KEURBOOMS RESERVE DETERMINATION STUDY

Scoping Phase

Estuaries

Prepared for

Department of Water Affairs and Forestry

by

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Executive Summary

A literature review of available information on the Keurbooms / Bitou and Piesang estuaries was completed. From these data the level of ecological reserve assessment was recommended for the estuaries. The data requirements for the reserve assessments were also identified.

KEURBOOMS / BITOU

The Keurbooms / Bitou is one of few permanently open estuaries along the South African coastline. It is of national importance and was ranked 18th in South Africa (out of 256 estuaries) based on its biodiversity important. The Plettenberg Bay Coastal Catchment study in 1996 investigated the response of the Keurbooms Estuary to different freshwater inflow scenarios, which represented different on-channel and off-channel dam options. Sedimentation as a result of a reduction in floods and saline intrusion upstream were identified as the two greatest threats to the estuary. Mouth closure would mean an unacceptable ecological change for the estuary.

Instream Flow Requirements (IFR) for the Keurbooms / Bitou Estuary was estimated at approximately 144 x $10^{-6}.m^{-3}$ per annum or 77% of the present day MAR (1999) at the estuary (Ninham Shand 1999). A conservative approach was followed during this study due to the paucity of information and the uncertainty regarding the response of the estuary to any abstractions (Ninham Shand 1995). The findings of the IFR study were that the estuary required 100% of present day flows (baseflow) due to the absence of information.

A comprehensive Reserve determination is recommended for the Keurbooms because:

1) the estuary has high social, economic and ecological importance, and
2) there are available data on floods, sedimentation and cross-section profiles usually only considered in a comprehensive assessment and which can be used to assess changes over time.

PIESANG

The Piesang is an intermittently open estuary ranked 62nd in South Africa in terms of biodiversity importance. Available literature indicates that the estuary is in a disturbed and degraded state. There is very little information available on the Piesang Estuary and therefore an intermediate Reserve determination is recommended. The lack of reliable hydrological data and the relationship between flow and mouth condition, would reduce the confidence of the reserve assessment and thus a comprehensive assessment is not justified.

Ninham Shand (1995) recommended that base flow be maintained at 0.1 $m^3.s^{-1}$ and that two elevated flow releases take place from the Roodefontain dam of approximately 2.0 $m^3.s^{-1}$ to coincide with breaching of the estuary. As there is no flow gauge in the system it is unclear if the municipality is adhering to these recommendations. During the IFR study it was decided that the riverine requirement takes precedence over the estuarine requirements (Ninham Shand 1995).

An intermediate reserve assessment allows for some field sampling so that an initial understanding of the estuary is obtained.

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1. Introduction

The purpose of a scoping phase of an Ecological Reserve determination study is to establish the following:

- The level of current use (level of stress) in the catchment area in which water use is proposed,
- The ecological importance and sensitivity of the study area,
- The present ecological condition of the study area,
- The magnitude and type of impact proposed by the water use licence application,
- The information collected and applicable historic Reserve determination studies which have already being conducted in the study area or adjacent ecologically similar areas, and
- The various aquatic ecosystems that will be affected by the proposed water use activity, e.g. identifying the wetlands, estuaries, groundwater and surface water components that will be impacted upon.

It is important at the inception stage of an Ecological Reserve determination study to identify data and information that are already available in the published literature and to evaluate their suitability for use in the Ecological Reserve determination process (Taljaard *et al.* 2003).

The following terms of reference are applicable to the estuarine component of the scoping study:

- Literature review of all available information on the abiotic (hydrodynamics, water quality & sediments) and biotic components (microalgae, fish, macrophytes, invertebrates and birds) of the Keurbooms / Bitou and Piesang estuaries,
- Determine the level of Ecological Reserve determination study that will be required, and
- Recommend additional studies and monitoring that needs is required to determine the different levels of Ecological Reserve for the estuaries.

2. Climate of the Plettenberg Bay area

(data provided by the South African Weather Services)

2.1. Temperature and rainfall

The mean maximum and minimum temperatures for Plettenberg Bay indicate mild summers and winters (Figure 1). Although high (during berg wind conditions) and close to zero temperatures have been recorded, the coastal zone is influenced by both the cooling and warming effects of the sea, resulting in an overall temperate climate.

Plettenberg Bay receives rainfall all-year-round with peaks in autumn (March/April) and spring (August-November) (see Figure 2). The higher rainfall for Plettenberg Bay in spring (dominant rainfall period) is a product of the late winter frontal systems together with the effect of orographic rain resulting from the proximity to the coastal mountains. The rain is mainly cyclonic and orographic while thunderstorms are rare. Winter rainfall is associated with the increase in cold fronts (east moving cyclones) passing over the coast. Autumn rain comes predominantly from the east (Stone *et al.* 1998).

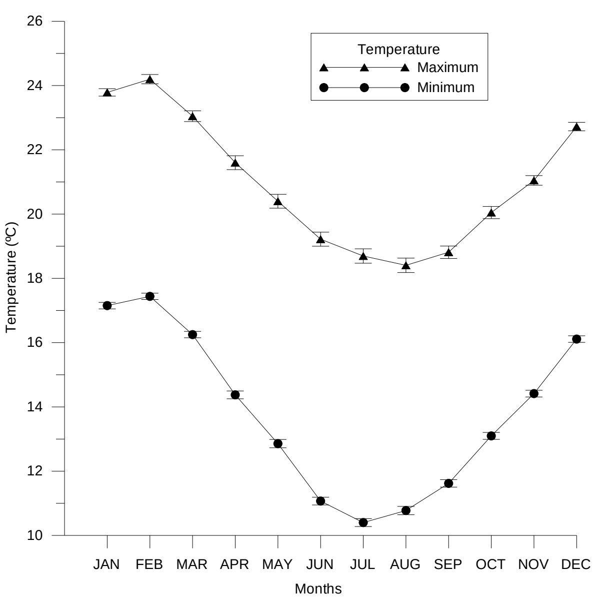


Figure 1. Mean minimum and maximum temperatures over the last 12 years (1992 – May 2004).

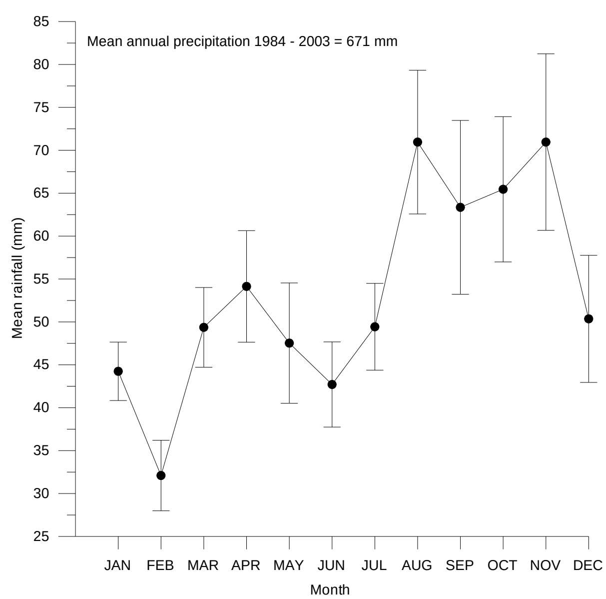
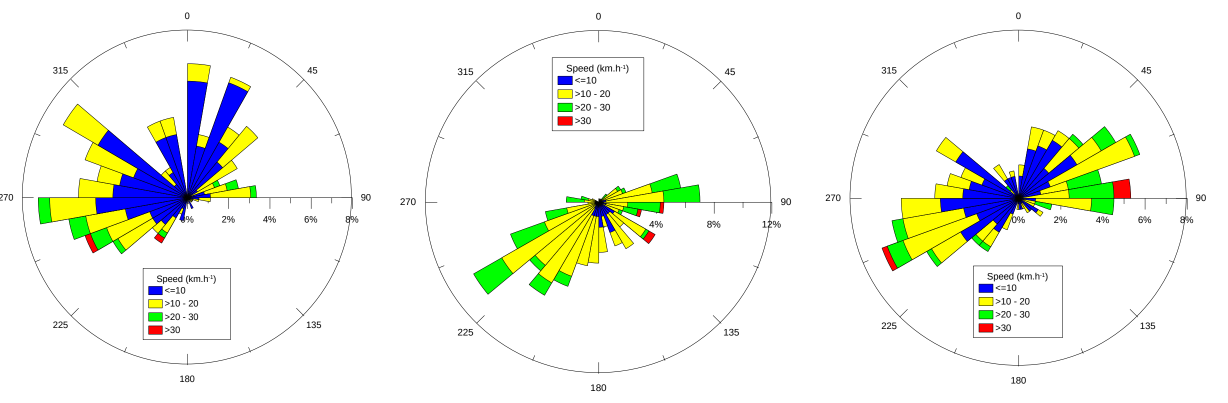


Figure 2. Mean monthly precipitation over the last 20 years (1984 – May 2004).

2.2. Wind

Plettenberg Bay predominantly experiences westerly winds, especially during spring (Figure 5) and summer (Figure 6). Precipitation along this coast occurs with the eastward passage of cyclonic low-pressure systems or from the advection of cool moist air by the South Indian Ocean anticyclone towards low pressure cells inland. Easterly winds are very well developed during March (Figure 3; responsible for the autumn rain) and December (Figure 6). The strong easterly winds in summer are responsible for upwelling events along the coastline. The South Atlantic and Indian anticyclones are responsible for the dominance of easterly winds in spring and summer. The dominance of north-westerly winds in winter (Figure 4) is the cause for the low rainfall (Figure 2) experienced during that period.



a) b) c)

Figure 3. Mean wind speed, direction and frequency over the last 12 years (1992 – May 2004) for March; a) 08:00, b) 14:00 and c) 20:00.

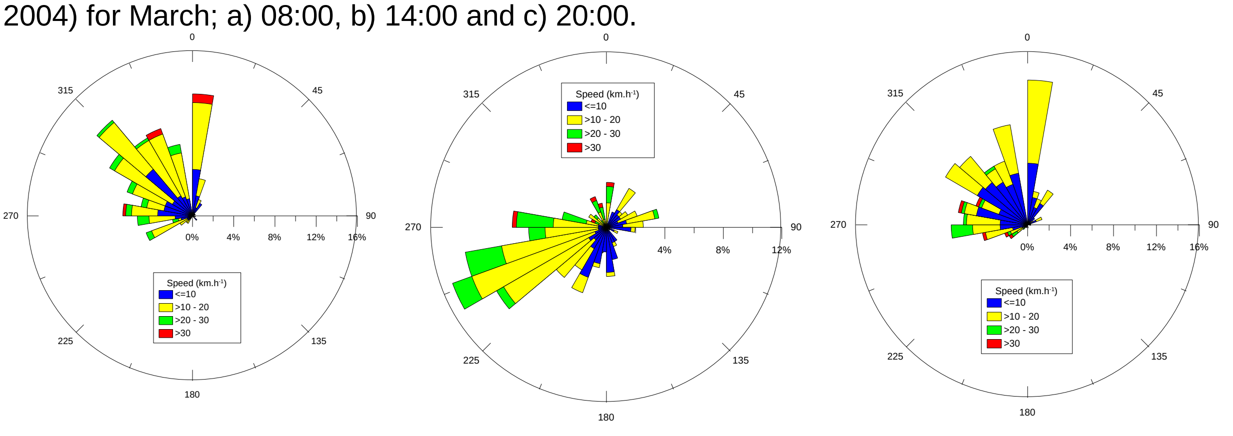


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Figure 4. Mean wind speed, direction and frequency in over the last 12 years (1992 – May 2004) for June; a) 08:00, b) 14:00 and c) 20:00.

