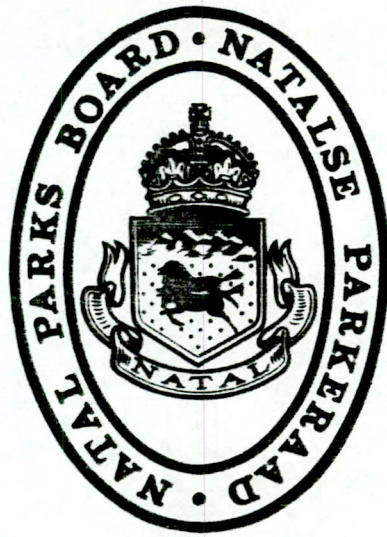


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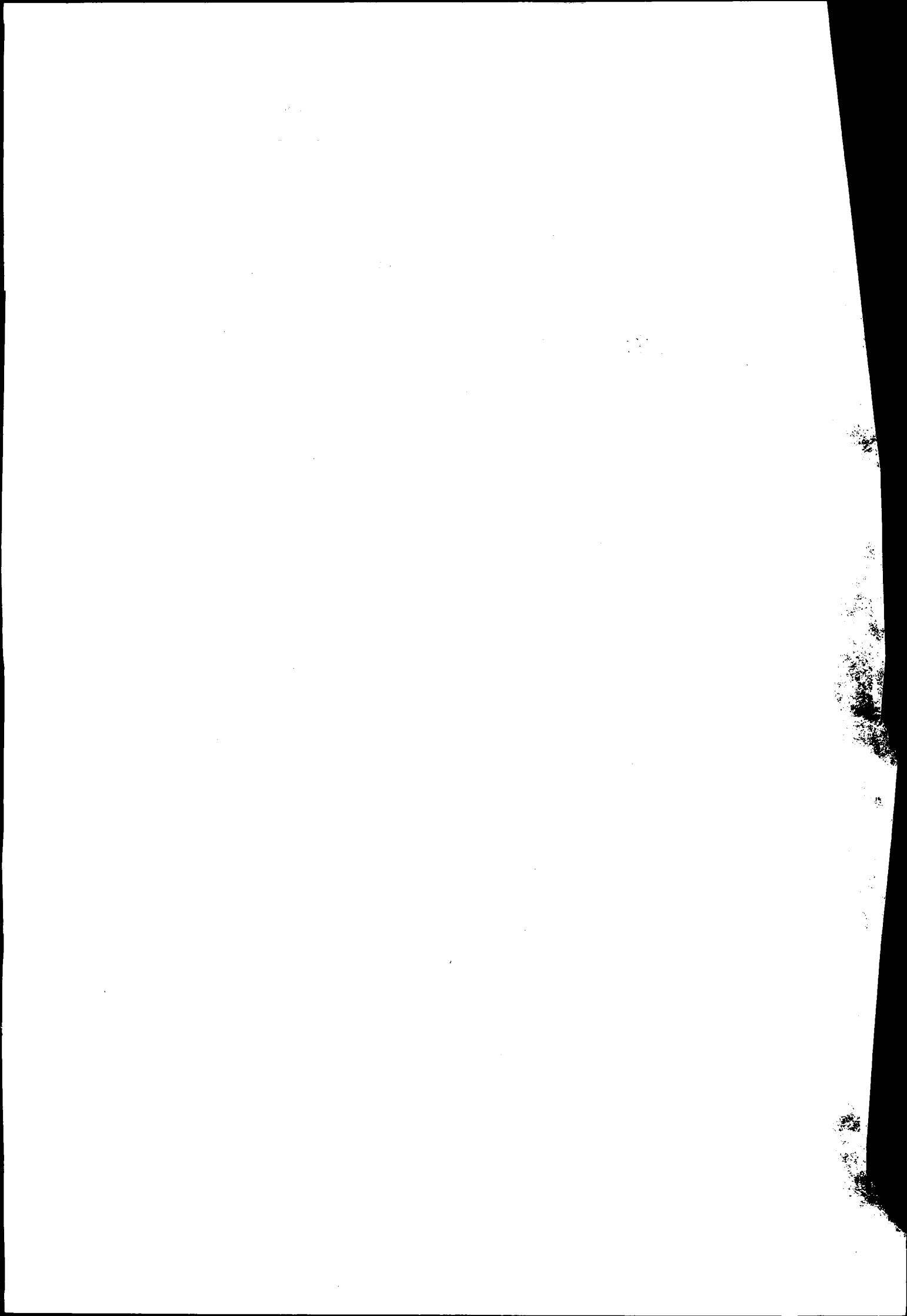


