environmental investigations.

Oil Pollution

A number of studies have been made of ways and means to prevent oil pollution of the Knysna Estuary in the event of an oil spill at sea. The circumstances under which oil could enter through the Knysna Heads if no preventive measures were taken, along with various means of solving the problem, are reviewed by Retief *et al.*, (1979). Attention is focussed on the possible use of oil barriers (booms) and their probable effectiveness at various locations is evaluated.

The conclusions drawn are that the probability of oil entering Knysna Lagoon from a spill at sea is remote. If oil did enter between The Heads, commercially available oil booms would only be effective in keeping oil out at that point during favourable conditions such as neap-tides. More promising solutions could, however, probably be achieved within the estuary (Jackson and Lipshitz, 1984).

Following the collision between the super-tankers *Venpet* and *Venoil* south of Knysna in December 1977, oil pollution in the form of tar-balls did enter the lagoon in small quantities. The sinking of a fishing vessel at the Thesen's Island wharf caused local oil pollution in 1983. The widespread use of outboard engines on Knysna Lagoon is responsible for some pollution but no data are available.

Heavy Metals

Trace-metal concentrations are low (Day, 1981). A series of papers by Watling and Watling (1975, 1976, 1977, 1979 and 1980) and Watling, Watling and Butler (1977 and 1978) have established a substantial data base. Knysna Estuary is one of the most, if not the most, biologically productive estuaries in South Africa, and as such is listed as an area of primary importance in the National Marine Pollution Monitoring Programme.

There are, however, indications that transitory anomalies do occur and represent point sources of input. Of particular interest in this respect is the 1976 mercury anomaly near The Point. In addition certain of the town drains are responsible for the input of zinc, copper, nickel, cobalt and mercury. The anomalous areas associated with these drains are small and consequently their ecological impact is insignificant.

Analysis of cores taken during the 1976 and 1978 surveys indicate the possibility of transitory anomalies forming along the Leisure Island shore. Four sites of metal accumulation of a more permanent nature have been identified from the results of the 1978 survey. These are Thesen's Island Point, Thesen's Island Jetty, the Rail Bridge and the National Road Bridge. However, concentrations at these sites are only slightly elevated above background levels and do not represent significant metal inputs (Watling and Watling, 1980).

Comparison of the trace-metal concentrations in three species of oysters grown at Knysna with those reported for many other locations, immediately showed that there is no major trace-metal source in the estuary. It is particularly fortunate that so many other species of molluscs also grow in the estuary because we can assume that trace-metal concentrations in these will also represent background levels. It will therefore be possible to compare these results with those obtained for the same species from other estuaries, many of which do not have naturally occurring oyster populations.

Metal concentrations in *Crassostrea gigas* and *Ostrea edulis* from Knysna Estuary are much lower than many of the reported values for these species (Watling and Watling, 1976); this indicates that Knysna Estuary is unpolluted with respect to zinc, cadmium, copper, iron, manganese and nickel. Metal concentrations in other molluscs growing in or near the Knysna Estuary are generally low and it is assumed that these values represent near-natural levels for indigenous species.

The fact that the estuary is relatively unpolluted makes Knysna an excellent marine-pollution monitoring station for the southern coast of South Africa.

Other Forms of Pollution

Other types of pollution include wood preservatives (Grindley, 1970). Industrial pollution (e.g. wood preservatives) will probably decrease as the local population becomes more aware of the dangers (Chmelik *et al.*, 1975).

Recent information from Britain and France indicates that modern anti-fouling paints with a high TBT (Tetra Butyl Tin) content may have serious effects (A Genade, pers. comm.).

No data are available but pesticides are widely used in the catchment and in the surroundings of the estuary, so pesticide residues might be significant.

Considerable volumes of sawdust have been dumped into the lagoon at times and creosote-treated wood chips appear in core samples (Watling and Watling, 1980).

Public Health Aspects

Bilharzia or schistosomiasis is unknown today in the Knysna Estuary or the surrounding fresh water streams and ponds. The western limit of bilharzia distribution is the Humansdorp Division 150 km to the east. It is considered that there is no bilharzia risk at salinities above 7 parts per thousand (Chmelik *et al.*, 1975).

Bacteriological studies are carried out routinely by the Health Department.

Special investigations were carried out in 1978 and 1983 in connection with the environmental effects of the sewage effluent discharge. Coliform bacilli were found to be over 1 800/100 ml of water at several stations and *Escherichia coli* were also found to exceed acceptable values at several stations. These values were unusually high and most bacterial counts are lower. The waters of Knysna Lagoon are used extensively for recreational purposes including swimming. There are great variations in the standards adopted for recreational waters by authorities in various parts of the world and *E. coli* standards range from 70 to 5 000/100 ml (Grindley and Eagle, 1978; Grindley and Snow, 1983). The presence of coliform bacteria and particularly *E. coli* in the waters of the lagoon is specially undesirable because of the use of the lagoon for the culture of oysters on a commercial scale. The danger of contamination of human food in this way is considerable. Pathogenic bacteria may originate from faecal pollution of the shores of the lagoon or from boats in the vicinity of the oyster culture rafts.

4. BIOTIC CHARACTERISTICS

4.1 Flora

4.1.1 Phytoplankton/Diatoms

The phytoplankton biomass has not been investigated but the clarity of the water suggests that it is low (Day, 1981). A total of 39 species were identified by Korringa (1956) in phytoplankton samples taken from Thesen's Wharf, The Heads, Featherbed Bay and 2,5 miles offshore (Appendix I).

The phytoplankton has not been studied in detail but a number of species of diatoms have been recorded. These include *Skeletonema costatum*, species of *Chaetoceros*, *Coscinodiscus*, *Navicula* and *Pleurosigma*. Among the dinoflagellata *Noctiluca miliaris* is abundant at times and species of *Ceratium* and *Peridinium* are common (Grindley, 1976a; Grindley and Eagle, 1978).

4.1.2 Algae

Attached algal vegetation is rich. The rocky banks at The Heads are colonised by an unusually wide variety of algal macrophytes (Day, 1981).

The species of algae present include *Gelidium pristoides, Ulva lactuca, Enteromorpha* sp. and *Zonaria tournefortii* (Day, *et al.*, 1952; Day, 1967; 1981). Algae present within the lagoon include *Ulva* spp., *Enteromorpha* spp. and *Chaetomorpha* spp. (Grindley, 1976a; Grindley and Eagle, 1978; Grindley and Snow, 1983). The alga *Zonaria tournefortii* is common in *Zostera* beds. Algae collected at The Heads include *Splachnidium rugosum, Gelidium pristoides, Codium duthiae, Ulva rigida, Bryopsis* sp.

Biomass measurements are given in this section and in Appendix II to indicate variations in abundance in different areas. The dry biomass of *Ulva* east of Thesen's Causeway was 61,5 g/m^2 (Grindley, 1976a). While the ash-free dry biomass of *Ulva* east of Thesen's Causeway was 241 g/m^2 (Grindley and Snow, 1983). Patches of *Ulva, Entermorpha* and *Chaetomorpha* occur along the banks of tidal channels and on the surface of the mud on the lower shore. The alga *Bostrychia vaga* forms tufts entangling the bases of intertidal saltmarsh plants.

4.1.3 Aquatic Vegetation

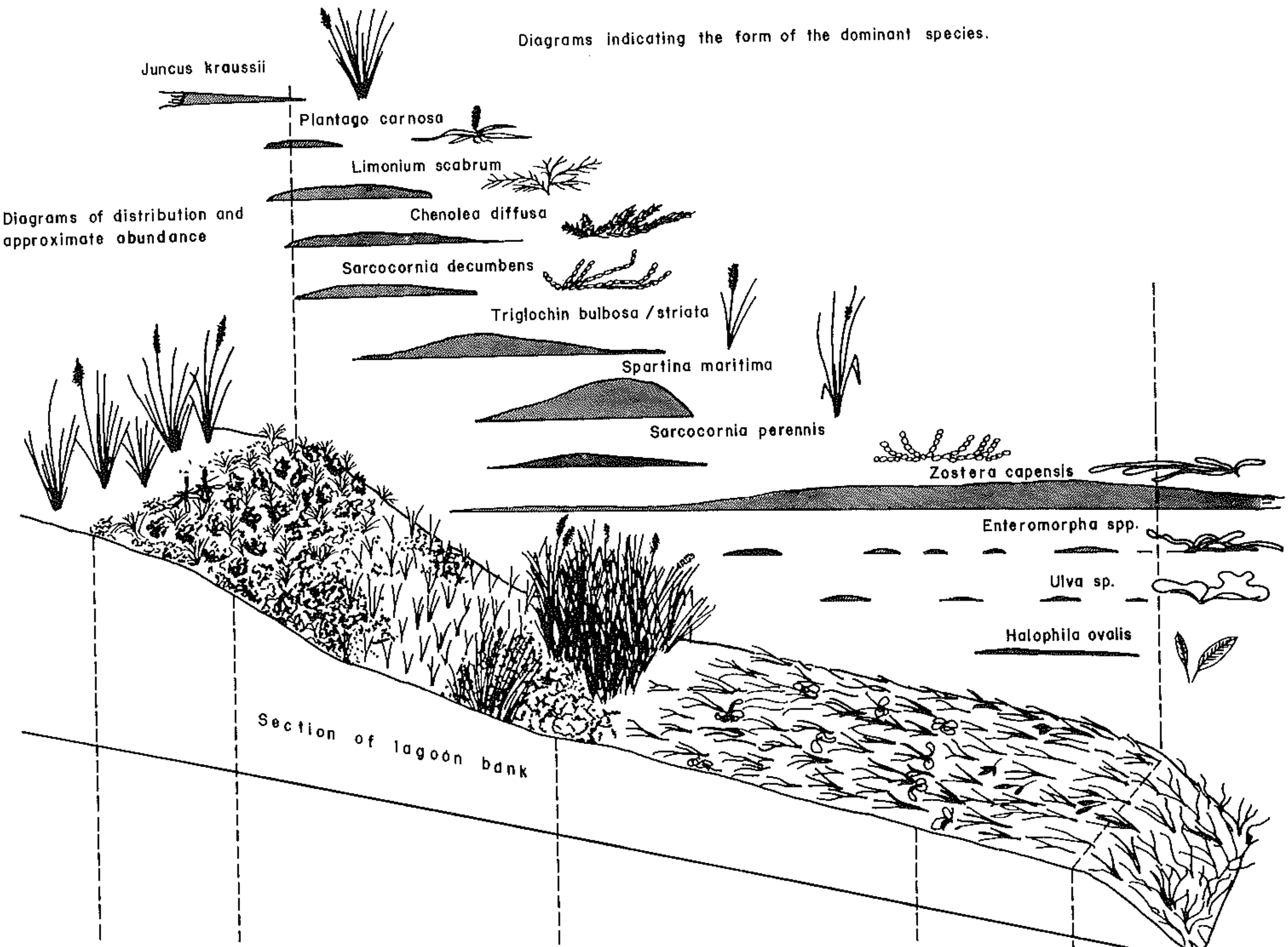
From mid-tide down to the lowest level of spring-tide and even below, the dominant plant is the sea-grass *Zostera capensis*. It grows all over the estuary up to the Old Drift. It is most luxuriant at the low water of spring-tide level on shelving mud banks where the salinity is about 30 parts per thousand. It is sometimes mixed with *Halophila ovalis*. The mean dry biomass of *Zostera* is 67,5 g/m^2 at Ashmead and 238,4 g/m^2 north of Leisure Island (Grindley, 1976a). The mean dry biomass of *Zostera* near the sewage outfall is 135 g/m^2, the ash-free dry biomass of *Zostera* in this area was 125 g/m^2 (Grindley and Snow, 1983). From Westford Bridge upstream *Ruppia maritima* becomes common eventually largely replacing *Zostera* at the Old Drift.