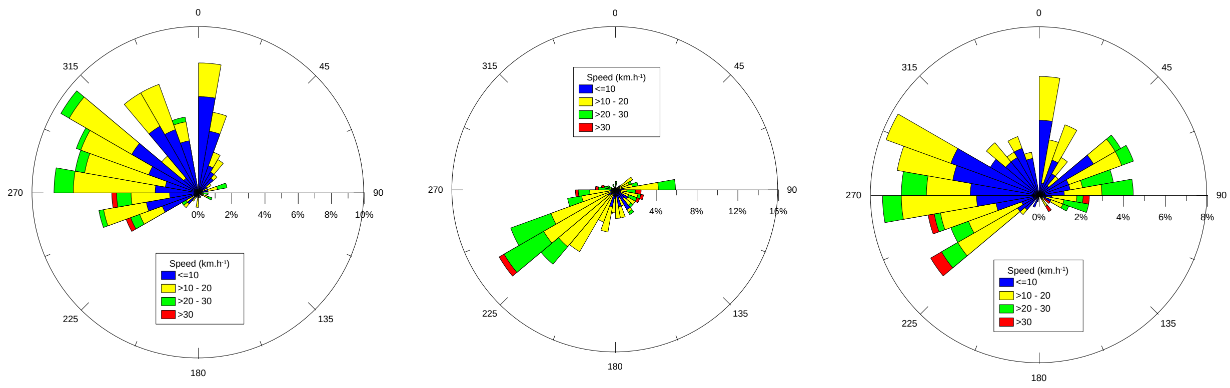

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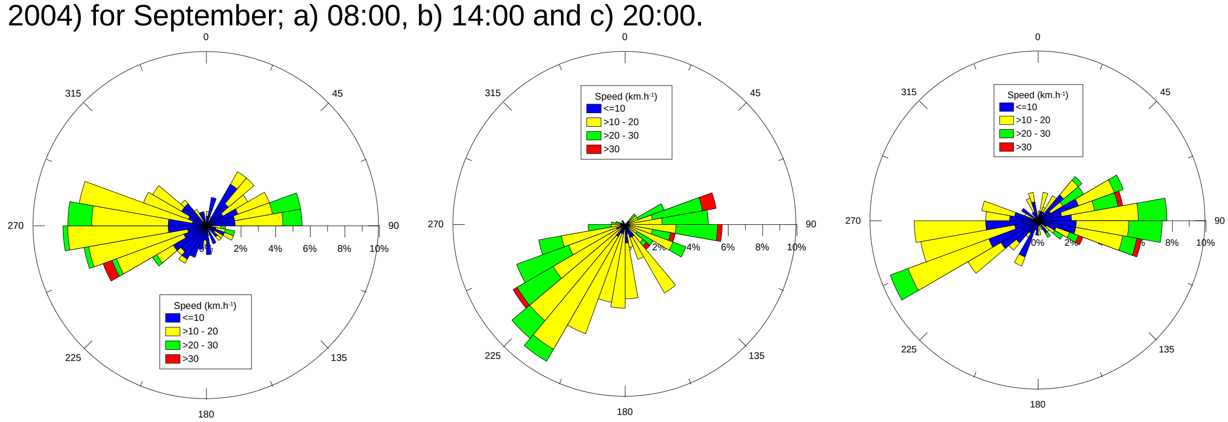
Figure 5. Mean wind speed, direction and frequency over the last 12 years (1992 – May 2004) for September; a) 08:00, b) 14:00 and c) 20:00.



a) b) c)

Figure 6. Mean wind speed, direction and frequency over the last 12 years (1992 – May 2004) for December; a) 08:00, b) 14:00 and c) 20:00.

Berg winds occur periodically along the coast and result from air rotating in an anti-clockwise direction around an interior high-pressure system, passing offshore to fill a low-pressure cell off the coast (Stone *et al.* 1998). Coastal lows appear a couple of times a month along this stretch of the coastline and although they have a relatively weak circulation they result in sharp changes in wind direction (to the SW), temperature and relative humidity (Heydorn and Tinley 1980).

Table 1. *Wind direction ranges applicable to Figure 8 – Figure 11.*

Direction	Degrees	Direction	Degrees
N	348.75 to 11.25	S	168.75 to 191.24
NNE	11.25 to 33.74	SSW	191.25 to 213.74
NE	33.75 to 56.24	SW	213.75 to 236.24
ENE	56.25 to 78.74	WSW	236.25 to 258.74
E	78.75 to 101.24	W	258.75 to 281.24
ESE	101.25 to 123.74	WNW	281.25 to 303.74
SE	123.75 to 146.24	NW	303.75 to 326.24
SSE	146.25 to 168.74	NNW	326.25 to 348.74

3. The Keurbooms / Bitou Estuary

3.1. Introduction

The combined Keurbooms and Bitou catchments were calculated as 1188 km^2 by Heydorn & Tinley (1980) and 1096 km^2 by Reddering (1981). The Keurbooms River has a total length of 70 km (from the mouth to the head) (Duvenhage & Morant 1984). The Bitou River is 23 km long from its confluence with the Keurbooms to its head.

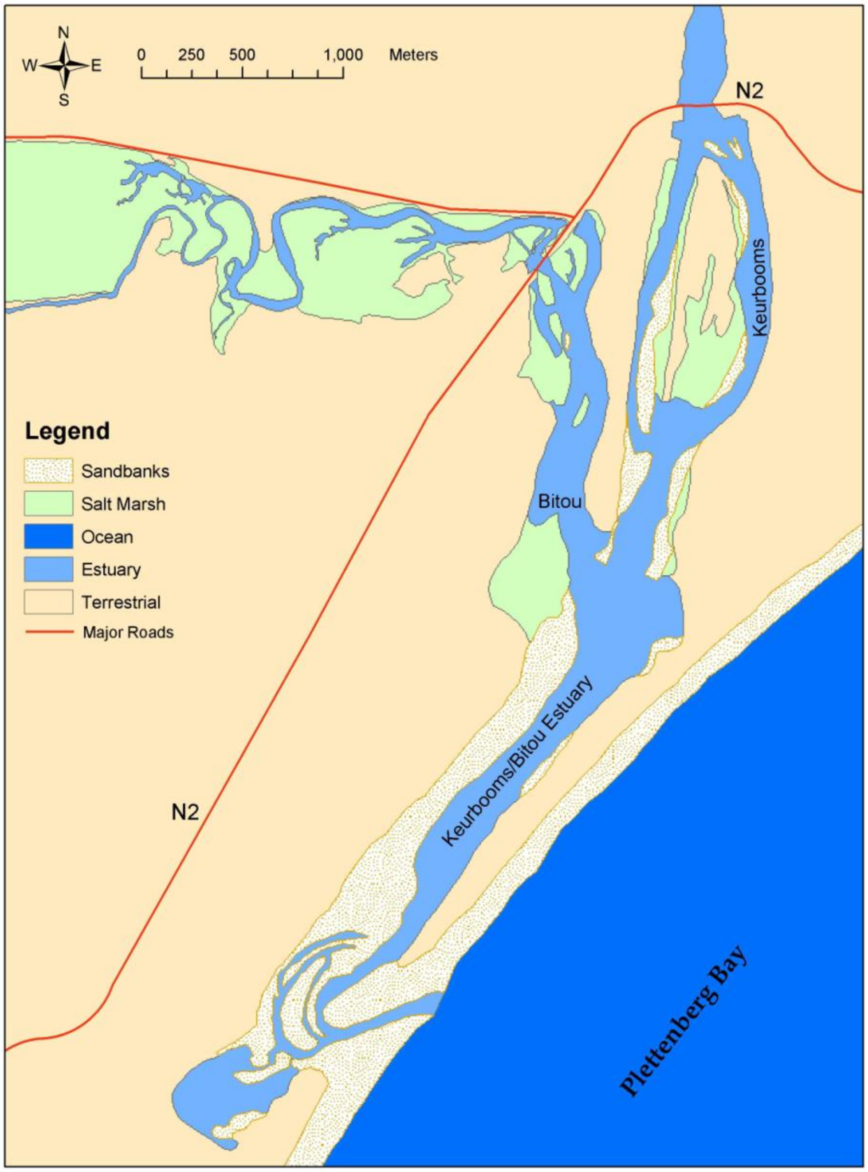


Figure 7. Map of the lower and middle reaches of the Keurbooms / Bitou Estuary

The Keurbooms / Bitou Estuary consists of the Keurbooms Estuary (extends for 7 km from its confluence with the Bitou to Whiskey Creek), the Bitou Estuary (extends for 6.7 km from its confluence with the Keurbooms to its head at the Wittedrift bridge) and the back-barrier estuary (extends for 3.5 km from the mouth of the estuary to the confluence of the Keurbooms and Bitou Rivers).

3.2. Importance and conservation status

The Keurbooms / Bitou Estuary is ranked as the 18th most important system in South Africa in terms of conservation importance (out of 256 functional estuaries) (Turpie 2004). The conservation importance was calculated on the basis of size, habitat, zonal type rarity and biodiversity importance.

Criterion	Score
Estuary size	100
Zonal Type Rarity	20
Habitat Diversity	90
Biodiversity Importance	95.0

The Keurbooms River estuary is partially protected by the Keurbooms River Nature Reserve and the adjacent Whiskey Creek Nature Reserve. There are no protected areas on the Bitou River.

3.3. Description of the Present State

3.3.1. Abiotic components

3.3.1.1. Seasonal variability in river inflow

Mean annual runoff of the Keurbooms River (Figure 8) has been highly variable in the past. Mean monthly runoff (Figure 9) appears to mirror the rainfall pattern for Plettenberg Bay (Figure 2). Unfortunately the lowest runoff is recorded at times when the water demand is highest. Run-off data was provided by DWAF for the M'Kama station (Station no. K6H001). The profile of the mean monthly flow (Figure 9) closely resembles that recorded by Duvenhage & Morant (1984), with peaks in May and September, although the values are much lower. The new gauging station at Newlands (operational since 1997) indicates a much higher mean monthly run-off (Figure 10) than that of the M'Kama station and is more similar to the flow measured by Duvenhage & Morant (1984). This can be attributed to the location of the stations, with the Newlands station situated below the confluence of the major tributaries and the M'Kama in the upper reaches of the Keurbooms River.

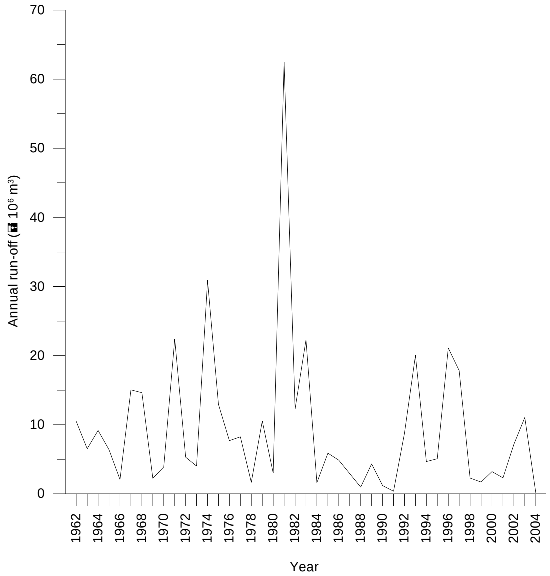


Figure 8. Mean annual run-off over the last 42 years (1962 – May 2004) at the M'Kama gauging station.

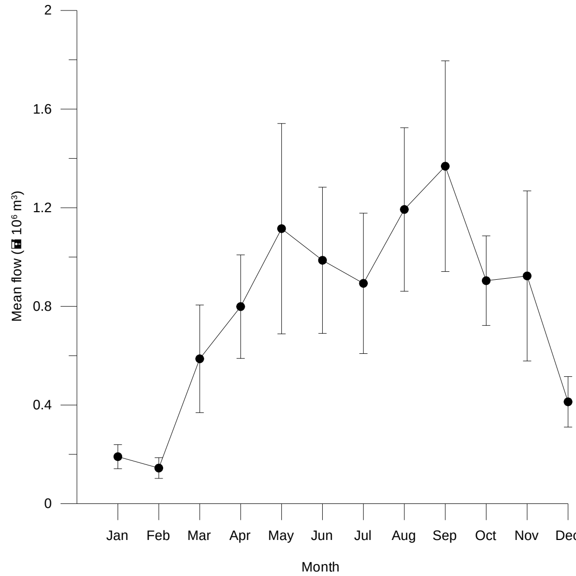


Figure 9. Mean monthly run-off over the last 42 years (1962 – May 2004) at the M'Kama gauging station.

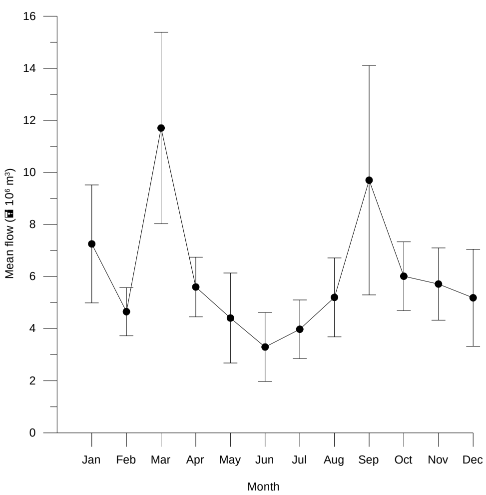


Figure 10. Mean monthly run-off over the last 7 years (1997 – 2004) at the Newlands gauging station.

Ninham Shand (2003) reported that the new flow gauging station at Newlands (K6H019) reported a much lower flow than they had simulated in 1996. A large proportion of the catchment is ungauged in terms of area (85%) and runoff (92%).

Several authors have calculated the mean annual run-off (MAR) for the Keurbooms and Bitou catchments (Table 2). Present MAR values are questionable (Ninham Shand 1995).

Table 2. Mean Annual Run-off values for the Keurbooms and Bitou Rivers

Reference	**Keurbooms x $10^6 m^3$**	**Bitou x $10^6 m^3$**	**Total x $10^6 m^3$**
Midgley and Pitman (1969)	127	32	159
Noble and Hemens (1978)			160
Reddering (1981)			> 72.9
DWAF 1978 (In: Duvenhage & Morant 1984)	64		
DWAF 1981 (In: Duvenhage & Morant 1984)	71		
Ninham Shand (1999; 2003)	154	33	187 (at mouth)

3.3.1.2. Present flood regime

The Keurbooms River is subject to substantial floods (Duvenhage & Morant 1984). Historical records showed that the recurrence interval and magnitude of floods are 417 $m^3.s^{-1}$ for the 1:2 year flood, 893$m^3.s^{-1}$ for the 1:5 year flood and 1459 $m^3.s^{-1}$ for the 1:10 year flood (Ninham Shand 1995). Huizinga & Rossouw (1998) modelled the 1:5 year flood for the Keurbooms at ~720 $m^3.s^{-1}$ and for the Bitou at ~370$m^3.s^{-1}$. The 1:50 year flood model calculated flows of ~1900$m^3.s^{-1}$ for the Keurbooms and ~900$m^3.s^{-1}$ for the Bitou (Huizinga & Rossouw 1998).