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796

**MANAGEMENT PROPOSALS FOR THE ST. LUCIA ESTUARY MOUTH.**

by

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**SPECIAL REPORT NO.3 FOR NATAL PARKS BOARD**  
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## DOCUMENT SUMMARY

- Dredging operations should be suspended during strong to gale-force north-easterly winds as longshore drift transports the dredged sediment back to the estuary mouth.
- Shoaling caused by the dredger pipeline reduces the tidal prism and increases the instability of the inlet.
- The dredger spoil must not be dumped on the south bank as most of it is recycled back into the estuary.
- Large tidal prisms support stable tidal inlets.
- The dredger sink should not be more than 6 m deep, as deeper holes will excavate the underlying muddy sediments.
- When lake levels are high the St. Lucia system maintains an open outlet to the sea with minimal help from the dredging. When lake levels are low, increased meandering and shoaling takes place within the estuary mouth which causes erosion of the north bank. Increased shoaling also reduces the tidal prism volume, ultimately causing the mouth to close.
- Dredger efficiency is still an unknown quantity.
- The sandbar at Honeymoon Bend is not marine-derived but local, probably from the dredger harbour construction site.
- Cross-section measurements and sediment sample collection should continue. A Furuno FE-400 echo sounder should be purchased for logging cross-sections. This is faster than surveying the cross-sections.
- Aeolian transport estimates vary greatly depending on the basic physical assumptions which are built into the equations. Significant volumes of sand are potentially capable of being transported into the estuary no matter which equations are used.
- Removal of Casuarinas from the north and south banks may cause the mouth position to migrate further north or south of its present position.
- Removal of trees from the south bank will also destabilise the large dredger spoil site, enabling wind to blow large amounts of sand into the estuary.
- Dredging activity should be suspended when lake levels are high. If shoaling ultimately causes the mouth to close the dredger could then be used to reopen the mouth.
- Innovative alternative methods of opening the mouth ought to be investigated.

## INTRODUCTION

For the past two years the sediment dynamics of St. Lucia Estuary Mouth have been monitored with a view to making management recommendations. Other interim reports have been submitted to Natal Parks Board including:

- (1) Preliminary report on the sedimentation in St. Lucia Estuary Mouth;
- (2) Evolution of sedimentary environments and facies, St. Lucia Estuary Mouth.

This is a special report outlining our views on the management of the estuary. The report deals with:

- (1) the dredger and pipeline associated with it;
- (2) aeolian sand transport and the effects of Casuarina removal.

The geography and geomorphology of the St. Lucia Estuary Mouth are shown in figures 1, 2 and 3.

## 1. DREDGING

### 1.1. Dredge outlet and pipeline.

Under normal circumstances net longshore drift is northward but our observations indicate that during strong to gale-force north to north-easterly winds a southerly reversal of longshore drift occurs. This transports pumped sediment back into the estuary mouth. Evidence for the existence of this southerly current includes:

- (a) pumped debris found scattered along the beach south of the outlet pipe;
- (b) the beach south of the outlet is discoloured with fine organic matter and mud, indicating southerly transport of pumped sediment;
- (c) pumped sediment causes the beach to locally prograde outward, but only to the south of the dredge outlet pipe;
- (d) when the organic dye rhodamine B was dissolved in the ocean, approximately 75 m offshore in the mid-break, it moved in a southerly direction at a rate of approximately  $1 \text{ m sec}^{-1}$ .

During moderate north and north-easterly winds the longshore drift is to the north. The reversal which occurs during strong to gale-force winds prompts us to recommend that dredging operations be temporarily halted under these circumstances, as any pumped sediment will be transported back into the estuary mouth. It was initially thought that the dredger outlet pipe was placed within the effect of the local longshore current reversal. The reversal is set up by the dominant south-easterly wave regime being refracted around the ebb-tidal delta. Closer inspection showed that a northerly longshore drift prevailed at the outlet pipe, except during strong to gale-force north to north-easterly winds.