4.1.4 Semi-aquatic Vegetation

While *Zostera* beds predominate near the low-tide mark, broad saltmarshes comprised of various other species occur at higher levels. *Spartina maritima* is abundant at mid levels and species of *Sarcocornia, Triglochin, Chenolea, Limonium* and *Plantago* carpet the upper levels of the saltmarshes. Near the high spring-tide mark, *Juncus kraussii* appears and it covers extensive areas of mud banks in the upper reaches of the estuary (Grindley, 1976a). Biomass values for these macrophytes are high but primary production has not been measured (Day, 1981).

The highest intertidal areas are carpeted with a dense growth of *Limonium scabrum* or *Chenolea diffusa*. These species tend to form large patches covering areas of several hundred square metres each rather than a continuous band. *Limonium* patches extend down to 15 cm below HWST. Below this it forms mixed communities with *Chenolea, Sarcocornia* and *Triglochin* but with *Limonium* still dominant in patches down to 20 cm below HWST. Slightly lower, occasional isolated plants of *Limonium* are each enmeshed in tufts of the alga *Bostrychia vaga*. *Sarcocornia decumbens* tends to border the patches of *Limonium* but not spreading as widely in area. The densest patches are in the region of 15-20 cm below HWST. Below this there are mixed patches of *Chenolea* and *Limonium* with *Sarcocornia*. The lowest isolated specimens of *Sarcocornia* were observed at 50 cm below HWST in the *Triglochin* zone. *Chenolea diffusa* covers patches up to several hundred square metres in area between about 10-20 cm below HWST. Isolated

FIG. 15: The Zonation of saltmarsh vegetation on the eastern shores of the Knysna Lagoon.



plants merge into the *Triglochin* zone about 25 cm below HWST. *Chenolea* appears to tend to favour the margins of channels and the slopes of humps perhaps favouring better drainage. The lowest specimens occur in humps in the *Triglochin* zone at levels between 20-30 cm below HWST.

Triglochin bulbosa first appears as isolated plants with *Limonium* and other plants at about 20 cm below HWST. Patches of *Triglochin* appear in hollows 25 cm below HWST and on open slopes 35 cm below HWST. The main band of *Triglochin* extends between 40-65 cm below HWST. The densest growth is between 50-60 cm below HWST. Dry biomasses were up to 4 603 g/m^2 at the sewage outfall. Where this zone is intersected by tidal channels the *Triglochin* appear to favour the banks on the inside of bends (regions of accretion) rather than the outside of bends which are favoured by *Spartina*. *Spartina* appears highest on humps on the lower shore 45 cm below HWST. The main zone on the open shore commences 55 cm below HWST and extends down to 85 cm below HWST. As mentioned above patches of *Spartina* tend to favour the outside bank of bends in tidal channels where they appear able to withstand the erosion processes. *Spartina* dry biomass values of from 5 114 g/m^2 to 6 465 g/m^2 have been recorded (Grindley and Snow, 1983). Below the *Spartina* zone the apparently bare mud is covered by *Zostera capensis*. On humps on the lower shore the *Zostera* begins at 80 cm below HWST and extends down about one metre below LWST. Along the banks of tidal channels and on the surface of the mud on the lower shore *Halophila ovalis* appears in the *Zostera*. (Grindley and Eagle, 1978).

The range of variation of biomass values recorded in the eastern marshes of Knysna is shown in the following dry biomasses of saltmarsh plants. *Plantago carnosa* 1943 - 2456 g/m^2, *Limonium scabrum* 388-1059 g/m^2, *Chenolea diffusa* 630-2096 g/m^2, *Sarcocornia decumbens* 397-958 g/m^2, *Triglochin bulbosa/striata* 854-4603 g/m^2, *Spartina* sp. 1614-6465 g/m^2 (Grindley, 1976a; Grindley and Eagle, 1978; Grindley and Snow, 1983).

It should be noted that *Spartina* has apparently been referred to as *Puccinella* (Day *et al.*, 1967) and misspelled as *punninella* (Department of Planning, 1970). That report (1970) also refers to *Zostera, Jimoao* (sic), *Salicornia* and *Ruppia*.

In the upper reaches of the estuary in addition to *Juncus kraussi* which is abundant, reeds including *Phragmites communis* (sic = *australis)* and *Scirpus venustulus* and *Scirpus globiceps* appear (Day *et al.*, 1952).

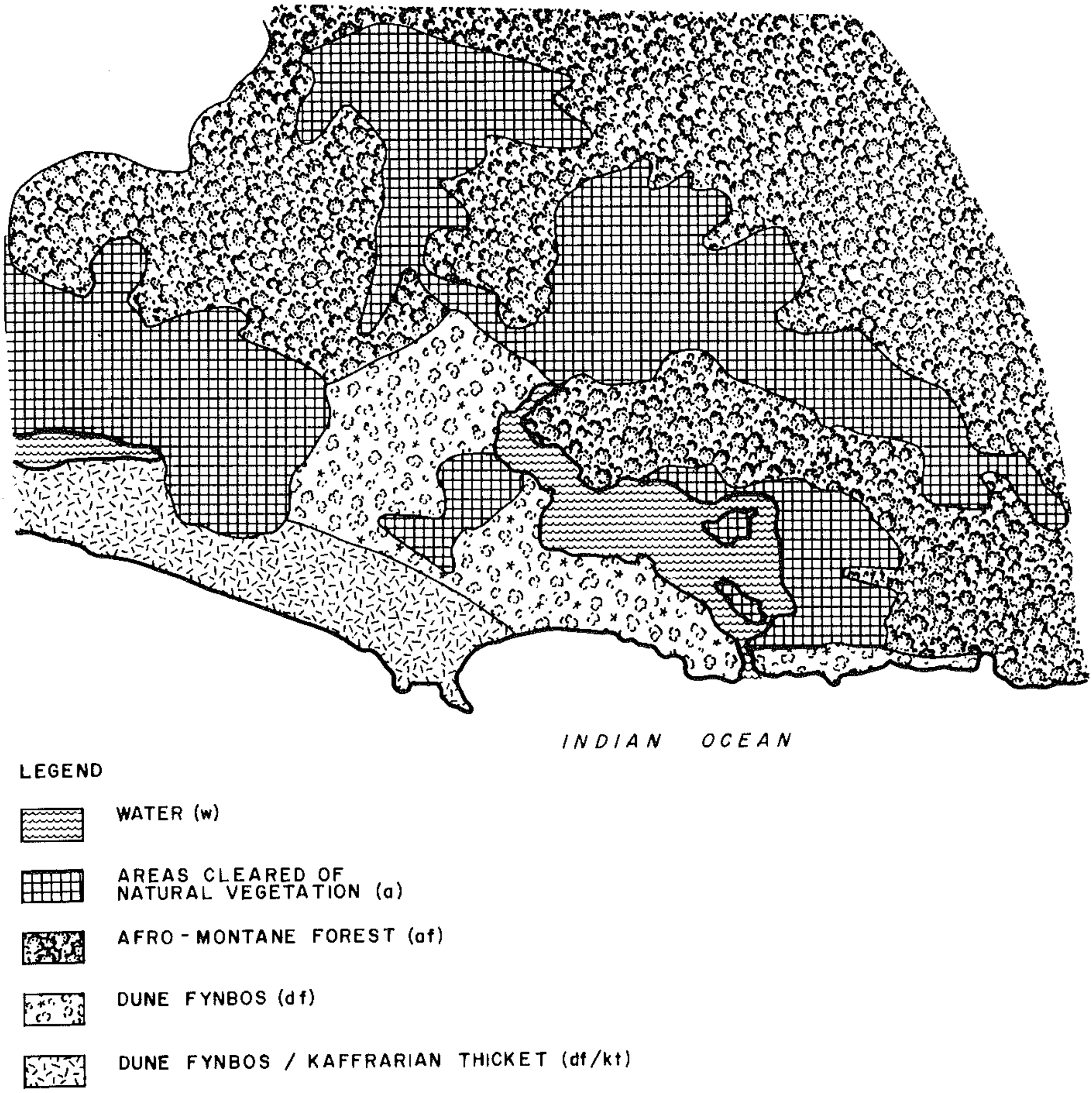
Recently following an investigation by Ms S M Pierce the *Spartina* at Knysna, usually considered to be *S. capensis*, has been referred to as *Spartina maritima* (Day, 1981). The role of saltmarsh vegetation as a source of detritus has been discussed by Grindley (1976a). The species composition of detrital litter suggests that *Spartina, Juncus* and *Zostera* are the major sources of detritus in most of the Knysna Estuary (Grindley, 1976a).

4.1.5 Terrestrial Vegetation

On the banks of the lagoon above HWST a large number of species of plants appear which are tolerant of marginal conditions including occasional salt spray. Some of the main species are listed in Appendix II. Away from the immediate shore there is dense bush or scrub forest on the slopes. The coastal bush on the Eastern Head (Foundation Point) and Western Heads (Brenton Head) includes melkbos *Sideroxylon inerme,* camphor bush *Tarconanthus camphoratus,* taaibos *Rhus glauca,* assegaihout *Curtisia dentata,* aloe *Aloe ferox,* num-num *Carissa bispinosa,* bietou *Chrysanthomoides monilifera,* blombos *Metalasia muricata,* polygala *Poilygala* sp., asparagus *Asparagus* sp. and buchu *Agathosma* sp. (J R Grindley, pers. obs.).

FIG. 16: General vegetation map of the Knysna area.

(Moll and Bossi, 1983)



Acock's map of the Veld Types of South Africa indicates that the whole of the catchment and the surroundings of Knysna river and estuary fall in the Knysna Forest (veld type 4). However, the crest of the hills stretching west from the western or Brenton Head support plant communities which appear to be representative of Coastal Fynbos (veld type 47) although in Acock's map this is only represented west of Mossel Bay. The vegetation of the Knysna Forest has been exhaustively described by Phillips (1931) in his monograph on forest succession and ecology in the Knysna region. Acocks (1975) points out that it is probable that the importance of Fynbos in the forest succession may be due to a large extent to careless exploitation. He considers that sub-tropical grassveld might have been more important in the past in this region with high, well-distributed rainfall, sour sandy soils and vigorous growth.

More recently, Moll and Bossi (1983) have mapped the main vegetation types of the Fynbos Biome. Those of the Knysna area are depicted in Figure 16.

The composition of the forests is described by Von Breitenbach (1974). There are about 125 tree and major shrub species of which about 100 are trees. There are descriptions and keys to these species in Von Breitenbach (1974) as well as accounts of the forest types and notes on other plants associated with the forests (ferns, grasses, herbs, shrubs, lianas and epiphytes). The major species are listed in Appendix III. Throughout the Knysna area invasive alien vegetation has become a major problem. *Acacia saligna, Acacia cyclops, Acacia longifolia* and *Acacia melanoxylon* have invaded large areas, sometimes eliminating the natural vegetation in the coastal belt. In the Outeniqua Mountains *Pinus pinaster* and *Hakea sericea* now seriously threaten the survival of the rich Cape flora (Stirton, 1978).

4.2 Fauna

4.2.1 Zooplankton

A list of species recorded is presented in Appendix IV.