3.3.1.3. Estuarine hydrodynamics

Huizinga & Slinger (1999) surveyed the bathymetry of the estuary. They found that the lower reaches of the Keurbooms Estuary is approximately 3 m below MSL and becomes shallower towards the middle reaches (0.9 m below MSL). The channel to the west of Stanley Island is considerably shallower than the eastern channel. The depth of the Bitou Estuary varies between 2.7 m below and 0.7 m above MSL. Depths increase upstream of the N2 bridge. Five surveys of the mouth of the estuary indicated that the depth varied generally between 1 and 2 m below MSL (Huizinga & Slinger 1999). Tidal variation inside the mouth was 1.35 m (minor attenuation of sea tidal amplitude) and the amplitude decreased to 0.95 m at the N2 bridge (70 % reduction due to the shallowness of the estuary) (Huizinga & Slinger 1999). The tidal variation in the Bitou Estuary is reduced from 1.35 m at the mouth to 0.85 m at the N2 bridge and 0.38 m at the Wittedrif Bridge (Huizinga & Slinger 1999). Although tidal variation occurs throughout the estuarine basin on the spring tide, active tidal exchange in which the entire water column is flushed, occurs primarily in the lower reaches (below the N2 bridges) (Huizinga & Slinger 1999). The middle reaches are characterised by saline bottom water overlayed by fresher surface water. Stratification is more intense on the neap tide than on the spring tide (Huizinga & Slinger 1999).

3.3.1.4. Present sediment processes and characteristics

The Keurbooms back-barrier estuary lies in the sheltered Plettenberg Bay on the southern Cape coast. A coastal barrier separates the lower estuary reaches from the sea, and a tidal inlet through the barrier provides tidal connections between the estuary and the sea. North of the back-barrier lagoonal area, the Keurbooms estuary and its Bitou tributary occupy two drowned river valleys. The bay of Plettenberg Bay is characterised by a wave dominated shoreline where very high longshore sediment transport rates are recorded during southeasterly storms (Reddering & Rust 1994). The surf zone is the main sediment source of the estuary (Reddering 1999).

The tidal prism of the Keurbooms / Bitou estuary is in the order of 1.8 x 10^6 m^3 (Reddering 1981). The mean spring tidal range in the bay is about 1.6 m (increasing to over 2 m during equinox spring tides). The neap tidal range is very small in the estuary due to the large accumulation of sand in the tidal inlet. Due to the constriction of the tidal inlet, the estuary is flood tide dominated with a tidal range of about 60% of that along the beach (Reddering & Rust 1994). Annually about 1.5 x 10^4 m^3 of marine sand enters the back-barrier lagoon (Reddering 1981). In the Keurbooms estuary the scour by tidal flows removes enough of the wave deposited sand to maintain the inlet channel and allow restricted tidal exchange. River floods are important to temporarily scour open inlets and remove tidal-accumulated sediment from the lower reaches (Reddering 1981; 1999).

The main inlet channel consists of an ebb dominated and a flood dominated sector. The ebb-dominated channel forms the deepest part of the inlet (3- 5 m below MSL). Since the tide is ebb-dominated, the flood tide has very little effect on sediment in the ebb channel. The flood dominated channel (along the northern bank) ranges in depth from 0.5 to 2.5 m below MSL and flood directed bedforms dominate (Reddering & Rust 1994). The flood tide decelerates as it enters the back-barrier lagoon and deposits a major fraction of its bedload on the flood tidal deltas (Figure 11). As the inlet migrates southwestwards, the flood deltas accrete laterally into an elongate sediment body that occupies the entire landward edge of the back-barrier lagoon to form intertidal sand flats (Figure 11) (Reddering & Rust 1994).

The inlet migrates southwestward by erosion of the southern inlet margin and the growth of the northern margin (Reddering & Rust 1994). The primary reason for the southwesterly migration of the mouth is the scouring of the southwest spit that occurs on ebb tides as the flow alters direction to accommodate the 45º angle of the mouth to the coastline (Huizinga & Slinger 1999). During major flood events (e.g. 1915 flood) the estuary breaches the spit at the north-eastern corner (Duvenhage & Morant 1984). The effect of small to medium sized floods on the mouth of the estuary is short-lived as they do not cause breaching of the sand spit and alteration in the position of the mouth (Huizinga & Slinger 1999). Several evenly spaced washover channels are present on the sand barrier and washover sand is an important local source of marine sand in the estuary (Schumann 2003).

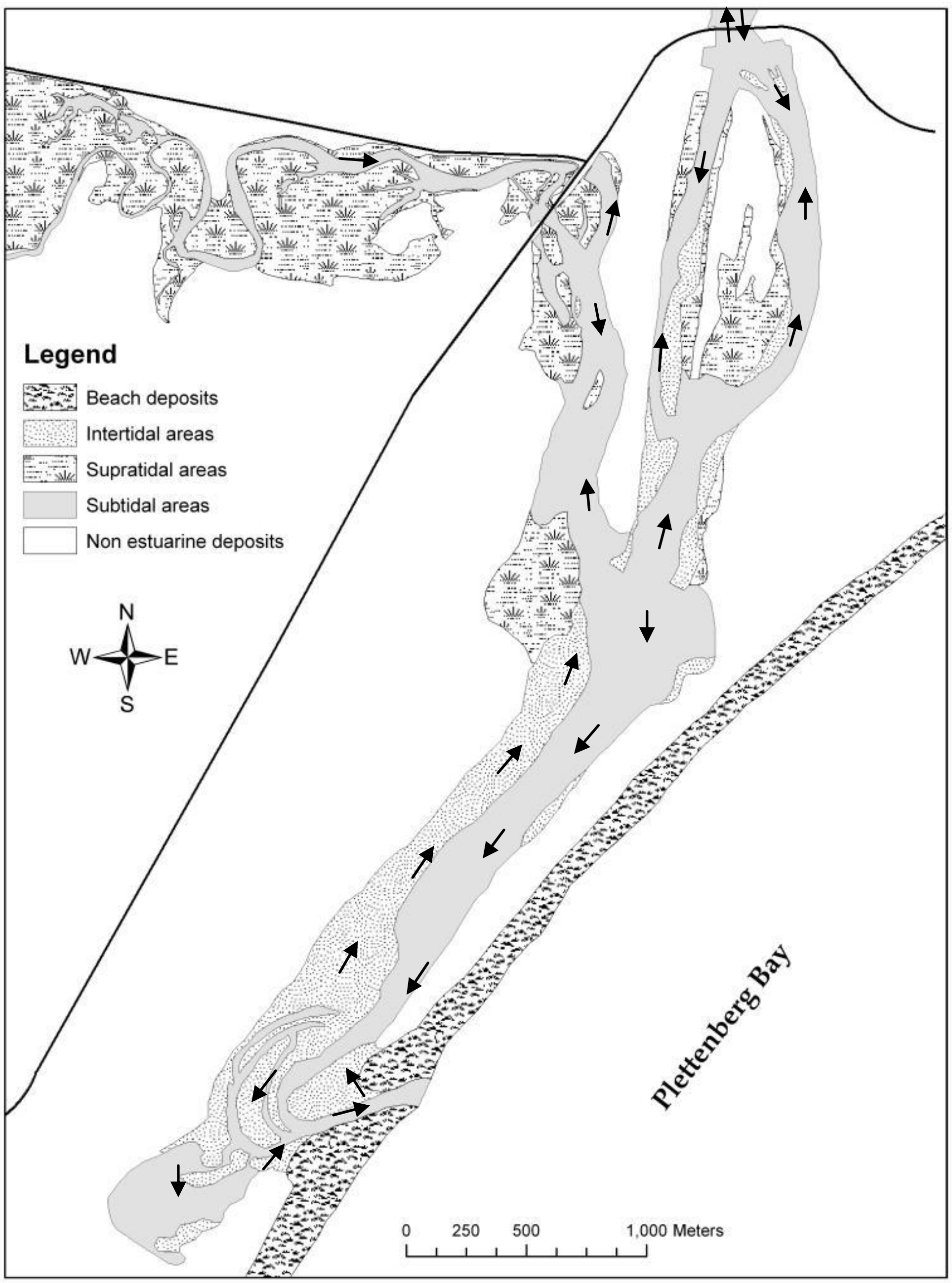


Figure 11. Distribution of depositional zones of the Keurbooms / Bitou estuarine facies. Arrows indicate dominant current direction (modified after Reddering 1981; Reddering and Rust 1994).

Sediment in the Keurbooms / Bitou Estuary consists of fine-grained quartz (sand and silt), organic material and clay. The Keurbooms River and the lower reaches of the Bitou River are underlain by Tertiary to Quaternary marine and estuarine terrace gravel and partly calcareous sand (Duvenhage & Morant 1984). The more extensive supratidal flats lie near the clay producing sources. These sources are the outcrop of the Cedarberg Shale in the southern back-barrier lagoon, and the mud bearing Bitou tributary (Reddering & Rust 1994). The Keurbooms River originates in the Tsitsikamma mountain range that forms part of the Cape Fold Belt. As a result, sediment from the Keurbooms River consists almost exclusively of quartz sand (Reddering 1981). The drainage basin of the Bitou river is underlain by semi-consolidated immature sandstone, conglomerate and shale of Cretaceous age (Reddering 1981). The sediment yield from this tributary is small but contains clastic suspension material (clay content between 5 and 25 %) (Reddering 1981).

Sediment in the Bitou is likely to be more resistant to erosion than the sandy sediment in the Keurbooms Estuary (Reddering 1999). Suspended mud particles entering the estuary in freshwater, mixes with the saline water in the Bitou Estuary. The presence of electrolytes in the water causes the clay particles to flocculate and settle from suspension in the Bitou Estuary (Reddering 1999). Most of the mud from the Bitou estuary accumulates on the intertidal saltmarshes and mudflats and very little fine sediment enter the Keurbooms Estuary from the Bitou Estuary (Reddering 1999).

Meandering tidal creeks traverse the supratidal flats, and during spring high tide form the water conduits between the estuary and the supratidal flats. Although mostly inactive, these creeks have a considerable bank full discharge at spring high tide The gradual up-estuary variation of hydrodynamics and sedimentary conditions has a profound influence on the behaviour of burrowing organisms.

Regular floods scour tide accumulated sediment from the flood dominant Keurbooms estuary, maintaining the channels and preventing complete sediment infill. When the discharge rate and the frequency of river floods becomes less, the erosional capacity of floods decreases, allowing unnatural sediment build up. Tidal current energy decreases upstream resulting in a change from well developed bedforms in the mouth area to small bedforms and profuse bioturbation upstream (Reddering & Rust 1994). The Keurbooms / Bitou Estuary lack well developed intertidal areas due to the low flow conditions typical of microtidal estuaries (Reddering & Rust 1994). The estuary contains almost no clay and the sand is non-cohesive and readily reworked by tidal currents and small wind driven waves. The Bitou Estuary is a flood dominated system and requires flooding to prevent consolidation of its muddy sediments.

$CaCO_3$ poor sediment enters the estuary from the rivers, but carbonate rich (35% by mass) sediment enters the estuary from the sea through the tidal inlet. These marine sediments extend 1.7 km upstream to the north and 0.6 km into the southern back-barrier lagoon (Reddering 1981).

3.3.1.5. Water quality

pH: The river water has a low pH (slightly acidic) due to the humic acid that is responsible for the brown colouration of the water (Duvenhage & Morant 1984). The pH is higher in the estuary than in the river due to the higher pH of the mixing seawater (Duvenhage & Morant 1984).

Temperature: Water temperatures vary between 12ºC and 28ºC (Day 1981; Duvenhage & Morant 1984). The water from the Bitou Estuary is warmer than the Keurbooms Estuary because the Bitou is shallower (Duvenhage & Morant 1984).

Turbidity: Turbidity in the system is generally low and secchi depth readings of over a meter have been recorded by various researchers as reported in Duvenhage & Morant (1984).

Salinity: Day (1981) recorded salinity values ranging from 13 ppt at the N2 bridge to 30 ppt at the mouth. Duvenhage & Morant (1984) recorded salinity values ranging from 14 ppt to 34 ppt. The Bitou is more saline than the Keurbooms due to longer residence periods brought about by the obstructions to natural flow in the system (Duvenhage & Morant 1984). Salinity values normally decrease in winter due to reduced evaporation and increased freshwater run-off (Duvenhage & Morant 1984). Vertical salinity gradients are recorded in the Keurbooms above the confluence with the Bitou (Duvenhage & Morant 1984). The shallow sill at the N2 Bridge over the Keurbooms restricts to some extent the upstream migration of dense saline water (Duvenhage & Morant 1984). In the majority of physico-chemical surveys the salinity at the N2 bridge did not exceed 15 ppt. This indicates that despite the presence of high salinity bottom water, the Keurbooms Estuary has a brackish component upstream of the bridge that is maintained by base flows (Huizinga & Slinger 1999). Hypoxic, saline water is trapped in deep holes in the upper and middle reaches of the Keurbooms Estuary and flushing and renewal of this water will only take place during large floods and under conditions of enhanced tidal intrusion (Huizinga & Slinger 1999). Reddering (1999) postulated that the origin of the saltwater in these deep scour pools might be from saline groundwater and that the sandy bed of the upper estuary is extremely porous and permeable and allow free transfer of seawater up the drowned river valley.