The pipeline connecting the dredger to the northern estuary bank modifies the tidal flow within the estuary, decreasing current velocities and depositing sediment. The sediment is deposited as a side-attached bar and as a flood-tidal delta (Fig.3). These deposits are both laid down within the intertidal zone, and according to Reddering (1988) excessive intertidal sedimentation reduces the tidal prism, thus reducing the stability of the inlet. (The tidal prism is defined as the volume of water which moves in and out of an estuary during one complete tidal cycle). This is undesirable in St. Lucia as the dredging is designed to improve the stability of the inlet.

Dredged spoil should not be dumped on the southern bank of the estuary as wind action will blow sand back into the estuary mouth. When dredged spoil was pumped onto the south bank it was noticed that the water flowed away from the dredger outlet, through the Casuarina trees to the back-beach where it then flowed northward, entering the estuary mouth behind the southern spit moving sand back into the mouth! (Fig.4).

## 1.2. Shoaling

Under normal circumstances little sediment accumulates in the intertidal zone during intervals between river floods. Therefore, the tidal prism is relatively unaffected by volume displacement caused by sediment accumulation in an estuary (Reddering, 1988). This is the key to the maintenance of a stable tidal inlet because the inlet's stability is controlled by the tidal prism. "The larger the tidal prism, the better the tidal water mass will be able to scour wave-deposited sediment from the inlet channel" (Reddering, 1988). Inlet stability will thus be little affected by changes in the channel dimensions of an estuary resulting from sediment accumulation during extensive periods of low discharge. Since a significant component of the sediment that enters an estuary accumulates in the subtidal zone, the extent of possible shoaling may be hidden and thus overlooked for a considerable period. This could create the false impression that the estuary is not suffering the adverse effects of artificially reduced discharge, as may be the case with the St. Lucia system, since the diversion of the Mfolozi River in the nineteen fifties.

The decrease in catchment discharge by the removal of the Mfolozi River flow from the St. Lucia System, has meant that shoaling will be a major problem at the estuary mouth. During years when lake level is high the estuary may maintain an open inlet, without dredging, but the channel width would be expected to decrease (Wright & Mason, 1989). During drought years there will be no hydraulic head within the main lake to help flush accumulated marine sediment from the estuary. This combines with the effects of a reduced catchment discharge which causes shoaling at the estuary mouth and thus necessitates a dredging programme.

The marine sediment wedge initially advanced rapidly up the estuary after the September 1987 floods as a series of overlapping flood-tidal deltas (Figs.2 & 3), reaching 730 m up the estuary by February 1988. By the end of October 1989 the furthest flood-tidal delta was 800 m up the estuary, having moved only 70 m since February 1988. If the dredger maintains its present position and pumps sediment at optimum efficiency, some of the marine sediment influx can be pumped out of the system. We do not know how efficient this dredger operation is, but we estimate 97200 m<sup>3</sup> has bypassed the dredger.

The sand-bar built up at Honeymoon bend comprises catchment-derived material, and not marine (Wright et al., in press; fig.5). The sand-bar is formed by catchment material brought down on the ebb-tide and deposited where the estuary widens, decreasing flow velocities and depositing sediment. Sampling indicates that the sediment forming the sand-bar was not brought down the Narrows but has a closer provenance, possibly from the harbour being built on the north bank 3 km up from Honeymoon Bend. This supposition is reasonable as there are no upstream sand sources in the channel north of the harbour, and the channel bed is muddy.

For maximum effect and economy, dredging should take place in a limited area to form a sediment trap within the flood tidal channel. This sediment trap should be located as close to the tidal inlet as possible to catch the sediment before it forms a flood-tidal delta. The strong wave influence does not

make it possible for the dredger to be sited near the tidal inlet, thus the dredger is situated further up the estuary. The ebb- and flood-tidal channels often fluctuate positions between traverse lines D1 to D3, depending where the flood-tidal deltas form. A semi-permanent flood-tidal channel is present between traverses D3 and D4, near the southern bank. It is at this position that the dredger would be of most use, forming a hole to trap the marine sediment brought in on the flood tide.

### 1.3. Cross-sections

It is recommended that the ten estuarine cross-sections continue to be monitored. At present the cross-section traverses are surveyed by the Natal Parks Board. We recommend the purchase of a Furuno FE-400 echo sounder, with a paper print out to record the cross-sections. An echo sounder is very useful for logging quick, continuous depth profiles across the channel. Provided the depth sound gain is kept constant, the nature of the bottom sediment (sand or mud) may be assessed, as each has different reflective characteristics. Thus regular echo sounding, combined with sample collecting, will provide a detailed record of sediment distribution, channel configuration and the effect of dredging on the channel bottom.