The mouth of the Knysna Estuary is inhabited by neritic species while further up estuarine species dominate the zooplankton. Among the copepod genera *Paracalanus* is abundant in the lower reaches while *Pseudodiaptomus* and *Acartia* species become abundant further up (Grindley and Eagle, 1978). Day (1967) has desribed the zooplankton as rather poor and suggested that plankton is not a major source of food in the estuary. He pointed out that there are relatively few plankton feeders. The ostracods of Knysna have been described by Benson and Maddocks (1961).

Samples of zooplankton taken in Knysna Lagoon, at The Heads and 2,5 miles offshore are listed in Table 1 of Korringa (1956). The commonest species recorded were *Oithona nana, Paracalanus parvus, Harpacticus gracilis* and *Euterpina acutifrons,* while *Oithona oculata* and *Oncaea subtilis* also appeared in samples from a cold current.

Day *et al.* (1952) recorded the following Mysidacea: *Gastrosaccus* spp., *Mesopodopsis africanis* and *Rhophalopthalamus egregius*.

The dominant copepods through most of the estuary are *Acartiella natalensis, Paracartia longipatella, Paracalanus crassirostris, Paracalanus parvus, Oithona nana, Pseudodiaptomus nudus* and *Harpacticus gracilis*. These species occur in most estuaries on the south and east coasts of South Africa. In addition various neritic marine forms such as *Clausoclanus furcatus, Centropages brachiatus, Pleuromamma abdominalis, Euterpina acutifrons* and various species of *Corycaeus* penetrate some distance into the estuary. The Knysna Estuary is unusual among South African estuaries in being a deep open estuary in which clear blue open water penetrates on each high-tide. The blue water during spring-tides penetrates to well beyond the railway bridge mixing with the more turbid green water in the shallows. This facilitates the penetration of neritic marine species and limits the survival of purely estuarine species such as *Pseudodiaptomus hessei* and various Harpacticoids. These latter species are most abundant in the upper reaches from the Belvedere area right up to Charlesford Rapids. The true estuarine plankton species can only survive in areas where the residence time of the water is sufficiently long for them to be able to complete their life cycles before being swept out to sea by the tides.

At times, very cold upwelled water appears at Knysna and penetrates into the lagoon. At such times various deep ocean species appear such as *Oncaea subtilis, Oithona oculata* and *Microsetella rosea*. These are oceanic pelagic species which do not usually form part of the estuarine or neritic marine plankton community.

Studies were made of the plankton of South African estuaries including Knysna Estuary as part of the South African National Programme of Oceanographic Research (Grindley, 1981). Apart from the Copepoda, a wide range of other plankton organisms appear. Several species of Foraminifera and Radiolaria occur but have not yet been identified. A *Dinophyes* species is the commonest siphonophore. The medusa *Rhizostoma* is abundant at times particularly in the upper estuary.

The Chaetognatha are represented by a species of *Sagitta*. Large numbers of larvae of benthic invertebrates appear in the plankton particularly during the spring and summer months. These include polychaete larvae, larvae and post-larval stages of gastropods and lamellibranchs, ophiopluteus and other echinoderm larvae, copepod nauplii, cirripede nauplii, cirripede cyprids, crab zoea and megalopa larvae and mysis larvae of decapods. Several species of Ostracoda have been recorded. Among the Mysidacea *Gastrosaccus brevifissura* and *Leptomysis tattersali* occur in the lower estuary while *Mesopodopsis africana* and *Rhophalopthalamus egregius* occur in the upper estuary. Cumacea include *Iphinoe truncata*. Amphipoda include *Paramoera capensis, Lysianassa ceratina* and *Corophium triaenonyx*. Isopoda include *Eurydice longicornis, Janira capensis, Paridotea ungulata* and *Exosphaeroma* spp. Various fish eggs and larvae appear and occasionally small fish such as the pipefish *Syngnathus acus*.

As might be expected in a clear open estuary penetrated by ocean water at every tide there are more neritic marine species of phytoplankton and zooplankton than in most South African estuaries. Organic detritus particles are abundant in most plankton samples sometimes even exceeding the plankton in abundance. It is clear that the detritus derived from the attached plants of the saltmarshes plays an important role in this estuary. Nanoplankton is particularly abundant in the upper reaches of the estuary and it appears to be the major food source of the dominant copepod in that area *Pseudodiaptomus hessei* (Grindley, 1976a; Grindley, 1976b; Grindley and Eagle, 1978; Grindley, 1981).

The distribution of plankton in estuaries is affected by the extent of tidal exchange. Studies were therefore carried out with the Knysna hydraulic model at the National Research Institute for Oceanology, Stellenbosch to determine the residence time of water in relation to the distribution of plankton. The results of these experiments are described by Grindley in pp 28-38 and Figures 75-91 in Knysna Lagoon Model (1976). Few fresh-water species enter the lagoon as the plankton in the Knysna River was described as "very low" (Le Roi Le Riche and Hey, 1947).

The plankton appearing in the channel to the north of Thesen's Island would appear to be a normal estuarine plankton community. It is dominated by true estuarine plankton species such as *Pseudodiaptomus hessei*. This indicates a very limited tidal exchange as the true estuarine species can only survive where the water has a long residence time such as at the head of an estuary. There is no evidence apparent of changes in the zooplankton of this area as a result of the presence of the sewage outfall. The somewhat unusual composition of the zooplankton appears to be related to the extent of tidal exchange with maximum numbers of the estuarine species at the head of the channel to the east of Thesen's Island Causeway and lower numbers towards the mouth.

4.2.2 Aquatic Invertebrates

The benthic macrofauna includes 310 species with rich beds of *Upogebia africana* and numbers of *Arenicola loveni, Solen corneus, Atrina squamifera* and other bivalves. The gastropods *Assiminea globulus, Hydrobia* sp. and *Nassarius kraussianus* are abundant. There are numerous amphipods and isopods and the saltmarsh vegetation harbours *Sesarme catenta, Cleistostoma* spp. and other crabs (Day, 1981).

Corresponding to physical changes along the length of the estuary there are a series of faunistic divisions. Day *et al.* (1952) pointed out that salinity changes, current strength, pH and temperature may all be important, but that the environment must be considered as a whole. Any one factor only becomes important when the limits of tolerance for that factor are reached. Four basic divisions of the Knysna Estuary were distinguished: (1) Knysna Heads, (2) the lagoon from Leisure Island to beyond The Point, (3) the Westford channels to the Old Drift and (4) Charlesford Rapids. It was shown that the diversity of species declines progressively as one passes upstream from The Heads. While the number of species present at Thesen's Island is roughly similar to that at The Heads, the component species are notably different. Thus over half the species at The Heads do not reach Leisure Island and three quarters of those found on Thesen's Island do not extend to The Heads. A characteristic lagoon fauna was recorded from Leisure Island to The Point. The percentage of typical seashore species decrease progressively up the lagoon and none reaches Charlesford Rapids.

A third group of species referred to as 'estuarine species' are widespread in the system.

A fourth group of 'brack-water species' favours the oligohaline conditions at Charlesford Rapids. The invertebrate species recorded are listed in Day *et al.* (1952).

In another paper Day (1964) reconsidered the faunistic components of the Knysna Estuary in view of the fact that he had found that more than half of the fauna of Langebaan Lagoon, which is not an estuary, was the same as that found in Cape estuaries. The effects of shelter from wave action had been neglected in earlier studies. On this basis new analyses suggested that estuarine species form less than 14 percent of an estuarine population and are only important at the head of an estuary. Euryhaline marine species adapted to calm waters form the bulk of the population of the lagoon (Day, 1964). Therefore, Day (1967) characterised the faunistic components by their salinity tolerance as follows:

(1) The fresh water component comprising a few salt-tolerant species from the river.

(2) The stenohaline marine component near the mouth of the estuary.

(3) The euryhaline marine component extending from the sea throughout the estuary.

(4) The estuarine component restricted to estuaries.

(5) The migratory component including active forms such as prawns and cephalopods which move in and out of the estuary.

Millard (1950) published an account of a collection of sessile barnacles from Knysna Estuary. Apart from the typical marine barnacles which occur at the rocky Heads on either side of the mouth, there was found to be a rich estuarine population extending 13,6 km up the estuary into a salinity as low as 14 parts per thousand. The marine forms occurring near the mouth include *Tetraclita serrata, Chthamalus dentatus, Octomeris angulosa* and *Balanus trigonus*. The estuarine population of barnacles was composed mainly of *Balanus amphitrite* and *Balanus elizabethae* of which the former was the most numerous.

Biomasses values for the major benthic species were established by Grindley (1976a), Grindley and Eagle (1978) and Grindley and Snow (1983). The range of values determined are presented in Appendix V.

The first account of the zonation of intertidal benthic fauna was presented by Day *et al.* (1952) and a further more detailed account of vertical zonation was presented by Day (1967) including diagrams of a series of transects. The transects were at the Old Drift, Ashford, the Rail Bridge and Leisure Island.

The Pansy Shell, *Echinodiscus bisperforatus* occurs and breeds on particular sand banks in the main channel of the lagoon. They are popular with visitors but their numbers appear to have declined alarmingly in recent years, despite conservation legislation (Mrs F Freeman of Knysna, pers. comm.). In response to an appeal from Mrs Metelerkamp of Knysna, a regulation 51, subsection 2, paragraph 3 was added to the Sea Fisheries Act, 1973 (Act 58 of 1973). This states that "No person shall disturb or take away live shells ..." but walking on this soft sandbank is reported to be a destructive form of disturbance (M McKay, *in litt.)*. The Ministry for Environment Affairs has, however, pointed out that in terms of the Sea Fisheries Act (58 of 1973) it is not possible to prohibit public access to a specific area of the seashore or lagoon. The Director-General of Constitutional Development and Planning later indicated that the area where the Pansy Shells occur may in terms of paragraph 6.4.2.1(7) of the Guide Plan, be included in the area demarcated in the Guide Plan for a sea reserve. This was reported in the *Oudtshoorn Courant* and *Het Suid-Western* (see Figure 6).

Knysna is a major supplier of oysters (Bulpin, 1978). Korringa (1956) noted that oyster larvae settling on collectors placed inside the Knysna Lagoon come from parent stocks in the sea. They are carried by the counter-current flowing very close inshore, and are washed into the lagoon with the flood tide. Therefore settling takes place close to the entrance of the lagoon and at about high-tide. Conditions in the central part of the lagoon, above the Rail Bridge, are not suitable for oyster larvae, but spat and older oysters may thrive there because of the high food content of the water (Korringa, 1956).

Three species of indigenous oysters appear to occur at Knysna. Of these the common South African oyster, *Crassostrea margaritacea,* an oviparous species, is considered the most promising for oyster cultivation. The small *Ostrea algoensis* should be considered as a 'weed-oyster' because of its limited dimensions and slow growth. By means of proper timing of the placing of collectors it is possible to avoid this species settling in appreciable numbers. The red oyster, *Ostrea atherstonei,* another larviparous species, is very interesting because of its rapid growth and perfect shape. Previously this species was only known from fossil deposits. It occurs at many places along the coast of South Africa, including the west coast, but the numbers settling at Knysna are not of commercial significance, so that it will be extremely difficult to build up a stock of this oyster. In addition to the indigenous oysters, the Pacific oyster *Crassostrea gigas* was introduced for cultivation in 1973 (A Genade, pers. comm.).

Bottom conditions in the Knysna Lagoon are not inviting for the planting of oysters but other methods of cultivation are possible. Strong winds stirring up much sand and finer sediment are often inimical, especially for the more delicate types of oyster, like *Ostrea edulis,* the European flat oyster.