Dissolved oxygen: A wide range of dissolved oxygen concentrations (0 – 11.8 $mg.l^{-1}$) have been recorded in the Keurbooms / Bitou Estuary (Duvenhage & Morant 1984; Grange 1999). The deep upper reaches might be prone to hypoxia and it is important that periodic and extensive flooding take place to reduce the chances of developing large scale and persistent anoxia of the bottom water (Grange 1999; Huizinga & Slinger 1999; Reddering 1999).

Nutrients: Keurbooms River: Nitrate & Nitrite: 0 – 0.48 $mg.l^{-1}$. Ammonia: 0 – 0.71 $mg.l^{-1}$ (Duvenhage & Morant 1984). Estuary: Nitrate: 3.5 – 4.5 $mg.l^{-1}$. Inorganic orthophosphate: River: 0 – 0.16 $mg.l^{-1}$; Estuary: 0 – 0.9 $mg.l^{-1}$ (Duvenhage & Morant 1984). High nutrient levels in the estuary could be attributed to the release of sewage into the Bitou Estuary through the Gansvlei stream (Duvenhage & Morant 1984). Snow (2005, unpublished data) recorded the following nutrient levels in the Keurbooms Estuary during a minor flood in 2002: Total Organic Nitrogen ranged from 23.17 µM in the upper reaches to 3.58 µM in the lower reaches; PO_4 ranged from 1.96 µM in the upper reaches to 2.55 at the confluence with the Bitou; No detectable concentrations of NH_4 was found in the estuary; Silicate ranged from 35.02 in the upper reaches to 81.3 at the confluence of the Bitou.

Pollution: Watling & Watling (1980) found that the concentrations of copper, zinc, iron, manganese, cobalt, nickel and mercury in the surface water were average for Eastern Cape Rivers. The concentrations of metals in the sediment and water column collected from the Keurbooms River and estuary were much lower than that recorded in the Bitou River (Watling & Watling 1980). They attributed this to mineralization in the Bitou River catchment.

3.3.2 Non-flow related anthropogenic influences that are presently affecting abiotic characteristics.

3.3.2.1. Structures (e.g. weirs, bridges, mouth stabilization)

The road bridge at Wittedrift and the old causeway over the Bitou River act as obstructions to water flow and essentially form the upper limit of tidal exchange in the estuary (Bitou = Wittedrift bridge and N2 = Keurbooms). The existing road bridge (N2) and embankment obstructs more than 45% of the river width of the Bitou (Duvenage & Morant 1984). Floods washed the older bridge away in 1940 and the remaining concrete piers restrict flow in the northern channel of the Bitou Estuary (Duvenhage & Morant 1984). Flow was further restricted by the embankment of the N2 completely closing off the main channel of the Bitou Estuary and forcing water to flow through a secondary channel (Duvenhage & Morant 1984).

3.3.2.2. Wastewater discharges affecting water quality (e.g. dump sites, storm water, sewage discharges, etc.)

Treated sewage is discharged in the Bitou estuary, increasing the flux of nutrients into the system. As the town and water demand grows, so will the volume of sewage that needs to be discharged. Fortunately most of the treated sewage is currently used to irrigate existing golf courses and polo fields and it is expected that the demand for treated sewage will grow.

3.3.2.3. Input of toxic substances from the catchment

No industrial activities take place in the catchment of the Keurbooms or Bitou Rivers. The release of treated sewage through the Gansvlei stream might be a source of toxic substances to the Bitou Estuary, but this has not been specifically tested.

3.3.3. Biotic components

Description of the present state of biotic components

3.3.3.1 Microalgae

Adams *et al*. (1999) showed that an increase in freshwater input between August and November 1992 caused a decrease in mean salinity, an increase in the horizontal gradient and an increase in nitrate (0.3 – 4.4 µM) and chlorophyll-*a* concentrations (0 – 13.3 µg l^{-1}). Snow (2005, unpublished data) collected data on microalgae as well as the physical parameters of the water column (reported above in section 3.3.15) during a minor flood in 2002. Grange (1999) reported that, based on the appearance of the filter paper, phytoplankton is of little if any ecological significance in the estuary. Other studies do not support this observation and indicate that freshwater inflow can stimulate microalgal growth. Adams *et al*. (1999) also reported on the benthic microalgal biomass that ranged from 106 – 191 $mg.m^{-2}$ for intertidal sites and 257 to 64 $mg.m^{-2}$ for subtidal sites. Compared to other Cape estuaries these values were moderately high. A recent comparison of benthic microalgal biomass in permanently open estuaries by G Snow (2005 NMMU unpublished data) recorded intertidal biomass as 9.53 ± 0.78 $µg.g^{-1}$. This value was lower than most of the other estuaries sampled and was related to the sandy nature of the estuary and low sediment organic content compared to the other estuaries included in the analysis.

3.3.3.2. Macrophytes

Submerged macrophytes: *Zostera capensis* is the dominant submerged macrophyte in the system and occurs in both intertidal and subtidal habitats (Duvenhage & Morant 1984). Bornman (2004) recorded *Ruppia cirrhosa* to be the dominant submerged macrophyte in the Bitou Estuary. Although *Ruppia* has a wide salinity tolerance range (0-75 ppt), it does not survive in the lower reaches of the estuary since it has relatively weak stems that break in the presence of strong currents. Very little *Zostera* occurred in the Bitou because of the reduced tidal action caused by the obstructions. *Halophila ovalis* have also been recorded in the Keurbooms / Bitou Estuary (Duvenhage & Morant 1984).

Emergent macrophytes: In the Keurbooms Estuary, the reeds and sedges are limited to the supratidal marshes and areas of freshwater inflow. The Bitou Estuary is characterised by dense monospecific stands of *Schoenoplectus scirpoides* and *Phragmites australis* within the channel because of the low flow and restricted tidal action (Bornman 2004). The presence of these species within the main channel of the Bitou is indicative of relatively low salinities (0 – 25 ppt). This contradicts the previous statements that the Bitou Estuary is more saline than the Keurbooms (see section 3.3.1.5.). It could be that low flow and increased evaporation during summer temporarily increases the salinity, but the presence of the reeds and sedges indicate a fresher state for prolonged periods. Reeds and sedges can survive tidal inundation with saline water if their roots and rhizomes are located in brackish water (salinity < 15 ppt). Adams and Bate (1999) showed this for a site in the mouth / lagoon area of the Keurbooms Estuary where interstitial water salinity (15-28 ppt) was lower than surface water salinity (34 ppt). There was a decrease in the height of *Phragmites australis* with an increase in interstitial water salinity (112 cm vs 275 cm).

Intertidal salt marsh: The dominant intertidal salt marsh species in the Keurbooms are *Spartina maritima*, *Sarcocornia perennis* and *Sarcocornia decumbens* (Duvenhage & Morant 1984). Salt marshes are not extensive in the Keurbooms Estuary due to the geomorphology of the system (limited space). The Bitou Estuary has a wide floodplain connected to the estuary by numerous tidal creeks. The largest areas of salt marsh occur on these floodplains. The species recorded by Bornman (2004) are very similar to those reported in Duvenhage & Morant (1984).

Supratidal salt marsh: The elevated areas of the floodplains are covered with supratidal salt marsh vegetation, mainly dense cover of *Sarcocornia pillansii* (Bornman 2004). The largest supratidal salt marshes are found on the floodplain of the Bitou Estuary. Saline groundwater encourages the growth of salt marsh vegetation on the supratidal flats (Reddering & Rust 1994; Bornman 2004). Mats or swards of grasses such as brakgras (*Sporobolus virginicus*) and seaside quick (*Stenotaphrum secundatum*) dominate large sections of the disturbed upper marsh in both the Bitou and Keurbooms estuaries (Bornman 2004). The fringes of the floodplains are occupied by reeds, rushes and sedges, e.g. *Juncus kraussii*, *Juncus acutus*, *Schoenoplectus lacustris*, *Phragmites australis* and *Typha capensis* (Bornman 2004). These plants frequent less saline areas and are normally an indication of freshwater inflow.

3.3.3.3. Invertebrates

Zooplankton: Zooplankton is rich in the Keurbooms Estuary and Grindley recorded 39 taxa with *Pseudodiaptomus hessei* as the dominant copepod (Duvenhage & Morant 1984). Grange (1999) reported low biomass of zooplankton during his survey.

Benthic-invertebrates: Hard substrates are scarce in the Keurbooms / Bitou Estuary and as a result there are limited fauna present that require these habitats (Duvenhage & Morant 1984).
The largest proportion (42 taxa) of the invertebrate fauna is either benthic or associated with the aquatic vegetation (Duvenhage & Morant 1984; Zoutendyk & Bickerton 1999). The benthic fauna is well developed from the lower reaches to the middle reaches, with *Callianassa kraussi* in sandy areas, *Arenicola loveni* and *Solen capensis* in muddy sand and *Upogebia africana* abundant in sandy mud (Day 1981; Grange 1999).

The bivalve *Donax* and the echinoids *Echinodiscus* and *Echinocardium* also burrow the sand in the area proximal to the inlet (Reddering and Rust 1994). *Solen* (razor clam) and *Arenicola* (bloodworm) burrow into the sediment of the intertidal flats (between neap high tide and subtidal levels) and has a limited distribution north of the Keurbooms / Bitou confluence (Duvenhage & Morant 1984; Reddering & Rust 1994). The distal tidal flats are occupied by the prawns *Callianassa*, *Upogebia* and *Alpheus* (distributions are given in Reddering & Rust 1994). The largest and most closely spaced *Upogebia* population occurs in the Bitou Estuary, where muddier sediments are present (Duvenhage & Morant 1984; Reddering & Rust 1994). *Upogebia* populations are threatened in the system through the incursion of marine sand and exploitation for bait (Duvenhage & Morant 1984). *Alpheus* (snapper prawn) burrows in the *Zostera* covered intertidal areas where the currents are slower. Macro-invertebrates such as *Nassarius*, *Natica* and *Diogenes* are common on the mid and distal flat areas (Reddering & Rust 1994).

Intertidal macro-benthos standing stock (as carbon) ranged from < 10 $gC.m^{-2}$ in sand to 100 $gC.m^{-2}$ in muddy sediments (Zoutendyk & Bickerton 1999). *Upogebia africana* and *Callianassa kraussi* together contributed more than 50% (26 tonnes) of the standing stock of benthos carbon in the Keurbooms Estuary (Zoutendyk & Bickerton 1999).

3.3.3.4. Fish

Twenty-nine marine and estuarine fish species have been recorded in the Keurbooms / Bitou Estuary (Duvenhage & Morant 1984; Whitfield 1995). Whitfield (1999) stated that the permanently open mouth condition is vitally important in the species rich Keurbooms Estuary, which has sufficient nursery habitat to cater for large numbers of fish. The middle and lower reaches (below the N2 bridges) is the most important nursery area for fish and contained 80 – 90% of the juveniles (Whitfield 1999). The rare Knysna seahorse, which is limited to four estuaries in South Africa, is found in the Keurbooms Estuary (Whitfield 1995). Harrison *et al*. (1995) also have data on fish in the estuary as part of a once-off survey of estuaries around South Africa.

3.3.3.5. Birds

Twice annual (summer and winter) CWAC (Coordinated Waterbirds Counts) data are available for both the Bitou Estuary and the Keurbooms Estuary. Taylor *et al.* (1999) reported 53 species in the Bitou and 43 species in the Keurbooms over the period 1992 – 1997. These counts are still being conducted.

3.3.4. Effect of abiotic characteristics and processes, as well as other biotic components on estuarine biota

3.3.4.1. Mouth condition

The mouth, although shallow, has never been known to close (Huizinga & Slinger 1999). Closure of the mouth, even temporarily, would have a dramatic impact on the abiotic and biotic components of the estuary (Huizinga & Slinger 1999). A permanently open mouth is important in maintaining tidal flow and ensuring a salinity gradient (limited hypersalinity or hyposalinity). An open mouth is important in that it maintains the intertidal plant community types, i.e. intertidal salt marsh and *Zostera capensis* beds. Salt marsh plants occur in distinct zones along a tidal inundation gradient. If the mouth closes the plants found in these zones would die.

Important species such as the mudprawn *Upogebia africana* and salt marsh crabs all require a marine phase of development during their respective life cycles. Should mouth closure persist (2 – 3 years), local populations will become extinct. If mouth closure occurs during the breeding season, population abundance levels will decline in relation to the duration of mouth closure. Most fish species in the Keurbooms Estuary are dependant on an open mouth for the completion of their life cycles. Prolonged mouth closure (> 1 year) would result in a major decline in the abundance of estuarine associated marine taxa due to the absence of recruitment through the larvae and juveniles of these species. Emigration by adults of these species to the sea to spawn would also be adversely affected. There is little direct effect on birds, only indirect through impacts on habitat and food.

3.3.4.2. Exposure of intertidal areas

Tidal exposure is essential for benthic microalgal biomass. Intertidal biomass is always higher than subtidal biomass. Tidal flushing is important for salt marsh nutrient exchanges and for maintaining the zonation and diversity of salt marsh plants. If die-back of *Zostera* occurs, the numbers of some invertebrate intertidal species will decline because of their specific habitat requirements. If the estuary mouth were to close and intertidal areas were to become continuously inundated, then the availability of littoral habitat for fishes would increase. Tidal exposure is essential for estuarine birds, with the majority of species depending on these habitats for food, and several more using intertidal areas for roosting.