Disadvantages of the echo sounding method include wind and tidal current effects upon the boat, thus soundings should only be carried out on a calm day during slack tides. To obtain a true profile for the channel the horizontal distance has to be altered to the true channel width. This is done by digitising the echo sounding results using a computer. The data may be collected using technical personnel and may be obtained faster than conventional survey methods.

## 2. AEOLIAN TRANSPORT AND THE EFFECT OF CASUARINA REMOVAL

Sand transport rates were estimated using a sand rose calculated with voluntary observing ships (VOS) data (Fig.6). The calculations were based on methods documented by Fryberger (1979), Illenberger (1986) and Illenberger & Rust (1988). The results indicated a Resultant Drift Potential (RDP) of  $12.9 \times 10^3 \text{ m}^3/\text{km}/\text{year}$  in a northward direction.

Van Heerden & Swart (1986) indicate that aeolian transport is capable of moving approximately  $20 \times 10^3 \text{ m}^3/\text{km}/\text{year}$  of sediment northward into the St. Lucia Estuary Mouth. Van Heerden & Swart (1986) also state that a 400 m wide expanse of sand is present on the south bank of the estuary, resulting in  $8 \times 10^3 \text{ m}^3/\text{km}/\text{year}$  of sand being deposited into the estuary.

Although our estimates show a lesser volume of sand movement, Van Heerden & Swart's calculations may be out by a factor of three depending on the wind data and the sand moisture content (Van Heerden & Swart (1986)). These figures are the best available, but they are still crude estimates.

Field studies indicate a large open area on the north bank of the Mfolozi River Mouth which provides a potentially large sediment source. The net northward aeolian sand movement from this open area forms a prograding spit just south of the St. Lucia Estuary Mouth. The longshore drift reworks the spit northward into the estuary mouth. Thus the available width estimate of 400 m for aeolian sediment by Van Heerden & Swart (1986) is now an underestimate as they did not take the extra area north of the Mfolozi River into account.

We estimate that the net northward sand movement occurs over a 540 m stretch, providing  $7 \times 10^3 \text{ m}^3/\text{km}/\text{year}$  sand into the St. Lucia Estuary Mouth. Van Heerden & Swart's (1986) estimate for the same area is  $10.8 \times 10^3 \text{ m}^3/\text{km}/\text{year}$ . From these rough figures, calculated using different assumptions, it

is obvious that estimated aeolian transport rates are extremely variable. Aeolian processes along the beach north of the estuary mouth moves approximately  $0.7 \times 10^3 \text{ m}^3/\text{km}/\text{year}$  sand north into the Casuarina plantations. Casuarina trees are currently being harvested from the north bank. To date only a small percentage has been removed and the large amount of undergrowth and pine needle blanket protects the underlying sediment from the wind. A small  $15 \text{ m}^2$  blowout formed eighteen months ago, and frequent monitoring since then has demonstrated little increase in size. If all the trees are removed, theoretically  $6.2 \times 10^3 \text{ m}^3/\text{km}/\text{year}$  sand may be available for transport northward from the estuary mouth. If the Casuarina plantation on the south bank is removed, and the area remains stripped of vegetation, it would be theoretically possible for aeolian transport of approximately  $25.4 \times 10^3 \text{ m}^3/\text{km}/\text{year}$  sand to move into the estuary.

Although the felling of Casuarinas from the north bank does allow sediment to move north away from the estuary, it also has the detrimental effect of destabilising the area enabling the mouth to move north into the position which it occupied in the early nineteen hundreds (Fig.7). This would mean that the estuary mouth would effectively meander over a far greater distance than it does at present, causing increased dredger management problems. Removal of the plantation on the south bank will not only deposit more sediment into the estuary, but will further destabilise the area enabling the mouth to meander further south than it does at present.