Studies of the reproduction of *Crassostrea margaritacea* (non-incubatory) and *Ostrea algoensis* and *O. atherstonei* (incubatory) have been carried out by Genade (1973). Spawning of *C. margaritacea* occurs after a monthly mean water temperature of 20°C has been reached. Fertilisation of ova (50 µm diameter) occurs in the water. Veliger larvae (length 280 µm) develop within 36 hours, and mature larvae develop within three weeks under optimal conditions. Larvae of *O. algoensis* are liberated at an average length of 147 µm while *O. atherstonei* swarm at a length of 172 µm. Larvae of the latter two species mature and metamorphose within approximately two weeks of liberation. Shell growth in *C. margaritacea* occurs only above 16°C and in the Knysna Estuary marketable oysters are obtained after two growth seasons. Natural mortality during post-larval development was found to be approximately 40 percent. Spat settlement in South African estuaries is too irregular to provide a basis for the oyster cultivation industry, so hatchery techniques of spat production for the indigenous oyster species are being developed (Genade, 1973). Oyster enemies do occur at Knysna, but it is as yet possible to cope with them (Korringa, 1956).

The Pacific oyster *C. gigas* was introduced in 1973. Present production is two million per annum from Knysna Lagoon. This represents approximately 200 tonne or more per hectare per year. Cultured seed oysters are produced at the Fisheries Development Corporation (FDC) hatchery and supplied to the oyster farming industry. An intertidal tray system is currently employed for further growth until harvesting (A Genade, pers. comm.). The Portuguese oyster, *Crassostrea angulata,* grows and fattens satisfactorily in the Knysna Lagoon.

The saltmarsh epifauna includes many crabs including *Sesarme catenata, Cleistostoma* spp. and others (Day, 1961). It is not easy to separate these from the benthic fauna considered in the previous section and many of the benthic species such as *Assiminea globulus, Hymenosoma orbiculare, Talorchestia ancheidos* and *Paridotea ungulata* may be found on the surface.

4.2.3 Insects

Insects have not received detailed study but those collected included chironomid midges and their larvae, dragonflies, mayflies, kelp flies, staphylinid beetles and other beetles, house flies and water boatmen.

4.2.4 Fish

More than 200 species of fish are reputed to be found in the lagoon which is, *inter alia,* the home of a rare seahorse, *Hippocampus capensis* (Bulpin, 1978).

During the University of Cape Town ecological studies, over 50 species of fish were identified. Most of these were juveniles of marine species but anglers also take large kob, leervis, spotted grunter, white steenbras, elf and even stenohaline marine fish such as *Sparodon durbanensis* on occasion. Forage fish such as *Gilchristella, Hepsetia breviceps* and three or four species of mullet are plentiful (Day, 1981).

Day (1952) reported that the fish fauna was abundant and varied but did not publish details. Day (1967) stressed the role of predatory fishes which usually form the last link in the food chain. The white stumpnose *Rhabdosargus globiceps* is one of the commonest fishes and feeds on mussels and small crustaceans such as amphipods. The white steenbras *Lithognathus lithognathus* grubs in the sand for polychaetes such as *Orbinia* and *Nephthys* spp. and small crustaceans particularly *Pontogeloides* and *Urothoe*. Large specimens develop the capacity of blowing holes in the sand to feed on *Upogebia* and *Arenicola*. The kabeljou *Argyrosomus hololepidotus* appear when they are about 15 cm long. They feed on a variety of small crustaceans including mysids, shrimp, *Upogebia* and *Hymenosoma* but they do not seem to feed on the infauna of muddy bottoms. Large specimens are predatory and feed on *Sepia* and *Mugil* spp. Adult kob extend the whole length of the estuary including the upper reaches. The leervis *Lichia amia* is a vicious predator even when small, feeding on shoals of post-larval mullet in the shallows. They extend into the upper reaches of the estuary and as adults feed on *Mugil* spp. *Hyporhamphys* and juvenile *Lithognathus* and *Rhabdosargus*. They are swift predators and form the final link in the food web illustrated in a diagram of the trophic relations within Knysna Estuary (Day, 1967).

Because of the permanently open wide rocky entrance, the area near The Heads includes typical marine fishes. The width of the mouth is such that there is no barrier to shoals of pilchards, anchovies, etc. and their attendant predators, so they enter freely. As a result there have been many records of fishes unusual for estuaries. At times, the upwelling on the south coast drives numbers of species into the lagoon. Some of these are thrown ashore numbed or dead.

A list of fishes recorded from Knysna by the J L B Smith Institute is presented in Grindley (1976a). Some of the species frequently occurring in the estuary are listed in Appendix VI.

A new species of goby from the Knysna River *Gobius maxillaris* sp. n. was described by Davies (1948).

In the study of the occurrence of juvenile fishes in estuaries by Wallace and Van der Elst (1975) the following juveniles were recorded in Knysna Lagoon: *Lithognathus lithognathus, Liza richardsoni, Liza tricuspidens, Myxus capensis, Rhabdosargus globiceps*.

Le Roi Le Riche and Hey (1947) recorded *Barbus monodactylus, Sandelia* and 'springer' from Knysna River. Introduced fish in the Knysna River are trout and bass but the introduction results were reported as nil by Le Roi Le Riche and Hey (1947).

Wallace *et al*. (1984) stress that South Africa's estuarine-associated fish fauna can be divided into six categories according to the extent of dependence upon estuaries. Category I comprises eight species which are dependent upon estuaries for their entire life cycles and are thus particularly susceptible to any estuarine degradation. These species are all small in size but play an important role in estuarine food webs. Category II comprises 22 species which are dependent on estuaries during the juvenile phase of their life cycles and whose survival in South African waters is determined by the existence of ecologically viable estuaries. This category includes important angling fish, non-angling species and the four species of fresh water eels whose small elvers must pass through estuaries. Category III includes 19 species whose juveniles occur mainly in estuaries but are also found at sea. As a result these species are not entirely dependent on estuarine nurseries. Category IV comprises 28 species whose juveniles occur mainly at sea but are also abundant in estuaries, but estuaries are not essential to their survival. Category V consists of approximately 100 species whose juveniles occur at sea and only occasionally stray into estuaries. Category VI comprises 25 species which are associated with fresh water and whose juveniles seldom occur in estuaries. The category of estuarine dependence of each Knysna species recorded in Appendix VI is indicated by the appropriate roman numeral after the species name.

In the paper by Wallace and Van der Elst (1975) on the ecology of estuarine dependence of estuarine fishes it is stated that: "Although this in no way indicates that these species are totally dependent on estuaries the inference which can be drawn is that their life cycles are closely associated with this environment and are in large measure dependent upon it. It can thus be stated that the future of these sport angling and food species is directly related to the viability of estuaries."

4.2.5 Reptiles and Amphibians

Von Breitenbach (1974) lists 24 species of snakes that inhabit the Knysna area. Snakes and lizards that have been observed around the estuary include the russet snake *Duberria lutrix,* the night adder *Causus rhombeatus,* the puff adder *Bitis arietans,* a skink *Mabuya trivitata,* and a gecko *Pachydactylus porphyreus.* Reptile species are listed in Poynton (1964) and Passmore and Carruthers (1979) record a number of species of frogs and toads that occur in the Knysna area. These species are listed in Appendices VII and VIII.

4.2.6 Birds

A great diversity of birds frequent the Knysna area and the Knysna Estuary and its saltmarshes in particular. Grindley (1976a) recorded the birds frequenting the area of saltmarshes between Leisure Island and Thesen's Island in November 1975. Observations of the birds occurring in the vicinity of the sewage outfall and at a number of other localities for comparison were recorded during studies in January 1978 (Grindley and Eagle, 1978). Counts of waders in some areas of the Knysna Lagoon were made in December 1975 (Summers *et al.*, 1976). On 3 January 1979 more comprehensive counts of waders and other birds were made for Knysna Lagoon (Underhill *et al.*, 1980). The Appendix IX list of birds frequenting the estuary is a compilation of information from the above source and records the highest count for each species.

Underhill *et al.* (1980) note that it is difficult to explain the low numbers of waders recorded at Knysna on what is apparently suitable habitat. Their counts gave 75 non-Palaearctic waders, 2 799 Palaearctic waders, a total of 2 874 waders, a total of 1 015 non-waders, in all 3 889 birds. However, despite the unexpectedly low numbers of waders in that census, Knysna Lagoon was rated as the second most imporant wetland of major importance as habitats for waders in the southern and eastern Cape (Underhill *et al.*, 1980).

The southern Cape indigenous forests support a rich avifauna and Von Breitenbach (1974) lists 79 species which are commonly found in the region. The Knysna loerie, *Tauraco corythaix,* is well-known.

4.2.7 Mammals

An account of the mammals of the Knysna area is presented by Von Breitenbach (1974) who lists 46 species with notes on their habits and distribution. The largest mammal found in the Knysna area is the African elephant *Loxodonta africana africana*. Possibly as many as a dozen elephants inhabit the 25 000 ha of the Knysna forests. Accounts of the elephants of Knysna have been published by Phillips (1925), Carter (1971), Wildlife Society (EP Branch) (1970), Thesen (1981), Olivier (1982) and MacKay (1983). Mammals that are seen from time to time around the estuary include the Cape dassie *Procavia capensis*, the Cape grysbok *Raphicerus melanotis*, Cape grey mongoose *Herpestes pulverulentus pulverulentus*, the Cape dune mole *Bathyergus suillus* and the Cape fruit bat *Rousettus aegyptiacus* Leachii (J R Grindley, pers. obs.).

A list of mammals recorded from the Knysna area is presented in Appendix X.

5. SYNTHESIS AND RECOMMENDATIONS

Knysna Estuary

Knysna Lagoon is biologically the richest estuary in the Cape Province and one of the largest. Since it is permanently open, and the volume of influent fresh water relatively small, salinities are stable and near to that of seawater. This stable environment accounts for the remarkable diversity of species recorded here, the highest of any South African estuary. This biological richness and the beauty of the surrounding landscape and forests make the area particularly attractive. As a result residential and recreational developments are spreading rapidly and changing the natural and rural character of the area. This rapid development must not be allowed to affect the natural ecological processes that maintain the functioning of the lagoon, while the rural character and features which are so attractive should be maintained by carefully controlling any future development.

The Guide Plan Committee for the Knysna-Wilderness-Plettenberg Bay Area was established to provide guidelines for the future land and water use of the region (Physical Planning and Utilization of Resources Act No. 88 of 1967). In addition to this a working group of environmental experts was formed to make recommendations regarding the natural environment of the Guide Plan Area, including specific attention to the Knysna Estuary (Geldenhuys, 1979).

Nature Areas

In terms of the Guide Plan, large areas surrounding the lagoon are zoned as Nature Areas. A Nature Area is defined as follows in the Physical Planning and Utilization of Resources Act (Act 88 of 1967):

> "An area that could be utilized in the interests of and for the benefit and enjoyment of the public in general and for the reproduction, protection or preservation of wild animal life, wild vegetation or objects of geological, ethnological, historical or other scientific interest."

In the immediate vicinity of Knysna, the following have been proposed in the Guide Plan as Nature Areas: (1) Knysna Lagoon, (2) the Forests, (3) the Western Head, and (4) the Brenton Coast.

1. Knysna Lagoon

The entire area of Knysna Lagoon below the high-water mark is an ecosystem with many unique features. Consequently the lagoon has become the principal cause for concern. If the future use and conservation of Knysna Lagoon is to proceed in an orderly and co-ordinated fashion, overall management needs to be co-ordinated by a single authority exercising control over all aspects including recreational activities such as swimming, angling, water-skiing and boating. At the time of writing it appears that the National Parks Board will fulfil such a function but close collaboration with both the Knysna Local Authorities and the Environmental Conservation Directorate of the Department of Environment Affairs is essential. This joint controlling body should also ensure that all building development is appropriately sited and conforms to the criteria in the Guide Plan (Department of Constitutional Development and Planning, 1983).