3.3.4.3. Sediment processes and characteristics

Should scour of sediment be reduced owing to a reduction in the severity and occurrence of flooding, enhanced sedimentation of the lower reaches could result (Huizinga & Slinger 1999). The estuary would then become progressively shallower, reducing tidal flows in the estuary and increasing the potential for mouth closure (Huizinga & Slinger 1999). Sedimentation has been occurring in the Keurbooms / Bitou estuary, but at a very slow rate (Huizinga & Slinger 1999). Reducing the depth of the estuary will reduce the effectiveness of tidal exchange thereby reducing the intertidal areas. The impact on the biota would therefore be similar to that in section 3.3.4.2. Eventual closure of the estuary mouth will have a large impact on the biota (see section 3.3.4.1 for detail). Increasing the sand fraction in the estuary will impact on the benthic microalgae and benthic invertebrates that will in turn have ramifications further down the food chain (fish and birds).

3.3.4.4. Retention times of water masses

The development of microalgal biomass in the water column (phytoplankton) is dependant on flow velocity and retention time. A flow of less than 0.3 $m^3.s^{-1}$ has an estuarine retention time of 3.5 – 7 weeks. This is ideal for microalgae in an estuary with a well developed REI (River Estuary Interface) zone, such as the Keurbooms / Bitou Estuary. Prolonged retention of the water body will lead to increased salinities due to evaporation. This would adversely affect the intertidal salt marsh since surface sediment salinities would increase. This would decrease seed germination and macrophyte growth. An increase in the water column salinity will ultimately affect the groundwater salinity on which the supratidal / floodplain salt marsh plants depend.

Long retention time of the water mass will increase salinity in the estuary, leading to population decreases of important estuarine zooplankton. There will also be a shift in community composition of the zooplankton and the benthic invertebrates. In deeper areas (i.e. above the N2 bridge), long retention times of water masses can lead to oxygen depletion and physiological stress on benthic fauna. Increased retention time of water masses within the estuary will benefit the spawning of certain estuarine species (e.g. *Gilchristella* spp.) but will reduce the supply of olfactory cues to estuarine-associated marine fish larvae in the sea.

3.3.4.5. Flow velocities

The restriction of water flow caused by the N2 road bridge has had a negative impact on the benthic infauna, fish and birds of the upper reaches (Duvenage & Morant 1984). A reduction in freshwater flow or alteration in the pattern of inflow will affect the hydrodynamic character of the estuary, altering the residence time, distribution and flushing / renewal of saline water (Huizinga & Slinger 1999).

A decrease in flow velocity will influence the development of a REI (River Estuary Interface) zone, and hence phytoplankton production. Decreased flow can also result in increased sediment stability which, in turn, will lead to an increase in colonisation by submerged macrophytes and marine macroalgae. Reduced flows will also result in the expansion of reeds and sedges into shallowing freshwater channels.

Strong currents are unfavourable for the estuarine zooplankton. Stronger currents also lead to coarse sediments that are unfavourable for most estuarine benthic invertebrates. Strong water currents can result in the loss of estuarine fish eggs and larvae to the marine environment. High flow velocities will affect the foraging of piscivorous birds.

3.3.4.6. Volume of water in estuary

An increase in water volume provides more habitat for phytoplankton and, to a lesser extent, benthic microalgae. A larger volume of water in the estuary will lead to increased inundation of the intertidal salt marsh. This will lead to die-back of species that are intolerant of long periods of inundation.

Increased inundation of intertidal areas will lead to increased habitat for some species. Mouth closure and the resultant increased inundation of intertidal areas would lead to increased habitat for juvenile fishes and the adults of small littoral species. The inundation of intertidal habitats would lead to a reduction in bird numbers.

3.3.4.7. Salinities

A full salinity range from fresh at the head of the estuary becoming marine at the mouth with a strong vertical gradient is ideal for maximum microalgal biomass and diversity. Increased salinity of the water column further upstream will result in a change in the distribution of the macrophytes. Marine macroalgae and *Zostera* will extend further upstream and the area covered by reeds and sedges will be reduced. High water column salinity and reduced flushing by floods results in salt accumulation in the salt marshes.

The distribution of all benthic invertebrates are associated with the distribution of their habitats. An increase in the distribution of *Zostera* will favour invertebrates such as *Palaemon perengueyi*, but not *Upogebia africana*. Zonation of species is also negatively affected, particularly those species in the water column that are influenced by salinity gradients. Increased and more uniform salinities within the Keurbooms Estuary will favour more marine species and will lead to a reduction in the number of freshwater species that inhabit the head region of the estuary. Most estuarine birds tolerate a wide range of salinities, but a few species are typical of more freshwater or marine habitats, and the abundances of these species would be affected by change.

3.3.4.8 Other water quality variables

Phytoplankton chlorophyll-*a* responds positively to nutrients in freshwater (particularly PO_4^{3+}, NO_3^{2-} and NH_4^+). The Keurbooms Estuary is considered oligotrophic and any increase in nutrients will result in a substantial increase in microalgal biomass. An increase in the flux of nutrients (e.g. from sewage works) may cause macrophytes, as opposed to phytoplankton, to bloom. The increase of organic material could have negative effects on the biogeochemistry of the system, especially if the blooms are seasonal, with seasonal mortality. Another effect is that estuarine macrophytes trap fine grained sediment, and would cause accumulation of this sediment in the Bitou tributary (Reddering 1999). Since fine grained sediment resists erosion after synaeresis (attraction between mud particles after initial deposition of the flocs), this sediment accumulation would be undesirable. Conditions of sluggish tidal flow and freshwater mixing into seawater coincide in the middle estuarine reaches where most mud particles flocculate and accumulate (Reddering and Rust 1994). The present oligotrophic nature of the estuary indicates the effectiveness of the wetlands in the Bitou in absorbing the excess nutrients from the treated sewage.

Animal communities will respond to increases in food availability brought about by any increase in nutrient loading. Increased nutrient loading would result in a higher fish biomass and productivity. Increased nutrient loading would lead to increased biomass due to increased food supplies.

3.3.5. Non-flow related anthropogenic influences that are presently directly affecting biotic characteristics in the estuary

3.3.5.1. Structures (e.g. weirs, bridges, jetties)

Large salt marsh areas in the vicinity of the N2 bridge have been disturbed by the roadbridge. The roadbridge and abutment across the Bitou floodplain has probably changed the plant community composition, leading to changes in the intertidal invertebrate communities. Jetties provide perching and roosting habitat for kingfishers and cormorants. The road bridge interferes with flight paths but without major impact.

3.3.5.2. Human exploitation (consumptive and non-consumptive)

Zostera capensis is highly susceptible to destruction by bait collectors and boats. Boating activity may stir up bottom sediments that could impact the submerged macrophytes, reducing both cover and biomass. Boat activity can also cause the erosion of salt marshes. An increase in human numbers would have led to increased bait exploitation and disturbance to the substrate (e.g. trampling of mudbanks). This will also lead to increased mortality of newly settled larvae (e.g.

mudprawns). Increased number of anglers will lead to increased bait exploitation and targeting of recreational fish species. Human activity (including boats and dogs) has a major impact on birds during peak periods, disturbing both feeding and roost sites. Boating also erodes banks and hence destroy feeding habitat.

3.3.5.3. Floodplain developments

The total area covered by the supratidal zone have decreased substantially in recent years due to the restriction of tidal flow caused by the construction of berms on the floodplain and road bridges over the estuaries (Bornman 2004). The floodplains of the Bitou Estuary have been subjected to active reclamation of the salt marsh for agricultural purposes. This was not successful due to the presence of hypersaline groundwater that is hydrologically linked to the Bitou Estuary. Alien tree species, most notably *Acacia melanoxylon*, *Acacia saligna* and *Acacia mearnsii*, are invading the floodplain areas of the Bitou and Keurbooms Estuaries (Bornman 2004).

Floodplain development (e.g. agriculture on the Bitou floodplains) leads to habitat destruction and decrease of invertebrate populations. Bird species numbers and total counts for the Bitou Estuary have been on the decrease and is attributed to pollution from effluent, pesticides and fertilizers, damage by livestock, siltation of the estuary, reed encroachment and residential development (Taylor *et al.* 1999). Bird numbers in the Keurbooms Estuary are threatened by residential development, boating, fishing, general human disturbance, domestic animals and bank erosion (Taylor *et al.* 1999).

3.4. Available information on the freshwater requirements

Instream Flow Requirements (IFR) for the Keurbooms / Bitou Estuary was estimated at approximately 144 x $10^{-6}.m^{-3}$ per annum or 77% of the present day MAR (1999) at the estuary (Ninham Shand 1999). A conservative approach was followed due to the paucity of information and the uncertainty regarding the response of the estuary to any abstractions (Ninham Shand 1995). The findings of the IFR study were that the estuary required 100% of present day flows (baseflow) due to the absence of information, especially on the salinity requirements of estuarine plants. Due to the uncertainty regarding the role of floods, the IFR recommended that the estuary require all the floods (especially the 1:5 year flood or bigger) and that water could only be abstracted from the receding limb of the hydrograph of the flood event (Ninham Shand 1995). The flow requirements of the estuary was considered more substantial than that of the riverine requirements (Ninham Shand 1999). The Keurbooms must remain open with the re-setting event possibly being the 1:5 or 1:10 year flood (Ninham Shand 1995).

Subsequent studies by Huizinga and Rossouw (1998) assessed various dam options and found that the off-channel dam storage options would not influence the flushing of sediment from the estuary if river water was supplied at a constant rate of approximately 1 $m^3.s^{-1}$. Salinity changes in the estuary would also be insignificant. In these scenarios water abstraction was only considered during limited periods and at high abstraction rates which would imply considerable construction and operating costs. Two additional run-off scenarios with a more continuous water abstraction were also assessed, one with an abstraction rate of 200 $l.s^{-1}$ and one with a rate of 300 $l.s^{-1}$. The results showed that these scenarios would not influence sediment scouring during major floods and would only result in limited increases in salinity upstream in the estuary during low flow conditions. The ecological consequences of these effects were considered negligible (Huizinga and Rossouw 1998). The volumes of water to be abstracted considered in these assessments were approximately 6 x 10^6 m^3 per annum which are small compared to the mean annual run-off of the estuary.

A further worksession in 1996 concluded that the on-channel dam downstream of the confluence with the Palmiet River would have a greater impact on the estuary than the other augmentation schemes due to attenuation of floods (and subsequent biological response to changes in salinity and sediment) and the obstruction to the migration of freshwater fish and invertebrates (Luger 1999).

3.5. Level of Ecological Reserve determination study required

Taljaard *et al*. (2003) recommended that estuarine specialists are consulted at the inception phase of an Ecological Reserve study to assist with the specifications for the baseline studies. The tables in Section 5 list the data requirements for a comprehensive reserve determination and provide an inventory of available data and information on the Keurbooms Estuary. The next step in the process would be a detailed terms of reference for the specialists to conduct the reserve study. Each specialist needs to assess the suitability of data; in some cases adequate data may be available in others additional sampling may be required.

It is recommended that a comprehensive reserve determination study be undertaken for the Keurbooms / Bitou Estuary for the following reasons:

1) The Keurbooms is the 18th most important system in South Africa in terms of conservation importance (out of 256 functional estuaries) (Turpie 2004).
2) Taljaard *et al*. (2003) recommended that estuaries with high ecological importance that are already affected by developments in their catchments or that are targeted for future developments are carried out as a Comprehensive level as far as possible and that baseline surveys and subsequent long-term monitoring programmes be implemented fully.
3) The estuary is considered to be the most important natural resource in the area. It has high social, economic and ecological importance and therefore the health of the estuary must be maintained. A comprehensive reserve assessment and monitoring programme is justified.
4) There are available data on floods, sedimentation and cross-section profiles. These data are usually only considered in a comprehensive reserve assessment rather than an intermediate assessment. The available data will serve as valuable baseline information for the proposed comprehensive study.
5) From 1974 - 1994 sedimentation has been occurring in the lower reaches of the estuary (Huizinga and Slinger 1999, Huizinga and Rossouw 1999). The public perception has been that the estuary is getting shallower. Because sedimentation and the role of floods in removing sediment is already an issue in the Keurbooms Estuary, these aspects need to be considered further in a comprehensive assessment.
6) The 1996 assessment of the environmental flow requirements of the estuary recommended that a comprehensive study of the effects of the alterations in river inflow on the estuary be conducted.

3.6. Additional studies and monitoring required

The Table in the Appendix indicates the additional studies and monitoring required. This is also summarised below.

3.6.1. Co-ordinated multi-disciplinary field trip(s).

Available data are extensive but difficult to collate and make sense of. River inflow and estuary physico-chemical measurements need to be made at the same time as the biological surveys in both the Keurbooms and Bitou systems.

3.6.2. Sampling during high and low flow periods

In order to verify previous predictions e.g. fish, sampling during both low and high flow periods may be necessary.

3.6.3. Present MAR, hydrological and hydrodynamic studies

Accurate river inflow data (high confidence) is needed. This data is essential for modelling of reference and future scenarios and to interpret the response of the biota. Recent data on river inflow and water level recordings will need to be collated.

3.6.4. Sedimentation

Previous data indicate that slow ongoing sedimentation is occurring. Cross-sectional profiles are needed to quantify the sediment deposition rate.