### 3. BANK EROSION

Increased intertidal sedimentation in the lower estuary between traverse lines D4 and D1 has caused the inlet to migrate. The channel meandering has caused erosion along the north bank from the ski-boat clubhouse to Shark Basin. Bank erosion along the north bank between the ski-boat club and the boardwalk has deposited approximately  $14300 \text{ m}^3$  of sediment into the estuary. The erosion has: (1) removed the sand dumped by past dredging activity; (2) uncovered fill from the old groyne complex; (3) undercut a few trees (Fig.8). The exposed fill, which consists of dolerite pebbles and boulders, may hinder the erosion, but increased shoaling at the estuary mouth may cause the meander to tighten, causing increased erosion along the north bank. Erosion is caused by the meandering channel as well as the dominant south-easterly swell which enters the estuary mouth and dissipates its energy on the north bank. According to Van Heerden & Swart (1986) erosion of the dredge spoil site by Cyclone Domoina removed approximately  $500\,000 \text{ m}^3$  sand from the estuary mouth. Longshore drift reworked  $420\,000 \text{ m}^3$  sand into the estuary, forming the southern spit, resulting in the net loss of  $80\,000 \text{ m}^3$  of sand. The September 1987 floods did not alter the dredge spoil site on the south bank to the same degree as that of Cyclone Domoina.

### 4. MOUTH CLOSURE

We believe that different solutions to the problem of mouth closure ought to be explored. It is extremely expensive to maintain the dredger permanently on station in the mouth and we also have no good information on the volumes of sediment which are being pumped. The dredger acts as a baffle to the easy passage of the ebb and flood tidal currents and most of the time the dredger pipeline traps sand. If it is desirable and necessary to keep the mouth permanently open, and we are not convinced that this is the best policy, it ought to be possible to do so with simpler, cheaper methods. We suggest that a high pressure water jet could be used to sluice sand away and let the hydraulic head in the lake flush the

mouth. We have not investigated this proposal in detail, but a casual poll of several engineers and engineering geologists revealed no serious objections to the method. For reasons of economy, it would obviously be in NPB's best interests to conduct a cost-benefit analysis on the current dredger operation, and on the alternative methods of opening the mouth, if it were demonstrated that closure might be acceptable.

## 5. CONCLUSIONS

Post-flood sedimentation within an estuary mouth is a natural post-flood response (Cooper *et al.*, 1988; Reddering, 1988). During high lake levels, experienced during the last 6 years, since Cyclone Domoina flushed the estuary, St. Lucia was capable of maintaining an open inlet to the sea without dredging. It is recommended that dredging operations be kept to a minimum or completely stopped during times when there are high lake levels.

During drought years when lake levels are low, and there is an increased period between floods, there will be a decrease in catchment discharge which will lead to shoaling, and closure of the estuary mouth, thus the dredging programme will be needed if an open mouth is to be maintained.

Dredging operations should be suspended as the estuary mouth is behaving in a manner similar to that which prevailed before the Mfolozi River mouth was relocated in the late nineteen-fifties. During drought years the mouth may close but this is natural. It may be possible to open the mouth when necessary by using a front-end loader or a high pressure hose, thus completely doing away with the costly dredging operation. This will result in significant savings for the board.

Depending on which scenario is accepted, anticipated global warming will affect the climatic regime, and this may change the season during which rain falls, and also the volume of rain. There is no consensus about figures relating to sea-level rise, but there is no doubt that the eastern seaboard of South Africa, including the entire Natal coast, is most vulnerable to attack by the sea. It is likely, given the worst case scenario, that the east coast geomorphology will be drastically altered. This is especially true of estuaries and lagoons.

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Figure 1. Location of the study area and configuration of the St. Lucia Estuary Mouth, traced from a map made for Natal Parks Board. The mouth shape changes with the seasons.