The need for such co-ordinated management action is illustrated by the Ashmead Marina which appears to ignore these guidelines in that the Guide Plan states that:

"No marina development should be permitted in any part of the lagoon. Marinas are well-known to cause pollution and silting up and to create a concomitant need for maintenance. Development of this nature should be kept out of the productive intertidal zone."

However, in the Guide Plan, the area in question is zoned as a recreational area. Presumably, this is what the present owner is planning to accommodate with this marina. It appears, therefore, that there is a need to define what is meant by "recreation." However, the owner has appointed a firm of environmental planners and is thus attempting to build the marina in an environmentally acceptable manner.

The Eastern Marshes need specific conservation measures. The intertidal saltmarshes in the area between Thesen's Island and Leisure Island should, therefore, be controlled strictly and the reserve areas indicated in Figure 6 should be protected against any taking of bait and other human activities. Intertidal saltmarshes are primary producers and contribute substantially to the generation of organic detritus which supports much of the life in estuaries. The conservation of such areas is thus of fundamental importance for the survival of the lagoon ecosystem. In view of the encroachment in the area now occupied by the Ashmead Marina, the remainder of the East Marsh between Leisure Island and Ashmead should be granted Category A status. This implies that this area would be rigidly protected with limited public access, that is, restricted entry by permit only. No exploitation of any form should be allowed as such areas are to be kept in a natural state for conservation and research purposes (Grindley and Cooper, 1979). The East Marsh area from Ashmead southwards to the channel leading to the Leisure Island causeway and the saltmarshes and banks south of Thesen's Island, should be included in this reserve. The north bank of Leisure Island and the deep channel between Thesen's Island and Ashmead may be excluded.

Throughout the lagoon measures should be taken to ensure that the regulations governing fishing and the taking of bait are rigidly enforced. There are extensive areas of privately-owned land below the high-water mark as a result of purchases before 1935. The areas thus not subject to the controls specified in the Sea Shore Act (Act 21 of 1935) include Brenton-on-Lake, the area south of the caravan park at Ashmead and the area east of the link road between Knysna and The Heads opposite Leisure Island. It is unfortunate that these areas are still in private ownership as in the report on the Knysna-Wilderness Area (Department of Planning, 1970) it was recommended that all land below the high-water mark not yet the property of the State or the Provincial Administration should become so in order that control can be exercised. If necessary, the Sea Shore Act should be amended so that legal provision can be made to exercise control over the development and utilization of all land under the water which is not the property of the State.

It would seem that it was not possible for the State to acquire those portions of land and consequently the Guide Plan lays down the following guidelines to govern future development in these areas:

- No further physical development should be permitted here by the authorities concerned.

- No dredging or filling should be undertaken without the permission of the local authority.

- No revetments should be constructed, save in consultation with the local authority.

- No dumping of unpurified sewage or of toxic or other harmful substances should be allowed.

The flooded area east of the road to The Heads should be established as a bird sanctuary as it supports a very high diversity of bird life.

The whole of the Knysna Lagoon including the East Marshes, but excluding the abovementioned privately-owned land, is State land controlled by the Department of Community Development. This includes the area of the airstrip in the 'Rex Island' area and the adjoining areas cut off from tidal flow by dykes. The eastern half of Thesen's Island where there is another rough airstrip is also State land.

2. The Forests

The forests of indigenous trees and plantations of exotic trees to the north and west of Knysna are important because of the special character they impart to the area. The forests are mostly well protected and include stands of indigenous trees proclaimed "protected forests" in terms of Section 5 of the Forestry Act, (Act 72 of 1968).

The coastal plateau east of Knysna is covered by extensive forests, including the Harkerville forest, and areas of fynbos. Between the Eastern Head and Plettenberg Bay the plateau drops sharply to the sea. The section of coast between Noetsie and the Eastern Head is rugged and lies below high cliffs of exceptional scenic beauty. This coast has been proposed as a Category B coastal reserve, that is, with unrestricted public entry but no exploitation of any form being permitted (Grindley *et al.*, 1976).

3. The Western Head

The Western Head at the entrance to the Knysna Lagoon is a nature area of great interest and an outstanding landscape feature. The owner of the Western Head (Brenton Stands 59 and 60), Mr W Smith, is proposing to develop this private nature area for the benefit of the public. Certain works such as the construction of a scenic railway are already under way although the owner has not as yet applied for permission. Controls appropriate to a nature area should be applied here in keeping with this zoning of the Western Head in the Guide Plan. Reddering and Esterhuysen (1984) have stressed the need to avoid aeolian sand movement on the dunes of the Western Head. Sand influx from this source could cause serious sedimentation of the lagoon; therefore practices causing destruction of natural vegetation and thus unnecessary sedimentation, must be stopped. This would include destabilization of steep vegetated dune slopes which can lead to slumping.

Alien vegetation is replacing the indigenous vegetation in large areas around the lagoon. This has become a serious problem. There is an urgent need for control of the spreading aliens, particularly on the higher ground at the Western and Eastern Heads. In order to ensure that indigenous vegetation is not displaced by exotic plants, it should be mandatory that the aliens be removed and replaced by indigenous plants. Any such programme should be undertaken in close liaison with the Directorate of Forestry. Great care would be required to avoid the destabilization of the sensitive dune areas on the Western Head during such a replanting programme.

As has been pointed out the terrestrial portion of the Western Head is a nature area. The adjoining demarcated marine reserve between the high-water and low-water marks, should be controlled as a Category B reserve. As such there would be limited public access to the area with entry restricted by permit. Any exploitation should be strictly limited and development should be prohibited or rigidly controlled (Grindley *et al.*, 1976; Grindley and Cooper, 1979). While this area is demarcated as a marine reserve in terms of the Guide Plan no proclamation in terms of the Sea Fisheries Act (No. 58 of 1973) has taken place and it is unlikely that angling will be prohibited should the area be proclaimed a marine reserve (Chief Director of Sea Fisheries, *in litt.*).

Heydorn and Tinley (1980) proposed that the lagoon shoreline of the Brenton Peninsula up to and including the historic village of Belvedere be included in an estuarine reserve. This shoreline is of great interest in terms of natural history and educational value as well as being scenically beautiful. Unfortunately extensive foreshore development has already been allowed and the Director-General of Constitutional Development and Planning indicated that Portion 66 of the farm Belvedere which had been proposed as a nature area by the Wildlife Society could not be supported. The Minister has approved that the Guide Plan be amended to accommodate township development on that property (Director-General, Constitutional Development and Planning, *in litt.*).

4. <u>The Brenton Coast</u>

The coast between Buffels Bay and the Knysna Lagoon which includes Brenton-on-Sea has been zoned as a nature area mainly to protect the fynbos and the easily-disturbed sand dunes found there. The scenic beauty of these areas, and their high quality of indigenous vegetation, should be protected.

<u>Boats, mooring facilities and water sports</u>

It is desirable that boating and mooring facilities for boats on the Knysna Lagoon be properly organised. This need has already been identified in the Guide Plan. The creation of well-planned mooring facilites such as those included in the Ashmead Marina may thus be of benefit to the Knysna Lagoon until the proposed small boat harbour is built. The present lack of zoning of the water area for different activities gives rise to conflicts of interest. Areas for boat-launching, mooring facilities, sailing, power boating, water-skiing, swimming, oyster cultivation and saltmarsh and marine reserve areas all need to be clearly defined.

It has been suggested that implementation of appropriate zonation of the Knysna Estuary for the various purposes specified can be implemented by means of the Sea Fisheries Act (No. 59 of 1973), the Sea-Shore Act (No. 21 of 1935) and the Regulations for Water Sport Control areas. The responsible controlling body should identify areas for water-skiing where this sport will not interfere with other uses of the lagoon. Cabin cruisers and house boats providing residential accommodation introduce particular problems that will require the attention of the proposed controlling authority. For example, regulations are needed to provide, for the treatment and disposal of sewage and other refuse from these craft as well as for regular inspection and maintenance for licensing. There is no doubt that the availability for hire of cabin cruisers and houseboats can enhance Knysna's tourist potential and should, for this reason, be encouraged. At the same time, however, there should be effective control over this type of development to avoid exceeding the carrying capacity of the lagoon. An overall total of 20 commercial houseboat/residential cruisers for the entire lagoon has been suggested (Department Constitutional Development and Planning, Guide Plan, 1983).

According to informed sources, currently some 400 boats of various types are permanently based on the Knysna Lagoon but during the holiday seasons this number can double. This again highlights the need for zoning and control to prevent conflicts of interest. It has been widely recognized that there is a need for facilities for small recreational boats (Department of Planning, 1970; Grindley, 1976a). Proposals and plans for small boat harbour facilities adjoining the Thesen's Island Causeway and/or at the Thesen's Wharf were prepared by the Research Group for Ocean Engineering of Stellenbosch University together with the Fisheries Development Corporation (1980). The proposed site, near the causeway to Thesen's Island, is somewhat degraded but has retained some burrowing organisms and saltmarsh vegetation. Inevitably the proposed harbour in this area will reduce the productivity and richness of the estuary to an extent related to the area of the intertidal zone destroyed. This adverse impact should not be overlooked and the ecological costs need to be assessed in relation to the benefits of the proposed facilities. While some areas will be covered by fill, the areas that remain as the floor of the harbour should be open to tidal exchange so that their biological function may be retained.

Thesen's Island and Industrial Development

Thesen's Island is an important feature in Knysna Lagoon and the planning of this area must be carefully considered:

- The existing timber industry on the island is well-established and as such is not likely to be moved in the foreseeable future. Considering the need to protect the lagoon ecosystem against unnecessary human interference with concommitant pollution hazards and constriction of tidal exchange by causeways, the siting of this industrial endeavour on the island is far from ideal. The continued application of strict precautions to prevent both air and water pollution is therefore essential. The Guide Plan suggests that no form of permanent residential development should be permitted on the island but it seems reasonable to permit limited recreational activities such as camping and picnicking in suitable areas.

- The possibility of a small boat harbour on the western shore of the island should be considered.

- Boat-building activities on a limited scale are established on the island which seems to be suitable for this purpose and in keeping with the history and image of Knysna.

Future Developments

Development of Knysna's municipal waterfront requires careful attention. Appropriate recreational facilities to benefit users of the lagoon are needed but great care must be taken to ensure that such developments do not disrupt natural water movements in the lagoon. The specialists who considered waterfront development in 1976 recommended that it should be largely on pilings so as to avoid adversely affecting hydrological processes (Grindley, 1976a). According to this group an overall plan for waterfront development is desirable. This could include hotel and other accommodation, jetties, parking, boat storage and maintenance facilities. Since space is limited in the foreshore area it is important that planning of waterfront development be carried out in close liaison with the South African Transport Services. Thus the Knysna waterfront development should be closely integrated with the overall planning of the town. A key question at present is the potential effect of the proposed arterial road (the "internal bypass") which, if built, will separate the town from its primary feature, the Knysna Lagoon. While Knysna needs relief from internal traffic congestion, this should not be confused with the provision of a road to carry heavy traffic between Port Elizabeth and the industrial growth centres of the George/Mossel Bay region. During intensive debate at a number of heated public meetings strong opposition against the "internal bypass" was expressed on aesthetic, ecological and commercial grounds. Fears of pollution of the lagoon, either from road run-off, or worse, because of the danger of accidents involving road tankers, were expressed. The noise and vibrations emanating from such a road also elicited much concern.