3.6.5. Water quality

To set the reserve for water quality, an understanding of the quality of water in the freshwater inflow is required. Point sources such as the sewage input to the Bitou also need to be addressed. Benthic microalgal biomass and species composition can be used as indicators of nutrient enrichment.

3.6.6. Water column response to freshets

Little is know about water column production and response of phytoplankton and zooplankton to freshwater pulses that are thought to bring in nutrients and stimulate water column production.

3.6.7. Comparison of past and present

Analyses of past and present aerial photographs / (satellite imagery) to quantify changes in sandbank and macrophyte cover is essential for the interpretation of invertebrate and fish responses.

3.6.8 Biotic surveys

An understanding of seasonal responses is required for a comprehensive reserve assessment. Specialists will need to assess the available information and then recommend a sampling programme.

4. The Piesang River Estuary

4.1. Introduction

The total length of the Piesang River is 17 km and drains a catchment of approximately 30-45 km^2 (Duvenhage & Morant 1984; Reddering 1999). The Piesang Estuary extends for approximately 2 km from its mouth to the upper road bridge below the Plettenberg Bay Golf course. This Intermittently Open Estuary is open to the sea during high river flow when it scours a shallow channel along the landward side of Beacon Island (See Figure 12). During the closed phase a lagoon, 200 m x 600 m in extent, dams up behind the beach berm. Tidal exchange within the estuary is limited due to the shallow tidal inlet and the distance from the sea to the estuary (the beach berm is approximately 80 – 100 m wide) (Duvenhage & Morant 1984).

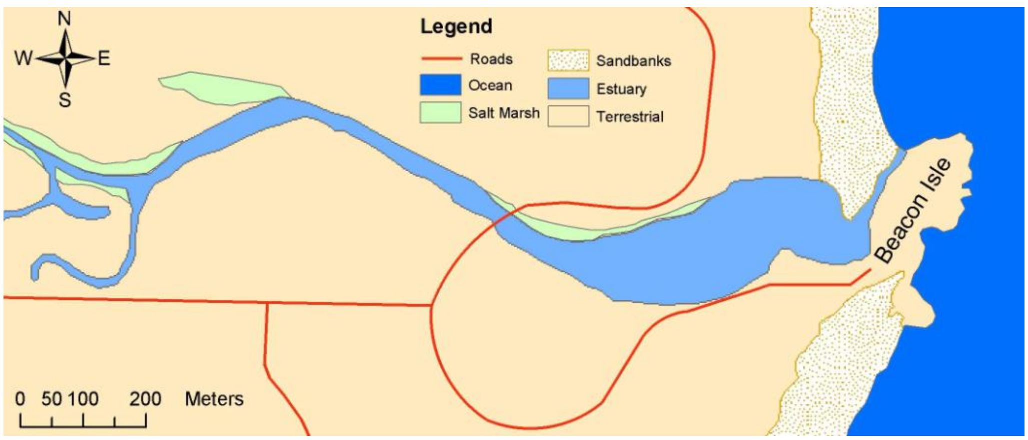


Figure 12. Map of the Piesang Estuary.

4.2. Importance and conservation status of the Piesang Estuary

The Piesang Estuary is ranked as the 62nd most important system in South Africa in terms of conservation importance (out of 256 functional estuaries) (Turpie 2004). The conservation importance was calculated on the basis of size, habitat, zonal type rarity and biodiversity importance.

Criterion	Score
Estuary size	80
Zonal Type Rarity	10
Habitat Diversity	80
Biodiversity Importance	71.0

4.3. Description of the Present State

4.3.1. Abiotic components

4.3.1.1. Seasonal variability in river inflow

No flow measurements have been taken on the Piesang River and/or Estuary. Reddering (1999) stated that the Piesang Estuary will require its entire natural run-off to function adequately. The Roodefontein Dam was constructed on a wetland that had under natural conditions probably provided sustained flows due to the attenuation role of the wetland (Ninham Shand 1995).

4.3.1.2. Present flood regime

The Roodefontein Dam has removed all the small and medium sized floods (Ninham Shand 1995). These floods are necessary to flush the estuary of accumulated sediment and encroaching macrophytes.

4.3.1.3. Present sediment processes and characteristics

The lower and middle reaches of the Piesang River drains Table Mountain Quartzites of the Peninsula Formation (30 % of catchment) as well as some areas of conglomerate (old marine and estuarine terraces), sandstone, silt and clay of the Enon Formation (Duvenhage & Morant 1984; Reddering 1999). The upper reaches are characterised by Bentonitic clay horizons of the Kirkwood Formation (Duvenhage & Morant 1984; Reddering 1999).

Wash-over across the northern berm is depositing marine sediment into the Piesang Estuary which has resulted in the formation of a 400 m x 100 m sand bar in the lower reaches (Duvenhage & Morant 1984). Up estuary accretion of sandbars is not prominent (Reddering 1999). The catchment basin supplies mud, sand and gravel and it is mostly the muddy fraction that settles out upstream of the Otto du Plessis bridge (Reddering 1999). The muddy sediment in the estuary is cohesive and the attenuation of major floods reduces the scouring of these fine sediments.

4.3.1.4. Water quality

<u>pH:</u> The river water has a low pH (slightly acidic) and the humic acid colours the water brown. Duvenhage & Morant (1984) reported pH between 7.4 - 7.6. Grange (1999) recorded a pH of 7.5 during open mouth conditions.

Temperature: Water temperature ranges from 13ºC in winter to 23ºC in summer have been reported (Duvenhage & Morant 1984).

Turbidity: The system is relatively clear with regular secchi depth readings of over 1 m (Duvenhage & Morant 1984).

Salinity: It is expected that the salinity will vary greatly dependant on river flow and mouth condition. Salinity values of 0.5 to 35 ppt have been recorded (Duvenhage & Morant 1984). Grange (1999) recorded a salinity of 24 ppt in the lower reaches during open mouth conditions, indicating the influence of freshwater inflow.

Dissolved Oxygen: It is expected that the Piesang would be well oxygenated due to the shallow depth of the system. Duvenhage & Morant (1984) reported oxygen values ranging from 8.3 to 11.6 $mg.l^{-1}$.

Nutrients: Duvenhage & Morant (1984) reported nitrate values between 3.5 and 4 $mg.l^{-1}$ and inorganic orthophosphate values ranging from 0.2 to 0.24 $mg.l^{-1}$.

4.3.2. Non-flow related anthropogenic influences that are presently affecting abiotic and biotic characteristics.

Three large structures obstruct natural water flow in the Piesang estuary. The Otto du Plessis Bridge, 600 m upstream of the mouth, is approximately 30 m long and consists of two columns in the estuary channel (Duvenhage & Morant 1984). Another road bridge crosses the Piesang below the Plettenberg Bay Golf Course. These bridges do not seriously impede flow because of low flow conditions brought about by reduced river inflow and the intermittently open nature of the estuary mouth (Duvenhage & Morant 1984). A 45 m long concrete footbridge extends from Beacon Island onto Central Beach and restricts natural migration of the estuary channel and mouth.

Several sewage pump stations occur in the Piesang River valley adjacent to the estuary. These pumpstations are prone to failure and may overflow during high rainfall events. Accidental discharge of sewage into the estuary has taken place in the past (Duvenhage & Morant 1984). There is also a refuse dump at the Klein Piesang River, which is a constant source of pollution to the system (Ninham Shand 1995).

Reclaiming and/or stabilising the banks of the estuary as well as recreation and residential developments have reduced the available habitat for emergent macrophytes (Duvenhage &

Morant 1984). This in turn would have led to a decrease in habitat for other biotic components thereby reducing the productivity of the system.

Alien vegetation has infested the valley and is encroaching and smothering the natural vegetation

4.3.3. Biotic components

Description of the present state of biotic components

4.3.3.1. Microalgae

Noctiluca miliaris was recorded in the estuary (Duvenhage & Morant 1984). Grange (1999) reported that epipelic microalgae covered small depressions in the intertidal sand bank. The species were not identified.

4.3.3.2. Macrophytes

Grange (1999) recorded small patches of *Ulva intestinalis* (previously known as *Enteromorpha intestinalis*) and the submerged macrophytes, *Zostera capensis* and *Ruppia* spp., in the lower reaches. The presence of *Zostera* indicates that the mouth of the Piesang opens regularly and that tidal exchange takes place during this phase. Emergent macrophytes include *Phragmites australis*, *Juncus kraussii*, *Triglochin* spp., *Paspalum vaginatum* and *Typha capensis* (Duvenhage & Morant 1984; Grange 1999). Grange also recorded *Sarcocornia perennis* on the floodplain.

4.3.3.3. Invertebrates

Grindley recorded 23 zooplankton taxa (Duvenhage & Morant 1984). Duvenhage & Morant (1984) reported that the bait organisms *Solen capensis*, *Callianassa kraussi* and *Upogebia africana* were common in the tidal sand banks in the lower reaches of the Piesang Estuary. *C. kraussi* was dominant in the sand flat near the mouth and *U*. *africana* was dominant in the more silty sediment closer to the Otto du Plessis Bridge (Duvenhage & Morant 1984). Grange (1999) reported that the burrows along the intertidal sand flats belonged to a mixture of *C*. *kraussi*, *Sesarma catenata* and *Cyclograpsus punctatus*. *Hymenosoma orbiculare* was dominant in amongst the *Phragmites* reed beds between the two bridges. Large macro-invertebrates such as *Scylla serrata* also occur in this small estuary (Duvenhage & Morant 1984). Grange (1999) reported that crab burrows dominated the benthic fauna in the muddy intertidal and subtidal sediments above the Otto du Plessis.

4.3.3.4. Fish

Mullet are the most abundant fish in this estuary (Duvenhage & Morant 1984). A list of all other species recorded in this system is given in Duvenhage & Morant (1984). Whitfield (1995; 1999) recorded 11 fish species in the Piesang Estuary of which 10 were estuarine dependant marine species (Field trip dates: September 1994 and February 1996). He also reported that the Piesang estuary would benefit from prolonged opening of the mouth, especially during summer to allow optimal recruitment of these species. The Piesang estuary is an important nursery area for juvenile fish as it offers *Zostera*, saltmarsh and reed bed habitats (Whitfield 1995).

4.3.3.5. Birds

Development along the banks of the estuary and the close proximity of the large Keurbooms / Bitou Estuary means that the Piesang Estuary does not maintain a large bird population. Large numbers of gulls are often recorded at the mouth of the Piesang Estuary (Duvenhage & Morant 1984). Martin (1995) recorded only 7 species and a total of 21 birds.

4.4. Available information on the freshwater requirements

Ninham Shand (1995) recommended that base flow be maintained at 0.1 $m^3.s^{-1}$ and that two elevated flow releases take place of approximately 2.0 $m^3.s^{-1}$ to coincide with breaching of the estuary. As there is no flow gauge in the system it is unclear if the municipality is adhering to these recommendations. It was decided that the riverine requirement takes precedence over the estuarine requirements (Ninham Shand 1995).

4.5. Level of Ecological Reserve determination study that will be required

Available literature indicates that the estuary is in a disturbed, degraded state. There are a number of permanent developments responsible for this. There is very little information available on the Piesang Estuary and therefore an intermediate reserve determination is recommended. The tables in Section 5 list the data requirements for an intermediate reserve determination and provide an inventory of available data and information on the Piesang Estuary.

It is recommended that an intermediate reserve determination study be undertaken for the Piesang Estuary for the following reasons:

1) The Piesang Estuary is ranked as the 62nd most important system in South Africa in terms of conservation importance (out of 256 functional estuaries).
2) Available data on the estuary are limited, particularly reliable hydrological data and the relationship between flow and mouth condition, this would reduce the confidence of the reserve assessment and thus a comprehensive assessment is not justified.
3) An Intermediate reserve assessment allows for some field sampling so that a preliminary understanding of the estuary is obtained.

4.6. Additional studies and monitoring required

The Table in Section 5 indicates the data requirements for an Intermediate Reserve Determination, these are briefly discussed below.

4.6.1. Co-ordinated multi-disciplinary field trip(s).

Two sampling trips including physico-chemical and biological studies to obtain a preliminary understanding of the structure and function of the Piesang Estuary.

4.6.2. Sampling during open and closed mouth conditions

Two sampling trips rather than one are needed, as the Piesang is an intermittently open estuary and therefore an understanding of the physico-chemical and biotic characteristics are necessary for both states.

4.6.3. Present MAR, hydrological and hydrodynamic studies

Hydrological studies are needed so that different run-off scenarios can be modelled i.e. present, reference and future run-off scenarios. Hydrodynamic studies will determine the relationship between flow, mouth state and salinity gradients

4.6.4 Water quality

To set the reserve for water quality, an understanding of the quality of water in the freshwater inflow is required. Point sources such as the sewage input also need to be addressed.

4.6.5 Comparison of past and present

Analyses of past and present aerial photographs / (satellite imagery) to quantify changes in habitats and macrophyte cover is essential for the interpretation of invertebrate and fish responses.