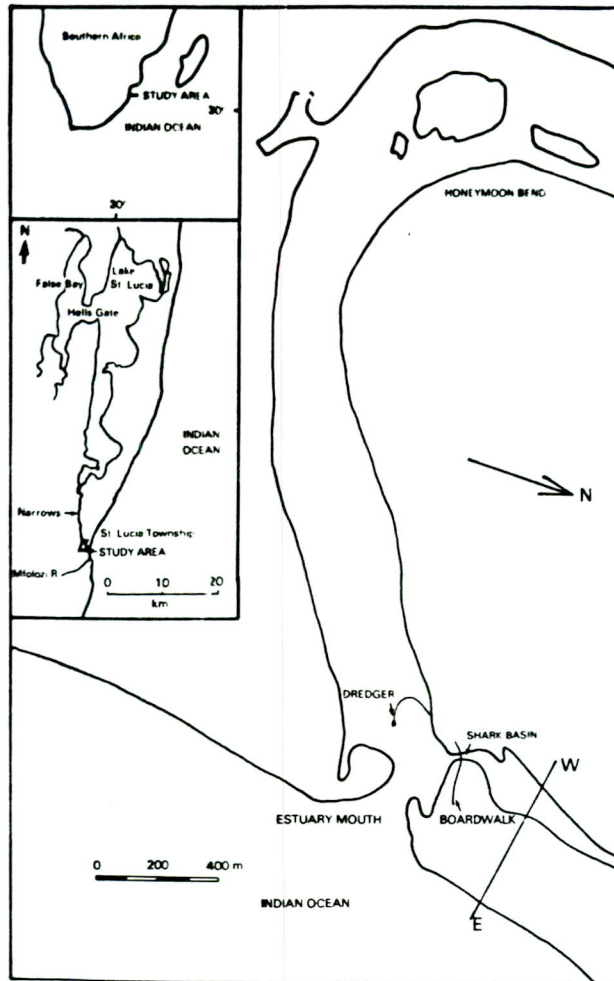


Figure 2. Tracing made from oblique aerial photograph taken by Natal Parks Board showing the configuration of St. Lucia Estuary Mouth and the sand banks constructed by the flood- and ebb-tidal deltas. Photograph by Frank Junor, NPB DATE 1986.

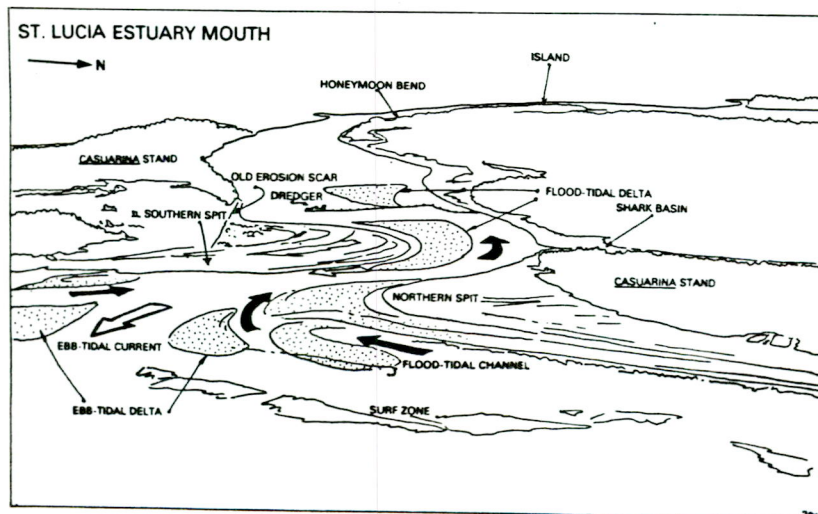


Figure 3. Sedimentary environments of St. Lucia Estuary Mouth, including flood-tidal deltas and a side-attached bar in the vicinity of the dredger pipeline.