Space does not permit discussion of the pros and cons of the "internal bypass." In summary it can be said, however, that a final decision should not be taken until a proper town planning scheme for Knysna and the Management Plan for the Knysna Lagoon ecosystem have been drawn up. The Municipality has undertaken to prepare the former and the National Parks Board the latter in view of the fact that Knysna Lagoon is to become a National Lakes Area under its control. The road must be seen as only one development project of many and what is really at stake is the future economic viability of the town and the ecological viability of the lagoon. The answer may well lie in the upgrading of the internal thoroughfare through Knysna on a more modest scale and the provision of an external bypass to the north of the town. The latter would be considerably more expensive, but the value of Knysna Lagoon in a healthy condition, simply cannot be assessed in monetary terms. Only in the short term will the latter option be considerably more expensive since the National Transport Commission have indicated that, in any event, the external bypass will have to be built in a few year's time.

No further causeways or dykes that might affect the hydraulic regime of the estuary should be allowed and any further bridges such as that for the upgraded National Road (N2) should not disturb natural flow patterns. The bridge will have a single span but special precautions are necessary to prevent deposition of material in the river during construction. Visual and ecological disturbances should also be limited to a minimum throughout the length of the route. This last requirement should apply in all cases where new roads are constructed or existing roads are upgraded. In this context the long causeway crossing of the lagoon proposed by the Cape Provincial Roads Department in 1965 in their plan CNR/S30/61 would be unacceptable.

When considering further residential development particular attention needs to be given to the requirements of the Black and Coloured people whose populations are growing rapidly. In 1982 Knysna's Black population stood at 4 900 and is expected to rise to about 7 500 by the end of the century. The land allocated for further Black and Coloured residential developments has been shown by the Guide Plan to be inadequate.

Water supply is one of the basic limiting resources for the future development of the Knysna region. Knysna's water is supplied by pipelines from three dams on rivers flowing into the lagoon. The water requirements of the proposed Black and Coloured residential areas and the rising consumption of water in the remainder of the town, have necessitated that the Town Council search for additional water supplies. Surveys have shown that the domestic water requirements of the area can still be supplied from local sources. However, it has been recognized already that there is a potential conflict between the needs of Knysna Lagoon for fresh water to maintain its natural ecological functions (Grindley, 1970) and the needs for water for the human population. Further studies are required here and at other estuaries to ensure that water abstraction from rivers does not destroy the functioning of estuarine ecosystems. Any dam or related structure that may be built should be so designed to have the minimum ecological and aesthetic impact.

Administrative Control of Amenities

Because of its natural assets for recreation and tourism, the Knysna area is assured of an increasing rate of development. It is essential, therefore, that public and private responsibility be directed towards maintaining the amenity value of the region which must be seen as part of the national heritage. Regional and local planning must play a role not only in improving the prosperity of the inhabitants but must also preserve the beauty and unrivalled charm of the area (Tyson, 1971).

A fundamental requirement that has been stressed recently by Government authorities is that environmental impact studies should be prepared for developments in sensitive coastal areas. Only in this way can unexpected adverse effects and unnecessary damage to our coastal environment be avoided.

A large number of authorities have legislation affecting various aspects of Knysna Lagoon. To promote co-ordinated government attention to environmental matters there is a need for the rationalisation of existing acts, regulations, ordinances and bye-laws. The increasing population and the many developments in the area are causing various problems in this estuary. The uniqueness of this system requires special attention to ensure protection of its ecological balance and provide for the multi-purpose utilization of the estuary and its environs. It is clearly necessary, as proposed earlier, that a single body manages the lagoon. This body, with representation from the Department of Environment Affairs and appropriate advisors, should control recreational activities and ensure that the requirements of the Knysna-Wilderness-Plettenberg Bay Guide Plan are implemented.

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Aerial Photography

Date	Job No.	Photos Nos	Scale	Colour	Source
1936	11436	19199, 19200	1:20 000	B&W	Trig. Survey
1942	6/42	10418, 10419, 10434, 10435	1:28 000	B&W	Trig. Survey
80-04-09	349	43	1:28 000	B&W	Trig. Survey
Dec. 1980	374	173-175	1:20 000	B&W	Trig. Survey
79-04-21	326	327-332	1:10 000	Col.	University of Natal

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^{o}, 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.

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APPENDIX I: Phytoplankton

Diatoms-
Achnanthes longipes Ag
Actinocyclus ehrenbergi Ralfs
Actinoptychus undulatus Ralfs
Amphora ovalis Kütz
Bacillaria paradoxa Gmelin
Bacteriastrum sp
Biddulphia pulchella Gray
Biddulphia regia (Schultze Ostf
Chaetoceros sp
Climacosphemia moniligera Ehr
Cocconeis scuttellum Ehr
Cocconeis sp
Coscinodiscus excentricus Ehr
Coscinodiscus marginatus Ehr
Coscinodiscus nitidus Greg
Coscinodiscus nodulifer A S
Concinodiscus radiatus Ehr
Coscinodiscus stellaris Roper
Grammatophora angulosa Ehr
Grammatophora marina Kütz
Isthmia enervis Ehr
Licmophora (type *flabellata* Ag.)
Licmophora (type *paradoxa* Ag.)
Mastogloia bonatata (Grun.) Cl
Melosira sulcata (Ehr.) Kütz
Melosira sp
Navicula sp
Nitzschia sigma (Kütz) W. Sm
Planktoniella sol (Wall) Schütt
Pleurosigma (type *aestuarii* W. Sm)
Rhizosolenia alata Brightw
Rhoicosphenia curvata (Kütz) Grun.
Skeletonema costatum (Grev.) Cleve
Stephanopyxis turris Ralfs
Striatella unipunctata (Lyngb.) Ag
Synedra sp
Thalassiothrix longissima Cl. and Grun
Thalassionema sp
Triceratium favus Ehr

Insertae sedis:
Spermagtogonia antiqua Leud. Fortm

Silicoflagellata:
Dictyocha fibula Ehr
Distephanus speculum (Ehr.) Haeck

Dinoflagellata:
Ceratium sp
Noctiluca miliaris Suriray
Peridinium sp.

(Sources: Korringa, 1956; Grindley, 1976a; Grindley, 1978b and Grindley & Eagle, 1978).

APPENDIX II: Aquatic, semi-aquatic and marginal vegetation.

Saltmarsh plant species

The dominant saltmarsh plants occurring in the Knysna Estuary are:

Chenolea diffusa
Halophila ovalis
Limonium scabrum
Plantago carnosa
Sarcocornia decumbens
Sarcocornia perenne
Spartina maritima
Triglochin bulbosa/striata
Zostera capensis

Marginal vegetation of Knysna Lagoon

Above HWST a large number of species appear including:

Carpobrotus edulis
Chenolea diffusa
Chenopodium album
Cotula coronopifolia
Dimorphotheca pluvialis
Disphyma crassifolium
Eragrostis spp
Falkia repens
Felecia ficoidea
Ficinia lateralis
Gazania rigens
Juncus kraussii
Limonium scabrum
Phragmites australis
Pycreus polystrachyus
Sarcocornia pillansii
Senecio burchellii
Samolus porosus
Sporobolus pungens
Sporobolus virginicus
Stenotaphrum secundatum
Typha capensis

APPENDIX III: Major species of trees in the Knysna Forests (Van Breitenbach, 1974)

The numbers from the South African National List of Trees are included.

Tree No.	Botanical name	Common name
2	*Cyathea capensis*	Tree fern
16	*Podocarpus falcatus*	Outenique yellowwood
18	*Podocarpus latifolius*	Upright yellowwood
20	*Widdringtonia nodiflora*	Mountain cypress
32	*Strelitzia alba*	Wild banana
39	*Celtis africana*	White stinkwood

APPENDIX III: (Cont.)

Tree No.	Botanical name	Common name
50	*Ficus capensis*	Wild fig
118	*Ocotea bullata*	Stinkwood
140	*Cunonia capensis*	Rooiels
141	*Platylophus trifoliatus*	Witels
142	*Trichocladus crinitus*	Onderbos
221	*Virgilia oroboides*	Keurboom
254	*Fagara davyi*	Knobwood
261	*Vepris undulata*	White ironwood
298	*Ekebergia capensis*	Essenhout
297	*Ilex mitis*	Without
298	*Maytenus acuminata*	Sybas
409	*Pterocelastrus tricuspidatus*	Kershout
415	*Cassine papillosa*	Saffron
422	*Apodytes dimidata*	White pear
451	*Scutia myrtina*	Katdoring
494	*Kiggelaria africana*	Wild peach
496	*Scolopia mundii*	Red pear
513	*Olinia cymosa*	Hard pear
565	*Cussonia thyrsiflora*	Cabbage tree
570	*Curtisia dentata*	Assegai wood
578	*Rapanea melanophloeos*	Boekenhout
579	*Sideroxylon inerme*	Milkwood
611	*Diospyros whyteana*	Swartbas
615	*Linociera foveolata*	Fynblaarysterhout
618	*Olea capensis macrocarpa*	Ironwood
634	*Nuxia floribunda*	Vlier
639	*Acokanthera oppositifolia*	Gifboom
641	*Gonioma kamassi*	Kamassie
670	*Haleria lucida*	Notsung
688	*Burchellia bubalina*	Wild pomegranate
733	*Tarconanthus camphoratus*	Camphor bush
736	*Chrysanthemoides monilifera*	Bietou

APPENDIX IV: Zooplankton species recorded from Knysna Lagoon and surrounding wetlands (from Korringa, 1956; Day *et al.* 1952; Benson and Maddocks, 1961; Grindley, 1976(a); Grindley and Eagle, 1978).

PROTOZOA
Foraminifera
Noctiluca milliaris

CNIDARIA
Hydroid medusae
Rhizostoma sp

ANNELIDA
Polychaete larvae

CHAETOGNATHA
Sagitta sp

APPENDIX IV: (Cont.)

CLADOCERA
Penilia avirostris

OSTRACODA
Perissocytherida sp. aff *estuaria*
Paracypris sp. aff *westforsdensis*
Cyclocypris pusilla
Physecocypria capensis
Cypridopsis assimilis
Cypridopsis viduella
Cypridopsis gregaria
Cypricercus suneatus
Eucypris corpulenta
Eucypris trigona
Heterocypris aurea
Heterocypris incongruens
Hemicypris sp.
Mesocypris terrestris
Potamocypris sp.

COPEPODA
Acartia (Paracartia) africana
Acartia (Paracartia) longipatella
Acartia (Acartiella) natalensis
Amphiascus sp.
Calanoides carinatus
Cyclops sp.
Clausidium sp.
Clausocalanus furcatus
Clausocalanus laticeps
Corycaeus africana
Corycaeus sp.
Corycaeus tenuis
Euterpina acutifrons
Halicyclops sp.
Harpacticus gracilis
Harpacticus sp.
Microsetella rosea
Oithona brevicornis
Oithona nana
Oithona oculata
Oithona similis
Oncaea subtilis
Oncaea mediterranea
Paracalanus aculeatus
Paracalanus crassirostris
Paracalanuus parvus
Pseudodiaptomus hessei
Pseudodiaptomus nudus
Saphirella stages

MYSIDACEA
Gastrosaccus brevifissura
Leptomysis tattersalli
Mesopodopsis africana
Rhopalopthalamus terranatalis

APPENDIX IV: (Cont.)