5. Data Availability

5.1. Keurbooms Estuary

Comprehensive Reserve Determination Study

5.1.1. Data availability on sediment dynamics, hydrodynamics and water quality

DATA REQUIRED	AVAIlABILITY	COMMENT
Simulated monthly runoff data (at the head of the estuary) for present state, reference conditions and the selected future runoff scenarios over a 50 to 70 year period	*Ninham Shand (1995)*	*Plettenberg Bay Coastal Catchment study and IFR worksession - different flow scenarios including different dam options were modelled. The hydrological models for the estuary will need to be updated using new flow data as there was uncertainty about the mean annual run-off in the past.*
Simulated flood hydrographs for present state, reference conditions and future runoff scenarios: • *1:1, 1:2, 1:5 floods (influencing aspects such as floodplain inundation)* • *1:20, 1:50, 1:100, 1:200 year floods (influencing sediment dynamics)*	*Huizinga and Rossouw (1999)*	*Some data available will need to be updated.*
Series of sediment core samples for the analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations) taken every 3 years along the length of an estuary (200 m to 2 km intervals).	*Reddering (1981), Reddering & Rust (1994)*	*Some data available will need to be updated.*
Series of cross-section profiles (collected at about 500 to 1000 m intervals) taken every 3 years to quantify the sediment deposition rate in an estuary [1].	*Topographical and bathymetric monitoring and survey programme (CSIR & DEAT). Huizinga & Slinger (1999)*	*Some data available will need to be updated.*
Set of cross-section profiles and a set of sediment grab samples for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations), need to be taken immediately after a major flood.		
Aerial photographs of estuary (earliest available year as well as most recent)	*CSIR, Surveys & Mapping, Cape Town, satellite imagery*	*Good coverage from 1936 to present.*
Nearshore wave data records (only if available)	*Fromme (1985)*	*Recent records need to be requested.*
Measured river inflow data (gauging stations) at the head of the estuary over a 5-15 year period	*Available from DWAF*	
Continuous water level recordings near mouth of the estuary	*DWAF*	*The estuary does have a water level recorder.*
Water level recordings at about 5 locations along the length of the estuary over a spring and a neap tidal cycle (i.e. at least a 14 day period).	*Huizinga & Slinger (1999)*	*Some data available will need to be updated.*
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: • *end of low flow season (i.e. period of maximum seawater intrusion)* • *peak of high flow season (i.e. period of*	*Huizinga and Slinger (1999)*	*Some data available, some hydrodynamic modelling completed.*

maximum flushing by river water)		
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • *end of low flow season* • *peak of high flow season*	*Duvenhage & Morant (1984)* *Huizinga & Slinger (1999)* *Grange (1999)* *Snow (2005, NMMU unpublished)*	*Some data available will need to be updated.*
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary.	*Watling & Watling (1980)*	*No data available on the reference condition.*
Water quality (e.g. system variables, nutrients and toxic substances)measurements on river water entering at the head of the estuary		
Water quality (e.g. system variables, nutrients and toxic substances)measurements on near-shore seawater[5]		*Usually obtainable from available literature.*

5.1.2. Data requirements on microalgae

DATA REQUIRED	AVAILABILITY	COMMENT
Chlorophyll-a measurements taken at 5 stations at the surface, 0.5 m and 1 m depths. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements must be taken coinciding with typically high and low flow conditions.	*Adams & Bate (1999)*	*This study showed that an increase in freshwater inflow introduced nutrients and increased phytoplankton biomass.*
Intertidal and subtidal benthic chlorophyll-a measurements taken at 5 stations (at least). *Epipelic diatoms need to be collected for identification.* *These measurements must to be taken coinciding with a typical high and low flow condition (in temporarily closed estuaries measurements must include open as well as closed mouth conditions).*	*Adams & Bate (1999)* *Snow (2005, NMMU Unpublished data)*	*Data available for August and November 1992.*
Simultaneous measurements of flow, light, salinity, temperature, nutrients and substrate type (for benthic microalgae) need to be taken at the sampling stations during both the phytoplankton and benthic microalgal surveys.	*Adams & Bate (1999)* *Snow (2005, NMMU Unpublished data)*	*Data available for August and November 1992.*

5.1.3. Data requirements on macrophytes

DATA REQUIRED	AVAILABILITY	COMMENT
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (if available) *Available orthophoto maps*	*CSIR & Surveys & Mapping, Cape Town* *Satellite image.*	*The earliest aerial photographs available and the most recent satellite images will be used to map changes in the macrophytes over time.*
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit.	*Coetzee et. al. (1997)* *Duvenhage & Morant (1984)*	*Data on botanical importance of the estuary* *Description of plant community types, species composition and area covered by each.*

Permanent transects: - *Measurements of percentage plant cover along an elevation gradient* - *Measurements of salinity, water level, sediment moisture content and turbidity*	*Grange (1999)*	*Once off measurement of distribution along two transects. If transects are repeated as part of a comprehensive study then these sites should be re-visited so that changes over time can be assessed.*

5.1.4. Data requirements on invertebrates

DATA REQUIRED	***AVAILABILITY***	***COMMENT***
Compile a detailed sediment distribution map of the estuary Obtain a detailed determination of the extent and distribution of shallows and tidally exposed substrates. During each survey, collect sediment samples for analysis of grain size [1] and organic content [2] at the six benthic sites.	*Reddering (1981), Reddering & Rust (1994)*	*Update on available information required.*
Surveys to determine salinity distribution pattern along the length of the estuary, as well as other system variables (e.g. temperature, pH and dissolved oxygen and turbidity) are required for different seasons and for different states of the tide [3] Seasonal (i.e. quarterly) physico-chemical data are also required for each of the six benthic sampling sites	*Duvenhage & Morant (1984)* *Grange (1999)*	*Data available, update may be required.*
Collect a set of six benthic samples each consisting of five grabs. Collect two each from sand, mud and interface substrates. If possible, spread sites for each between upper and lower reaches of the estuary. One mud sample should be in an organically rich area. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	*Day (1981)* *Duvenhage & Morant (1984)* *Reddering & Rust (1994)* *Zoutendyk & Bickerton (1999)*	*Some data available but insufficient for a comprehensive reserve assessment.*
Collect two sets of beam trawl samples (i.e. mud and sand). Lay two sets of five, baited prawn/crab traps overnight, one each in the upper and lower reaches of the estuary. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Survey as much shoreline as possible for signs of crabs and prawns and record observations. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	*Day (1981)* *Duvenhage & Morant (1984)* *Reddering & Rust (1994)* *Zoutendyk & Bickerton (1999)*	*Some data available but may be insufficient for a comprehensive reserve assessment.*
Additional trip(s) may be required to gather data on the occurrence/recruitment and emigration of key species such as Varuna litterata, Callianassa and Upogebia which require a connection to the marine environment at specific times of the year.	*Day (1981)* *Duvenhage & Morant (1984)* *Reddering & Rust (1994)* *Zoutendyk & Bickerton (1999)*	*Data available, understanding of recruitment patterns extrapolated from other estuaries.*
Collect three zooplankton samples, at night, one each from the upper, middle and lower reaches of the estuary. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	*Grange (1999)*	*Importance of zooplankton particularly during high flows largely unknown, update required.*

5.1.5. Data requirements on fish

DATA REQUIRED	AVAILABILITY	COMMENT
In a small estuary (<5km) collect at minimum three sets of samples from the lower, middle and upper reaches of the estuary. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets need to be in the 0 to 10 ppt reach of the estuary. Sampling should be representative of small fish (seine nets) and large fish (gill nets). *In a larger estuary (>5km) sampling can either be at fixed intervals (every 2km) or have the upper, middle and lower reaches subdivided into at least a further three sections each. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets should be in the 0 to 1 ppt reach of the system. Sampling should be representative of small fish (seine nets) and large fish (gill nets).* *Sampling should be done during both the low and the high flow season for the full extent of the system (as far as tidal variation) to allow for predictive capabilities.*	*Duvenhage & Morant (1984)* *Harrison et al. (1995)* *Whitfield (1995)* *Whitfield (1999)*	*Some data available, report available on different flow scenarios and fish response. Field surveys may be needed to verify these surveys.*

5.1.6. Data requirements on birds

DATA REQUIRED	AVAILABILITY	COMMENT
Undertake one full count of all water associated birds, covering as much of the estuarine area as possible. All birds should be identified to species level and the total number of each counted. *Monthly data sets for at least one year are required. It this is not possible, a minimum of four summer months and one winter month will be required (decisions on the extent of effort required will depend largely on the size of the estuary, extent of shallows present, as well as extent of tidally exposed areas).*	*Taylor et al. (1999)*	*CWAC count data available from 1992 to the present.*

5.2. Piesang Estuary

Intermediate Reserve Determination Study

5.2.1. Data availability on hydrodynamics and water quality

REQUIRED DATA	*AVAILABILITY*	*COMMENT*
Simulated monthly runoff data (at the head of the estuary) for Present State, Reference Condition, as well as selected future runoff scenarios over a 50 to 70 year period	*Ninham Shand (1995)*	*Some data available*
Aerial photographs of estuary (earliest available year as well as most recent)	*Surveys & Mapping, Cape Town*	
Measured river inflow data (gauging stations) at the head of the estuary over a 5-year period		*Unmeasured?*
Continuous water level recordings near mouth of the estuary		*No data*
Longitudinal salinity and temperature profiles (in situ) taken on a spring high and low tide at (river flow data must be collected during these periods as well): • *end of low flow season (i.e. period of maximum seawater intrusion)* • *peak of high flow season (i.e. period of maximum flushing by river water)*	*Grange (1999)* *Duvenhage & Morant (1984)*	*Some data available*
Water quality measurements (i.e. system variables and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring high tide at: • *end of low flow season* • *peak of high flow season*	*Grange (1999)* *Duvenhage & Morant (1984)*	*Some data available*
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary		*No data*
Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary		*May be data related to sewage input*
Water quality (e.g. system variables, nutrients and toxic substances) measurements of nearshore seawater		*Usually sourced from available literature.*

5.2.2. Data availability on macrophytes

REQUIRED DATA	AVAILABILITY	COMMENTS
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the Present State, as well as the Reference Condition. Orthophoto maps of the area	*Surveys & Mapping, Cape Town*	
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit.	*Duvenhage & Morant (1984)*	*Some data will need to be updated.*
Permanent transects (a fix monitoring station that can be used to measure change in vegetation in response to changes in salinity and inundation patterns) *Measurements of percentage plant cover along an elevation gradient.* *Measurements of salinity, water level, sediment moisture content and turbidity*	*Grange (1999)*	*Once-off survey.*

5.2.3. Data availability on microalgae

REQUIRED DATA	AVAILABILITY	COMMENTS
Chlorophyll-a measurements taken at 5 stations (at least) at the surface, 0.5 m and 1 m depths thereafter. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements should be taken coinciding with typically high and low flow conditions.	*Grange (1999)*	*Once-off survey of biomass, no group counts.*
Intertidal and subtidal benthic chlorophyll-a measurements taken at 5 stations. Epipelic diatoms need to be collected for identification. Measurements should be taken coinciding with a typical high and low flow condition (in temporarily closed estuaries measurements must include open as well as closed mouth conditions).		*No data*
Simultaneous measurements of flow, light, salinity, temperature, nutrients and substrate type (for benthic microalgae) need to be taken at the sampling stations during both the phytoplankton and benthic microalgal surveys.	*Grange (1999)*	*Once-off survey*

5.2.4. Data availability on invertebrates

REQUIRED DATA	AVAILABILITY	COMMENTS
Derive preliminary sediment map of the estuary.		
Obtain a preliminary determination of the extent and distribution of shallows and tidally exposed substrates.		
For six benthic sites, collect sediment samples for analysis of grain size and organic content		
Determine the longitudinal distribution of salinity, as well as other system variables (e.g. temperature, pH and dissolved oxygen and turbidity) at each of the six benthic sampling sites	*Duvenhage & Morant (1984)*	*Some data will need to be updated.*
During a spring tide (preferably for both low flow and high flow conditions), collect a set of six benthic samples each consisting of five grabs. Collect two each from sand, mud and interface substrates. If possible, spread sites for each between upper and lower reaches of the estuary. One mud sample should be in an organically rich area. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined.	*Duvenhage & Morant (1984)*	*Some data will need to be updated.*
During a spring tide (preferably at both low and high water and	*Duvenhage & Morant (1984)*	*Some data will need to*

REQUIRED DATA	AVAILABILITY	COMMENTS
for both low flow and high flow conditions), collect two sets of beam trawl samples (i.e. over mud and sand). Lay two sets of five, baited prawn/crab traps overnight, one each in the upper and lower reaches of the estuary. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Samples should be collected every second week under low and high flow conditions for at least two months each (i.e. five sampling sessions under the two flow scenarios). Survey as much shoreline for signs of crabs and prawns and record observations.		*be updated.*
During spring tides (preferably at both low and high water and for both low flow and high flow conditions), collect three samples, at night, one each from the upper, middle and lower reaches of the estuary for zooplankton. Samples should be collected every second week under low and high flow conditions for at least two months each (i.e. five sampling sessions under the two flow scenarios)		*No data*

5.2.5. Data availability on fish

REQUIRED DATA	AVAILABILITY	COMMENTS
In a small estuary (<5km) collect at minimum three sets of samples from the lower, middle and upper reaches of the estuary. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets need to be in the 0 to 10 ppt reach of the estuary. Sampling should be representative of small fish (seine nets) and large fish (gill nets). *In a larger estuary (>5km) sampling can either be at fixed intervals (every 2km) or have the upper, middle and lower reaches subdivided into at least a further three sections each. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets should be in the 0 to 1 ppt reach of the system. Sampling should be representative of small fish (seine nets) and large fish (gill nets).* *Sampling should be done during both the low and the high flow season for the full extent of the system (as far as tidal variation) to allow for predictive capabilities.*	*Duvenhage & Morant (1984)* *Whitfield (1995, 1999)* *Harrison et al. (1995)*	*Some data, will need to be updated.*

5.2.6. Data availability on birds

REQUIRED DATA	AVAILABILITY	COMMENTS
During a summer spring tide, undertake one full count of all water-associated birds, covering as much of the estuarine area as possible. All birds should be identified to species level and the total number of each counted.	*Duvenhage & Morant (1984)* *Martin (1995)*	*Once-off surveys, no CWAC counts.*

6. References

Adams, J.B. and G.C. Bate. 1999. Growth and photosynthetic performance of *Phragmites australis* in estuarine waters: a field and experimental evaluation. *Aquatic Botany 64*: 359-367.