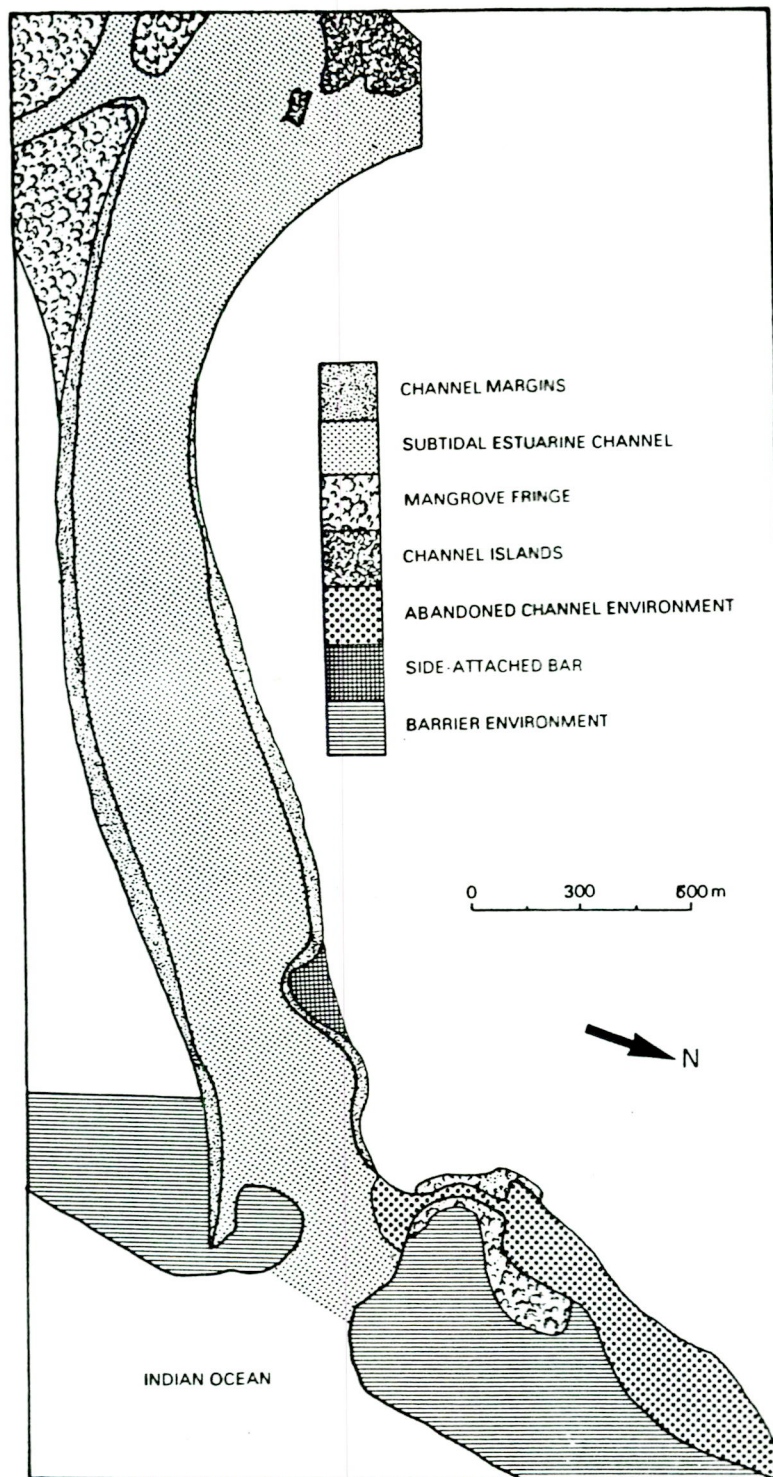


Figure 4. A photograph taken from the south spit looking north-west towards the dredger. The stream of water in the foreground is from the dredge outlet on the south bank of the estuary.



Figure 5. Sand content of the bottom sediment in St. Lucia Estuary Mouth sampled during December 1988. The arrow points to a sandbar built up in mid-channel at Honeymoon Bend.