CIRRIPEDIA
Cypris larvae
Nauplius larvae

CUMACEA
Iphinoe truncata

ISOPODA
Parasitic isopod
Paridotea ungulata

AMPHIPODA
Austrochiltonia subtenuis
Grandidierella bonnieroides
Melita zeylanica
Paramoera capensis

DECAPODA
Zoea and Mysis larvae
Palaemon pacificus

MOLLUSCA
Gastropod and Lamellibranch larvae

OSTEICHTHYES

Fish eggs and larvae

APPENDIX V: Common burrowing invertebrates of Knysna Lagoon. Invertebrate biomass values per square metre in eastern Knysna saltmarshes.

Species	Ashfree dry biomass (g/m^2)
Assiminia ovata	0,03 - 6,52
Sesarma catenata	0,84 - 102,93
Ceratonereis erythraeensis	0,03 - 3,30
Glycera convoluta	0,1 - 0,76
Upogebia africana	0,08 - 16,28
Diogenes brevirostris	0,23 - 2,4
Natica genuana	0,06
Solen capensis	0,87
Nassa kraussiana	0,01 - 4,4
Alphaeus crassimanus	1,3
Macoma littoralis	0,11 - 2,66
Dosinia hepatica	0,16 - 18,88
Marphysa sanguinea	9,19 - 21,58
Loripes clausus	1,65 - 22,70
Haminea alfredensis	0,01 - 0,13
Tellina trilatera	11,63
Cleistostoma spp.	1,38 - 4,61
Cyclograpsus punctatus	1,83 - 10,01
Hymenosoma orbiculare	0,23 - 0,50

APPENDIX V: (Cont.)

Species	Ashfree dry biomass (g/m^2)
Talorchestia ancheidos	0,08
Lysianassa ceratina	0,14
Paridotea ungulata	0,03
Lamya capensis	0,72
Thaumastoplax spiralis	0,02
Cyathura estuaria	0,025
Exosphaeroma hylecoetes	0,04
Cirriformia tentaculata	0,10
Betaeus jucundus	0,03

(Sources: Grindley, 1976a; Grindley & Eagle, 1978; Grindley and Snow, 1983). A comprehensive list including a total of 375 species recorded from Knysna Lagoon is presented in Day *et al.* 1952.

APPENDIX VI: Common fish species of Knysna Lagoon

Species	Common name	Category of estuarine dependance
Sphyrna zygaena	Hammerhead shark	V
Odontaspis taurus	Ragged tooth shark	V
Poroderma africanum	Striped catshark	V
Rhinobatus annulatus	Lesser guitarfish	V
Myliobatis aquila	Eagle ray	V
Dasyatis pastinacus	Blue stingray	V
Gymnura natalensis	Backwater butterfly ray	V
Torpedo fuscomaculata	Black spotted electric ray	V
Elops machnata	Ten pounder	II
Gilchristella aestuarius	Estuarine round-herring	I
Sardinops ocellata	South African pilchard	V
Engraulis capensis	Cape anchovy	V
Galeichthys feliceps	Sea barbel	IV
Trachinocephalus myops	Painted lizard fish	V
Hyporhamphus knysnaensis	Knysna halfbeak	II
Hemirhamphus far	Spotted halfbeak	IV
Heteromycteris capensis	Cape sole	III
Synaptura kleini	Lace sole	V
Solea bleekeri	Sand sole	III
Hippocampus capensis	Knysna seahorse	I
Syngnathus acus	Longnose pipefish	IV
Syngnathus spicifer	Bellybarred pipefish	IV
Terapon jarbua	Thornfish	II
Serranus knysnaensis	Knysna rockcod	V
Lichia amia	Leervis	II
Pomatomus saltatrix	Elf	IV

APPENDIX VI: (Cont.)

Species	Common name	Category of estuarine dependance
Argyrosomus hololepidotus	Kabeljou (kob)	IV
Umbrina capensis	Baardman	V
Monodactylus falciformis	Cape moony	II
Chaetodon marleyi	Butterfly fish	V
Coracinus capensis	Galjoen	V
Pomadasys olivaceum	Varkie	V
Pomadasys commersonni	Spotted grunter	II
Rhabdosargus globiceps	White stumpnose	IV
Rhabdosargus holubi	Cape stumpnose	II
Rhabdosargus sarba	Natal stumpnose	II
Diplodus sargus	Blacktail (dassie)	IV
Diplodus cervinus	Zebra	V
Lithognathus lithognathus	White steenbras	II
Lithognathus mormyrus	Sand steenbras	V
Sarpa salpa	Strepie	IV
Spondyliosoma emarginatum	Steentjie	V
Mugil cephalus	Flathead mullet	II
Liza tricuspidens	Striped mullet	III
Liza richardsoni	Southern mullet	IV
Myxus capensis	Freshwater mullet	II
Hepsetia brecíveps	Cape silverside	III
Psammogobius knysnaensis	Knysna sand goby	I
Stigmatogobius dewaali	Checked goby	II
Gobius nudiceps	Barehead goby	I
Omobranchus woodi	Kappie blenny	V
Clinus superciliosus	Super klipfish	V
Platycephalus indicus	Bartail flathead	IV
Trigla kumu	Bluefin gurnard	V
Apletodon pellegrini	Chubby clingish	V
Anguilla mossambica	Eel	II
Ophisurus serpens	Serpent eel	III
Conger wilsoni	Conger eel	V
Diodon hystrix	Porcupine fish	V
Amblyrhynchotes honckenii	Blaasop	IV

(List compiled by J R Grindley from information provided by Professor M M Smith. Category of estuarine dependance according to Wallace, *et al.* (1984)).

APPENDIX VII: The following species of frogs and toads have been recorded from the Knysna area by Poynton (1964) and Passmore & Carruthers (1979).

Amphibia

Platanna	-	*Xenopus laevis* (Daudin)
Southern Cape ghost frog	-	*Heleophryne p. regis* Hewitt
Common toad	-	*Bufo angusticeps* Smith
Raucous toad	-	*Bufo rangeri* Hewitt
Plain rain frog	-	*Breviceps fuscus* Hewitt
Common river frog	-	*Rana angolensis* Bacage

APPENDIX VII: (Cont.)

Amphibia		
Common rana	-	*Rana fuscigula* Dumeril & Bibron
Spotted rana	-	*Rana grayi grayi* Smith
Long-toed frog	-	*Rana fasciata fasciata* Smith
Common caco	-	*Cacostermyn boettgeri* (Boulenger)
Bronze caco	-	*Cacosternum nanum nanum* Boulenger
Rattling kassina	-	*Kassina wealei* Boulenger
Golden leaf-folding frog	-	*Afrixalus brachyenemis knysnae* (Loveridge)
Arum lily frog	-	*Hyperolius horstocki* (Schlegel)

APPENDIX VIII: Reptiles in and around the Knysna Lagoon (N G Palmer, CDNEC *in litt.)*

Reptiles		
Delalande's blind snake	-	*Typhlops lalandei*
Brown water snake	-	*Lycodonomorphys rufulus*
Aurora house snake	-	*Lamprophis aurora*
Olive house snake	-	*Lamprophis inornatus*
Brown house snake	-	*Lamprophis fuliginosus*
Russett garden snake	-	*Duberria lutrix*
Mole snake	-	*Pseudaspsis cana*
Rhombic skaapsteker	-	*Psammophylax rhombeatus*
Cross-marked grass snake	-	*Psammophis crucifer*
Green water snake	-	*Philothamnus hoplogaster*
Herald snake	-	*Crotaphopeltis hotamboeia*
Boomslang	-	*Dispholidus typus*
Common egg-eater	-	*Dasypeltis scabra*
Cape cobra	-	*Naja nivea*
Common night adder	-	*Causus rhombeatus*
Cape mountain adder	-	*Bitis atropos*
Pufadder	-	*Bitis arietans*
Striped skink	-	*Mabuya capensis*
Sand lizard	-	*Eremias lineocelata*
Amber acontias	-	*Acontias meleagris*
Black zonure	-	*Cordylus cordylus*
Gecko	-	*Pachydactylus geitjie*
Anguluate tortoise	-	*Chersine angulata*
Padlopertjie	-	*Homopus areolatus*
Cape terrapin	-	*Pelomedusa subrufa*
Loggerhead turtle	-	*Caretta caretta*

APPENDIX IX: Water associated birds of Knysna Lagoon. List provided by Palmer and Boshoff *(in litt.)*. Counts are maximum counts per species from Grindley (1976a), Grindley and Eagle (1978), Underhill *et al.* (1980) and Grindley (1983). Only published counts are included below.

Roberts number	Common Name	Species	Count
4	Great Crested Grebe	- *Podiceps cristatus*	-
6	Dabchick	- *Tachybaptus ruficollis*	-
47	White-breasted Cormorant	- *Phalacrocorax carbo*	5
48	Cape Cormorant	- *Phalacrocorax capensis*	4
50	Reed Cormorant	- *Phalacrocorax africanus*	134

APPENDIX IX: (Cont.)

Roberts number	Common Name	Species	Count
52	Darter	- *Anhinga rufa*	-
54	Grey Heron	- *Ardea cinerea*	17
56	Goliath Heron	- *Ardea goliath*	1
57	Purple Heron	- *Ardea purpurea*	3
59	Little Egret	- *Egretta garzetta*	68
60	Yellow-billed Egret	- *Egretta intermedia*	1
61	Cattle Egret	- *Bubulcus ibis*	108
69	Night Heron	- *Nycticorax nycticorax*	-
72	Hamerkop	- *Scopus umbretta*	-
81	Sacred Ibis	- *Threskiornis aethiopicus*	-
84	Hadeda	- *Hagedashia hagedash*	-
85	African Spoonbill	- *Platalea alba*	-
88	Spur-winged Goose	- *Plectropterus gambensis*	-
89	Egyptian Goose	- *Alopochen aegyptiacus*	1
94	Cape Shoveler	- *Anas smithii*	39
96	Yellow-billed Duck	- *Anas undulata*	172
97	Red-billed Teal	- *Anas erythrorhyncha*	-
98	Cape Teal	- *Anas capensis*	-
102	Red-eyed Pochard	- *Netta erythrophthalma*	-
130	Black-shouldered Kite	- *Elanus caeruleus*	4
149	Fish Eagle	- *Haliaeetus vocifer*	1
169	African Marsh Harrier	- *Circus ranivorus*	1
172	Osprey	- *Pandion haliaetus*	-
197	Water Rail	- *Rallus caerulescens*	-
203	Black Crake	- *Limnocorax flavirostris*	-
208	Purple Gallinule	- *Porphyrio porphyrio*	-
210	Moorhen	- *Gallinula chloropus*	-
212	Red-knobbed Coot	- *Fulica cristata*	-
231	Black Oystercatcher	- *Hematopus moquini*	13
231	Turnstone	- *Arenaria interpres*	12
233	Ringed Plover	- *Charadrius hiaticula*	115
235	White-fronted Sandplover	- *Charadrius marginatus*	12
237	Kittliz's Sandplover	- *Charadrius pecuarius*	8
238	Three-banded Sandplover	- *Charadrius tricollaris*	1
241	Grey Plover	- *Pluvialis squatarola*	451
242	Crowned Plover	- *Stephanibyx coronatus*	11
245	Blacksmith Plover	- *Hoplopterus armatus*	18
250	Ethiopian Snipe	- *Gallinago nigripennis*	-
251	Curlew Sandpiper	- *Calidris ferruginea*	1 385
253	Little Stint	- *Calidris minuta*	37
254	Knot	- *Calidrus canutus*	1
255	Sanderling	- *Calidris alba*	8
256	Ruff	- *Philomachus pugnax*	-
258	Common Sandpiper	- *Tringa hypoleucos*	28
262	Marsh Sandpiper	- *Tringa stagnatilis*	5
263	Greenshank	- *Tringa nebularia*	305
264	Wood Sandpiper	- *Tringa glareola*	4
267	Curlew	- *Numenius arquata*	1
268	Whimbrel	- *Numenius phaeopus*	176
269	Avocet	- *Recurvirostra avosetta*	-
270	Stilt	- *Himantopus himantopus*	10
274	Water Dikkop	- *Burhinus vermiculatus*	1

APPENDIX IX: (Cont.)