Adams, J.B. Bate, G.C. and M. O'Callaghan. 1999. Estuarine Primary Producers. In: (B.R. Allanson and D. Baird, eds). Estuaries of South Africa. Cambridge University Press. pp 91-118.

Bornman, T.G. 2004 Vegetation survey of the wetland component of the proposed Hanglip development. Institute for Environmental and Coastal Management, University of Port Elizabeth. IECM Report No. C99. 26 pp.

Coetzee, J.C., Adams, J.B. and Bate, G.C. 1997. A botanical importance rating of selected Cape estuaries. *Water SA 23*: 81-93.

Day, J.H. (ed) 1981. Estuarine Ecology with particular reference to Southern Africa. A.A. Balkema Press, Cape Town. 411 pp.

Duvenage, I.R. & Morant, P.D. 1984. Keurbooms / Bitou System (CMS 19) & Piesang (CMS 18). Report No. 31. In : Estuaries of the Cape. Part II. Synopses of available information on individual systems. Eds. Heydorn, A.E.F. & Grindley, J.R. CSIR Research Report 430. CSIR, Stellenbosch. 64 pp.

Grange, N. 1999. Estuarine Limnology. Appendix A-4. In: Plettenberg Bay Coastal Catchments Study. Second Phase. Keurbooms River Estuary Environmental Worksession. Ed: Luger, M.K. Ninham Shand. DWAF Report No. PK 000/00/1699.

Harrison, T.D., Cooper, J.A.G., Ramm, A.E.L., Singh, R.A. 1995a. Health of South African estuaries, Palmiet - Sout. Technical Report, Catchment and Coastal Environmental Programme, CSIR, Durban.

Harrison, T.D., Cooper, J.A.G., Ramm, A.E.L., Singh, R.A. 1995b. Health of South African estuaries, Palmiet - Sout. Executive Report, Catchment and Coastal Environmental Programme, CSIR, Durban.

Heydorn, A.E.F. & Tinley, K.L. 1980. Estuaries of the Cape. Part I. Synopsis of the Cape coast. Natural features, dynamics and utilisation. CSIR Research Report 380. CSIR, Stellenbosch. 96 pp.

Huizinga, P. & Rossouw, M. 1998. The effect of water abstraction on the Keurbooms Estuary. CSIR Report ENV/S-C 97006. 30 pp + appendices.

Huizinga, P. & Slinger, J. 1999. Physical dynamics of the Keurbooms-Bitou and Piesang Estuaries. Appendix A-2: Estuarine Dynamics. In: Plettenberg Bay Coastal Catchments Study. Second Phase. Keurbooms River Estuary Environmental Worksession. Ed: Luger, M.K. Ninham Shand. DWAF Report No. PK 000/00/1699

Luger, M. 1999. Executive Summary. Plettenberg Bay Coastal Catchments Study. Second Phase. Keurbooms River Estuary Environmental Worksession. Ed: Luger, M.K. Ninham Shand. DWAF Report No. PK 000/00/1699.

Martin, P. 1995. Proceedings of the IFR Worksession. Plettenberg Bay Catchment Study. Initial Environmental Assessment. Ninham Shand. DWAF Report No. K600/00/019. 93 pp.

Ninham Shand 1995. Proceedings of the IFR Worksession. Plettenberg Bay Catchment Study. Initial Environmental Assessment. Ninham Shand DWAF Report No. K600/00/019. 93 pp.

Reddering, J.S.V. 1981. The sedimentology of the Keurbooms Estuary. Unpublished M.Sc. thesis. University of Port Elizabeth, South Africa. 131 pp.

Reddering, J.S.V. 1999. The effects of proposed municipal water extraction from rivers in the Plettenberg Bay area on their estuarine sediment dynamics. Appendix A-3. In: Plettenberg Bay Coastal Catchments Study. Second Phase. Keurbooms River Estuary Environmental Worksession. Ed: Luger, M.K. Ninham Shand. DWAF Report No. PK 000/00/1699.

Reddering, J.S.V. 1999. The effects of proposed municipal water extraction from rivers in the Plettenberg Bay area on their estuarine sediment dynamics. Appendix A-3: Estuarine Sedimentation. In: Plettenberg Bay Coastal Catchments Study. Second Phase. Keurbooms River Estuary Environmental Worksession. Ed: Luger, M.K. Ninham Shand. DWAF Report No. PK 000/00/1699

Schumann, E.H. 2003. Towards the management of marine sedimentation in South African estuaries with special reference to the Eastern Cape. WRC Report No. 1109/1/03. 125 pp.

Snow, G.C. 2005. Unpublished data of 2002 field trip. Department of Botany, Nelson Mandela Metropolitan University, Port Elizabeth.

Stone, A.W., Weaver, A. B. & West, W.O. 1998. Climate and Weather. Field guide to the Eastern and Southern Cape Coasts. Eds: Lubke, R. & de Moor, I. University of Cape Town Press. pp 41 – 49.

Taljaard, S., Adams, J.B., Bate, G.C., Cyrus, D., Huizinga, P., Lamberth, S., Turpie, J., Van Niekerk, L. & Weston, B. 2004. Determination of Preliminary Ecological Reserve for Estuaries. 2004. Appendix E: Templates to be completed by specialists as part of Ecological Reserve determination process. 19 pp.

Taljaard, S., van Niekerk, L., Huizinga, P. & Joubert, W. 2003. Resource monitoring procedures for estuaries for application in the ecological reserve determination and implementation process. Water Reseaarch Commission Report 1308/1/03.

Taylor, P.B., Navarro, R.A., Wren-Sargent, M., Harrison, J.A. & Kieswetter, S.C. 1999. CWAC Report. Co-ordinated Waterbird Counts in South Africa, 1992 – 1997. Avian Demography Unit, University of Cape Town. 251 pp.

Turpie, J.K. 2004. Improving the Biodiversity Importance Rating of South African estuaries. Information requirements for the implementation of resource directed measures for estuaries. WRC Programme K5/1247. 121 pp.

Whitfield, A.K. 1995. Proceedings of the IFR Worksession. Plettenberg Bay Catchment Study. Initial Environmental Assessment. Ninham Shand. DWAF Report No. K600/00/019. 93 pp.

Zoutendyk, P. & Bickerton, I.B. 1999. Habitat types and standing stock of intertidal macro-benthos in the Keurbooms-Bitou Estuary. Appendix A6: Estuarine Vegetation. In: Plettenberg Bay Coastal Catchments Study. Second Phase. Keurbooms River Estuary Environmental Worksession. Ed: Luger, M.K. Ninham Shand. DWAF Report No. PK 000/00/1699

7. APPENDIX

Proposed data required for the Comprehensive Reserve Determination of the Keurbooms / Bitou Estuary

(will need to be refined after consultation with specialists)

SEDIMENT DYNAMICS, HYDRODYNAMICS & WATER QUALITY: DATA REQUIRED	**Yes** – study required **Previous data may be adequate** – specialist to advise **Available** – data available
Simulated monthly runoff data (at the head of the estuary) for present state, reference conditions and the selected future runoff scenarios over a 50 to 70 year period	*Yes*
Simulated flood hydrographs for present state, reference conditions and future runoff scenarios: *1:1, 1:2, 1:5 floods (influencing aspects such as floodplain inundation)* • *1:20, 1:50, 1:100, 1:200 year floods (influencing sediment dynamics)*	*Yes*
Series of sediment core samples for the analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations) taken every 3 years along the length of an estuary (200 m to 2 km intervals).	*Previous data may be adequate?*
Series of cross-section profiles (collected at about 500 to 1000 m intervals) taken every 3 years to quantify the sediment deposition rate in an estuary [1]*.*	*Yes, to check if there has been sedimentation.*
Set of cross-section profiles and a set of sediment grab samples for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations), need to be taken immediately after a major flood.	*Previous data may be adequate?*
Aerial photographs of estuary (earliest available year as well as most recent)	*Available*
Nearshore wave data records (only if available)	*Available*
Measured river inflow data (gauging stations) at the head of the estuary, 5-15 year period	*Available?*
Continuous water level recordings near mouth of the estuary	*Available*
Water level recordings at about 5 locations along the length of the estuary over a spring and a neap tidal cycle (i.e. at least a 14 day period).	*Previous data may be adequate?*
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: • *end of low flow season (i.e. period of maximum seawater intrusion)* • *peak of high flow season (i.e. period of maximum flushing by river water)*	*Previous data may be adequate?*
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • *end of low flow season* • *peak of high flow season*	*Yes, potential problems related to increased sewage discharge.*
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary.	*Previous data may be adequate?*
Water quality (e.g. system variables, nutrients and toxic substances)measurements on river water entering at the head of the estuary	*Yes, potential problems related to increased sewage discharge.*
Water quality (e.g. system variables, nutrients and toxic substances)measurements on near-shore seawater[5]	*Available?*
MICROALGAE : DATA REQUIRED	
Chlorophyll-a measurements taken at 5 stations at the surface, 0.5 m and 1 m depths. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements taken coinciding with typically high and low flow conditions.	*Yes, response to freshets unknown.*
Intertidal and subtidal benthic chlorophyll-a measurements taken at 5 stations (at least). Epipelic diatoms need to be collected for identification. These measurements must to be taken coinciding with a typical high and low flow condition (in temporarily closed estuaries measurements must include open as well as closed mouth conditions).	*Yes, response to nutrient input unknown.*
Simultaneous measurements of flow, light, salinity, temperature, nutrients and substrate type (for benthic microalgae) need to be taken at the sampling stations during both the phytoplankton and benthic microalgal surveys.	*Yes.*

MACROPHYTES:DATA REQUIRED	
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (if available) *Available orthophoto maps*	***Yes, changes over time need to be assessed in order to calculate the Estuarine Health Index.***
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit.	*Available*
Permanent transects: - *Measurements of percentage plant cover along an elevation gradient* - *Measurements of salinity, water level, sediment moisture content and turbidity*	*Yes, transects needed to assess the importance of groundwater input in maintaining brackish vegetated areas in the Bitou.*
INVERTEBRATES: DATA REQUIRED	
Compile a detailed sediment distribution map of the estuary Obtain a detailed determination of the extent and distribution of shallows and tidally exposed substrates. During each survey, collect sediment samples for analysis of grain size [1] and organic content [2] at the six benthic sites.	*Previous data may be adequate?*
Surveys to determine salinity distribution pattern along the length of the estuary, as well as other system variables (e.g. temperature, pH and dissolved oxygen and turbidity) are required for different seasons and for different states of the tide [3] Seasonal (i.e. quarterly) physico-chemical data are also required for each of the six benthic sampling sites	*Yes, included as part of the water quality survey.*
Collect a set of six benthic samples each consisting of five grabs. Collect two each from sand, mud and interface substrates. If possible, spread sites for each between upper and lower reaches of the estuary. One mud sample should be in an organically rich area. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	*Previous data may be adequate?*
Collect two sets of beam trawl samples (i.e. mud and sand). Lay two sets of five, baited prawn/crab traps overnight, one each in the upper and lower reaches of the estuary. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Survey as much shoreline as possible for signs of crabs and prawns and record observations. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	*Previous data may be adequate?*
Additional trip(s) may be required to gather data on the occurrence/recruitment and emigration of key species such as Varuna litterata, Callianassa and Upogebia which require a connection to the marine environment at specific times of the year.	*Previous data may be adequate?* *Mouth closure is not expected.*
Collect three zooplankton samples, at night, one each from the upper, middle and lower reaches of the estuary. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	*Yes, response to freshets unknown.*
FISH: DATA REQUIRED	
In a larger estuary (>5km) sampling can either be at fixed intervals (every 2km) or have the upper, middle and lower reaches subdivided into at least a further three sections each. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets should be in the 0 to 1 ppt reach of the system. Sampling should be representative of small fish (seine nets) and large fish (gill nets). *Sampling should be done during both the low and the high flow season for the full extent of the system (as far as tidal variation) to allow for predictive capabilities.*	*Previous data may be adequate?* *Yes, verification of previous predictions necessary.*
BIRDS: DATA REQUIRED	
Undertake one full count of all water associated birds, covering as much of the estuarine area as possible. All birds should be identified to species level and the total number of each counted. *Monthly data sets for at least one year are required. It this is not possible, a minimum of four summer months and one winter month will be required (decisions on the extent of effort required will depend largely on the size of the estuary, extent of shallows present, as well as extent of tidally exposed areas).*	*Yes, CWAC counts available but only for summer and winter annually.*