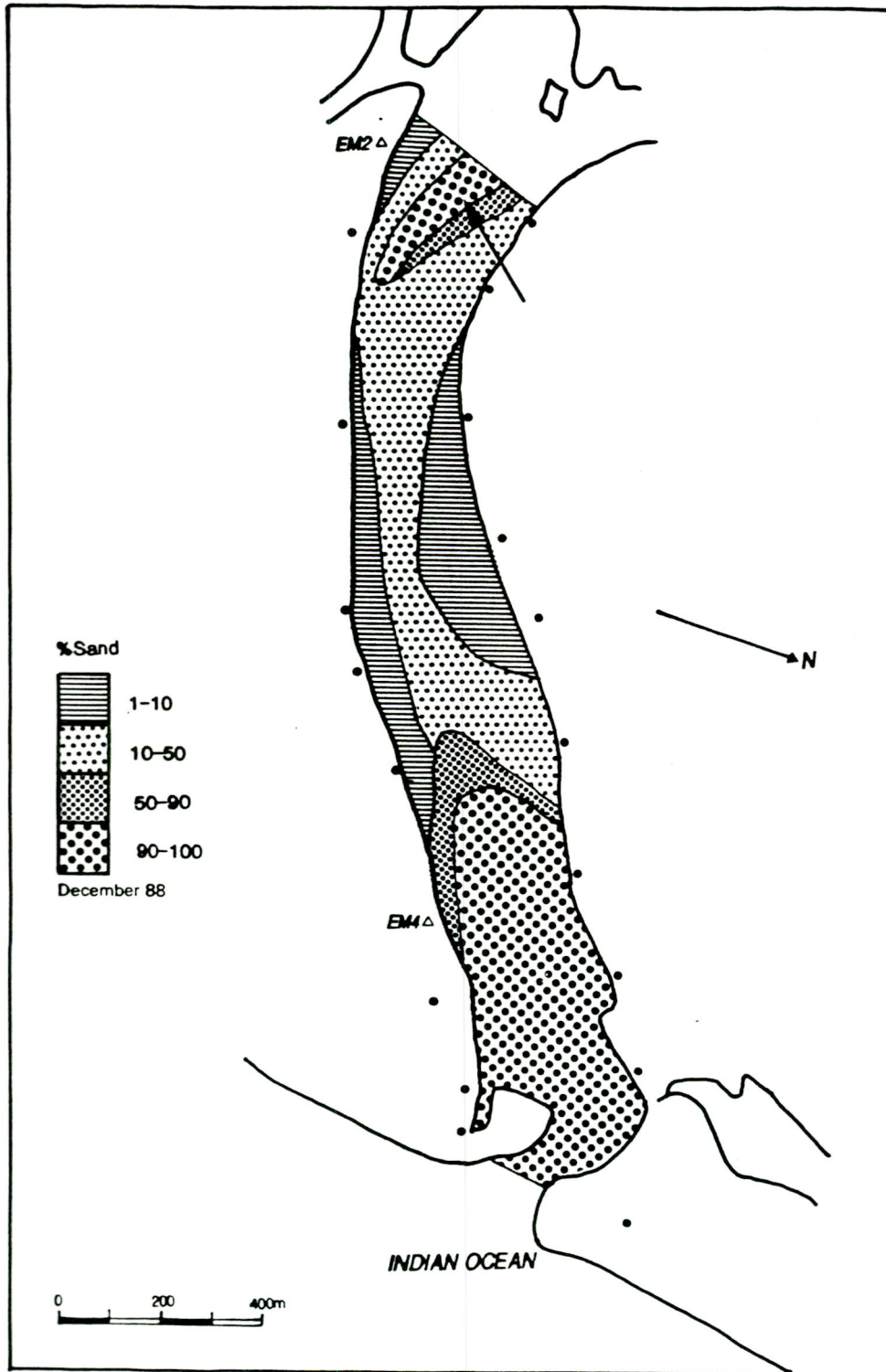


Figure 6. A wind rose showing a resultant drift vector of 13 m<sup>3</sup>/m/year, in a northerly direction for the St. Lucia area.

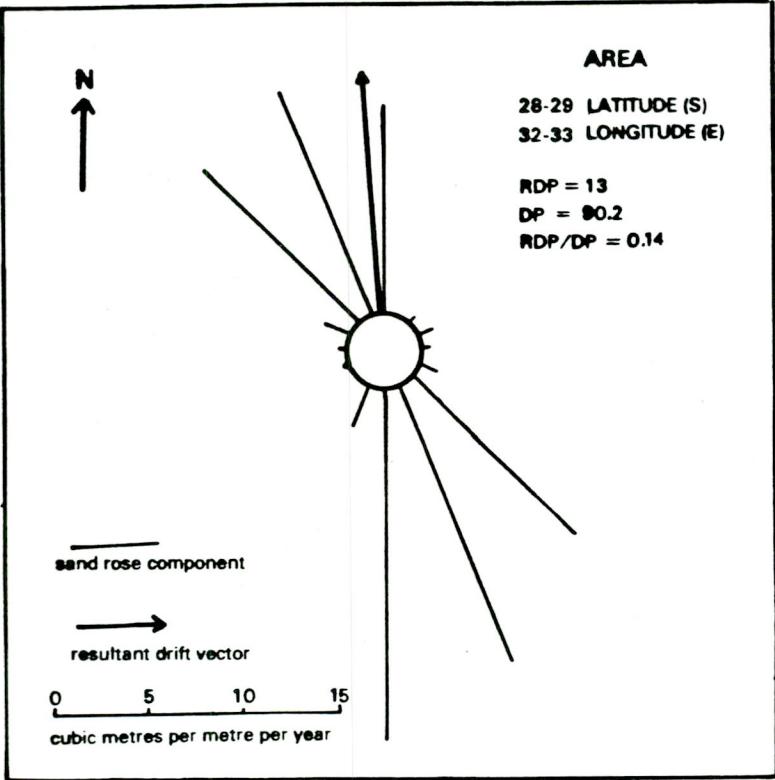




Figure 8. Erosion along the north bank of the estuary mouth.