Roberts number	Common Name	Species	Count
275	Dikkop	- *Burhinus capensis*	3
287	Kelp Gull	- *Larus dominicanus*	355
290	Caspian Tern	- *Hydroprogne caspia*	1
291	Common Tern	- *Sterna hirundo*	13
296	Sandwich Tern	- *Sterna sandvicensis*	21
298	Swift Tern	- *Sterna bergii*	-
304	White-winged Black Tern	- *Chlidonias leucoptera*	13
361	Marsh Owl	- *Asio capensis*	-
394	Pied Kingfisher	- *Ceryle rudis*	11
395	Giant Kingfisher	- *Megaceryle maxima*	1
296	Half-collared Kingfisher	- *Alcedo semitorquata*	-
397	Malachite Kingfisher	- *Corythornis cristata*	-
493	European Swallow	- *Hirundo rustica*	9
609	African Sedge Warbler	- *Bradypterus baboeculus*	2
686	Cape Wagtail	- *Motacilla capensis*	27

APPENDIX X: Mammals recorded in the Knysna area (Von Breitenbach, 1974).

CHRYSOCHLORIDAE, GOLDEN MOLE FAMILY
Chlorotalpa duthieae
(Duthie's Golden Mole)
Amblysomus hottentotus devilliersi
(Hottentot Golden Mole)
Amblysomus iris corriae
(Knysna Golden Mole)

PTEROPIDAE, FRUIT BAT FAMILY
Rousettus aegyptiacus leachii
(Cape Fruit Bat)

CERCOPITHECIDAE, MONKEY AND BABOON FAMILY
Cercopithecus pygerythrus pygerythrus
(Vervet Monkey)
Papio ursinus ursinus (Chacma Baboon)

LEPORIDAE, HARE FAMILY
Lepus saxatilis saxatilis
(Southern Bush Hare, Scrub Hare)

MURIDAE, COMMON MOUSE FAMILY
Praomys verreauxi (Cape Mouse)
Thamnomys dolichurus (Forest Mouse)

SORICIDAE, SHREW FAMILY
Myosorex varius (Forest Shrew)
Crocidura flavescens
(Giant Musk Shrew)

RHINOLOPHIDAE, HORSESHOE BAT FAMILY
Rhinolophus clivosus
(Geoffroy's Horseshoe Bat)
Rhinolophus capensis
(Cape Horseshoe Bat)
Nycteris thebaica (Long-eared Bat)
Miniopterus fraterculus
(Black Clinging Bat)
Kerivoula lanosa (Woolly Bat)
Myotis tricolor (Cape Hairy Bat)
Pipistrellus kuhlii broomi
(Kuhl's Bat)
Eptesicus hottentotus hottentotus
(Long-tailed Housebat)

MUSCARDINIDAE, DORMOUSE FAMILY
Graphiurus ocularis (Cape Dormouse)
Graphiurus murinus (Forest Dormouse)

HYSTRICIDAE, PORCUPINE FAMILY
Hystrix africae-australis (Porcupine)

APPENDIX X: (Cont.)

CRICETIDAE, OTOMYS AND CLIMBING MOUSE FAMILY
Otomys irroratus (Vlei Otomys)
Dendromus mesomelas (Climbing Mouse)

BATHYERGIDAE, MOLE-RAT FAMILY
Bathyergus suillus (Cape Dune Mole-rat)
Georychus capensis (Cape Mole-rat)
Cryptomys hottentotus hottentotus (Common Mole-rat)

VIVERRIDAE, GENET AND MONGOOSE FAMILY
Genetta tigrina (Large-spotted Genet)
Herpestes ichneumon cafer (Cape Ichneumon)
Herpestes pulverulentus pulverulentus (Cape Grey Mongoose)
Atilax paludinosus paludinosus (Water Mongoose)

ELEPHANTIDAE, ELEPHANT FAMILY
Loxodonta africana africana (African Elephant)

SUIDAE, PIG FAMILY
Potamochoerus porcus koiropotamus (Bush Pig)

MUSTELIDAE, RATEL, POLECAT AND OTHER FAMILY
Mellivora capensis capensis (Honey Badger)
Ictonyx striatus (Cape Polecat)
Aonyx capensis capensis (Clawless Otter)

FELIDAE, CAT FAMILY
Felis lybica cafra (Cape Wild Cat)
Felis serval serval (Serval Cat)
Felis caracal caracal (Caracal)
Panthera pardus melanotica (Leopard)

PROCAVIIDAE, HYRAX FAMILY
Procavia capensis (Cape Dassie)

BOVIDAE, ANTELOPE FAMILY
Pelea capreolus (Grey Rhebuck)
Tragelaphus scriptus sylvaticus (Cape Bushbuck)
Cephalophus monticola monticola (Blue Duiker)
Oreotragus oreotragus oreotragus (Cape Klipspringer)
Raphicerus melanotis Cape Grysbok

APPENDIX XI: Guide to available information

ESTUARY / RIVERMOUTH / LAGOON: KNYSNA

Guide to available information

Group	Subgroup	Sources of information	Acocks	Begg	Begg	Benson and Maddocks	Bulpin	Butzer and Helgren	Cape of Good Hope Proclamation 357 of	Cape Provincial Administration	Cape Provincial Administration	Carter	Chmelik *et al*	Chunnett	Coates Palgrave	Davies	Davies	Day	Day	Day (a)
YEAR (DATE OF INFORMATION)			1975	1978	1979	1961	1978	1972	1972	1965	1973	1971	1975	1965	1977	1948	1971	1964	1967	1980
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 XI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: KNYSNA

Guide to available information

Category	Group	Topic	Day (b)	Day (ed)	Day, Millard and Harrison	Dingle, Siesser and Newton	Du Toit	Duvenage	FitzSimons	FitzSimons	Geldenhuys	Geldreich	Genade	Greig	Grindley	Grindley (a)	Grindley (b)	Grindley	Grindley	Grindley, Cooper and Hall
YEAR (DATE OF INFORMATION)			1980	1981	1952	1983	1966	1983	1928	1962	1979	1974	1973	1982	1970	1976	1976	1980	1981	1976
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		*	*											*				

Sources of information

APPENDIX XI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: KNYSNA

Guide to available information

Sources of information	Grindley and Cooper	Grindley and Eagle	Grindley and Snow	Helgren and Butzer	Heydorn and Tinley	Hughes and Görgens	Jackson and Lipschitz	Isaac	Kirsten	Knysna Lagoon Model Investigation	Korringa	Krige	Le Roi le Riche and Hey	List of Hydrological Guaging stations	MacKay	McLachlan, Brenner and Mcmillan	McKenzie	Metlerkamp
YEAR (DATE OF INFORMATION)	1979	1978	1983	1977	1980	1981	1984	1937	1982	1976	1956	1927	1947	1979	1983	1976	1971	1961
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 XI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: KNYSNA

Category	Group	Guide to available information	Midgley and Pitman (1969)	Millard (1950)	Miller (1963)	Miller (1975)	Moll and Bossi (1983)	Monthly flow records (1960)	Mortelmans (1945)	Nimmo (1976)	Ninham Shand Inc. (1980)	Noble and Hemens (1978)	NRIO and VISKOR (1980)	Olivier (1982)	Passmore and Carruthers (1979)	Phillips (1925)	Phillips (1931)	Pitman *et al* (1981)	Poynton (1964)	Proposed Braamekraal Marina, Knysna Model (1974)
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										*					*			*

YEAR (DATE OF INFORMATION) — given in brackets after each source of information.

APPENDIX XI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON	YEAR (DATE OF INFORMATION)	ABIOTIC														BIOTIC																	MANAGEMENT				
		Physiography			Geology			Physics					Chemistry				Flora					Fauna															
		Catchment characteristics	Dams/Obstructions	Morphology	Geology	Palaeoenvironment	Sedimentology	Climate	Oceanography	Hydrology / Flood regime	Circulation and mixing	Salinity	General Chemistry	Eutrophication	Pollution	Microbiology	Phytoplankton	Algae	Aquatic vegetation	Semi-aquatic vegetation	Terrestrial vegetation	Zooplankton	Terrestrial invertebrates	Other aquatic invertebrates	Crustaceans	Molluscs	Fish	Amphibians	Reptiles	Birds	Mammals	Food webs / Ecosystems	Water	Legislation	Management / Planning	Conservation / Utilization	Historical
KNYSNA																																					
Sources of information		Guide to available information																																			
Reddering	1980			*																																	
Reddering and Esterhuysen	1984	*		*	*	*	*	*		*	*	*							*		*														*	*	*
Retief *et al*	1979			*					*	*	*																							*	*	*	
River flow data	1978		*								*																						*				
Roberts	1978																													*							
Smith	1949								*																		*		*			*				*	
Smithers	1983																														*						
Department of Constitutional Development	1983	*		*	*		*	*							*					*	*										*		*	*	*	*	*
Department of Planning	1970	*		*	*	*	*	*		*			*						*		*			*						*	*			*	*	*	*
South Africa, Forestry Act No 72	1968																				*													*	*		
South Africa, Physical Planning Act 88	1967																																	*	*	*	
South Africa, Sea Fisheries Act No 58	1973																*	*				*		*	*	*	*							*	*	*	
South Africa, Sea Shore Act 21	1935						*																											*	*	*	
South Africa, Water Act No 54	1956									*	*																						*	*	*	*	
South African Tide Tables	1980								*																										*		
Stirton (ed)	1978																				*													*	*	*	
Summers, Pringle and Cooper	1976																													*					*	*	
Tapson	1961																																				*

APPENDIX XI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: KNYSNA

Sources of information			Thesen	Thiergart, Frantz and Raukopf	Toerien	Tyson	Underhill, Cooper and Waltner	Von Breitenbach	Wallace and Van der Elst	Wallace *et al*	Watling and Watling	Watling and Watling	Watling and Watling	Watling and Watling	Watling and Watling	Watling, Watling and Butler	Watling, Watling and Butler	Wildlife Society of Southern Africa	Zietsman and Schutte	Zwamborn
YEAR (DATE OF INFORMATION)			1981	1963	1979	1971	1980	1974	1975	1984	1975	1975	1977	1979	1980	1977	1978	1970	1980	1980
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			*	*		*												

Guide to available information

NOTES

PLATE I:

The mouth of Knysna Lagoon from the Eastern Head with the Western Head on the right. The Western Head has a base of quartzitic rocks of the Peninsula Formation which are remarkably eroded to form cave and bridge formations by the sea. The upper part of the Western Head are aeolian sands fixed by natural vegetation. (Photo: J R Grindley, February 1983).

PLATE II:

The salt marshes of the eastern side of Knysna Lagoon near Ashmead. The foreground includes species of plants occurring near HWST including *Chenolea*, and *Limonium* while *Triglochin* and *Spartina* may be seen lower on the shore. Thesen's island lies beyond the channel to the right while Brenton-on-Lake is in the background on the other side of the lagoon. (Photo: J R Grindley, March 1977).

PLATE III:

Indigenous forest surrounding the upper reaches of Knysna Estuary beyond the Old Drift. This part of the estuary has water of reduced salinity because of the inflow of the Knysna River (Photo: J R Grindley, September 1984).