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**SPECIAL REPORT FOR
NATAL PARKS BOARD**

on

**A PILOT STUDY OF THE SEDIMENTOLOGY AND DYNAMICS
OF THE MFOLOZI ESTUARY,
ZULULAND**

T R MASON & C I WRIGHT

**Marine Geoscience Unit
Dept. of Geology & Appl. Geology
University of Natal
Durban, 4001**

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EXECUTIVE SUMMARY

The Mfolozi Estuary is characterised by 2 sedimentary environments:

1. A Barrier-associated environment comprising medium-grained marine sand.
2. An Estuarine/Lagoonal environment consisting almost entirely of catchment-derived mud.

The marine sand enters approximately 800 m up the estuary as pulses on spring flood-tides, forming emergent flood-tidal-deltas. The mud is responsible for the degradation of the estuary by causing shallowing and turbidity.

The main forces acting on the sediments are:

1. Fluvial flow transporting catchment-derived sediments and debris.
2. Tidal currents carrying marine sand into the estuary and removing minor marine and catchment-derived sediments offshore.
3. Wind action causing aeolian transport of sand from the spits into the 2 environments and limited bank erosion by wind-induced waves.

As with the St. Lucia Estuary Mouth, the dynamics of the Mfolozi Estuary are controlled by the interaction of catchment input, swell regime, tidal currents and wind action. Both systems are intricately linked, a change in one affecting the other. The common ebb-tidal-delta seems to be the driving mechanism for both estuaries. A great deal of information has to be collected before any significant understanding of processes can be obtained.

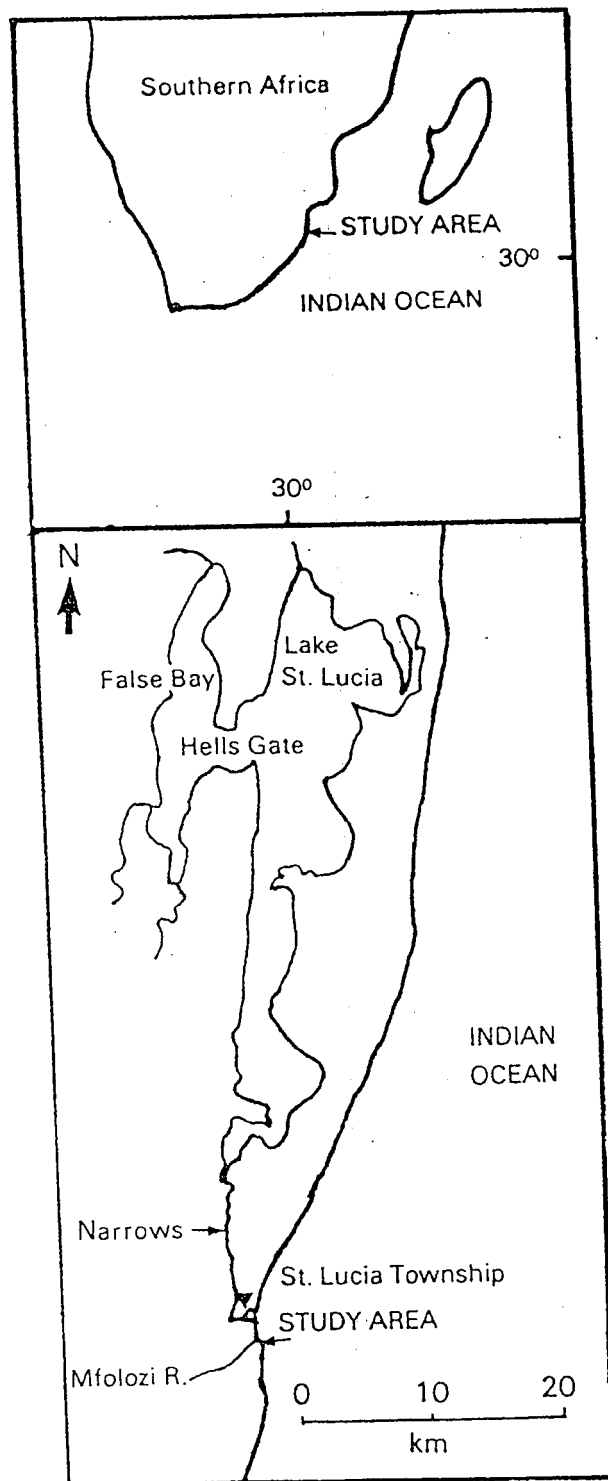


Fig.1. Location of study area.

1. INTRODUCTION

1.1. locality and aims

The Mfolozi - Msunduzi estuary complex is located 28° 24'S: 32° 25' 30"E (Fig.1.) and is regarded as a separate system to the St. Lucia Estuary as it is permanently separated by a barrier complex. The study area is shown as Fig. 2., comprising the first 3 km of the estuary. Although the sedimentation of the St. Lucia Estuary has been fairly comprehensively studied little is known of the Mfolozi Estuary.

The aims of this report are twofold:

1. To undertake a pilot study of the sedimentation within the Mfolozi Estuary.
2. To highlight future areas of research so that a more complete understanding of the Mfolozi system may be obtained and compared with the St. Lucia system. Only then can sound management ideas be formulated and then implemented.

1.2. Catchment characteristics

The Mfolozi River catchment is the second largest drainage basin in Natal/KwaZulu with estimates in size ranging from 9918 km² to 10700 km² (Begg, 1978). The Msunduzi River has a catchment of 559 km². The Mfolozi River, comprising the Black and White Mfolozi Rivers, have a combined length of 395 km while the Msunduzi River has a length of 70 km (Begg, 1978). Estimates of the mean annual runoff for the Mfolozi River vary from 1060 x 10⁶ m³ (Chew & Bowen, 1971) to 746 x 10⁶ m³ (Hutchinson, 1976) while the Msunduzi River has 89 x 10⁶ m³ runoff per annum. Van Heerden and Swart (1986) estimate a mean annual sediment yield of 1.5 x 10⁶ m³. The Mfolozi River has an extremely erratic flow with average winter flows being as little as 3 m³/sec and average summer flows 60 m³/sec although flood events such as Cyclone Domoina in 1984 are capable of delivering in excess of 16 000 m³/sec.

The catchment geology is fairly complex ranging in rocks of Swazian age (3 100 Ma) to recent unconsolidated sediments. Bad catchment management combined with recent droughts has caused a dramatic increase in sediment to the estuary. Human interference with the system, starting in the 1930's, has been documented by Orme (1975), Van Heerden and Swart (1986), Wright (1990) and Wright and Mason (1990).

13. Sample techniques

46 sediment samples were collected within the study area either by hand or Van Veen Grab supplied by The Natal Parks Board. Sample positions were fixed using a JRC JRL-4200 GPS (Global Positioning System) and depths recorded with a LOWRANCE X-16 computer sonar using an 8° beam. The sediment samples were analyzed in the laboratory using a computer-linked settling tube as outlined by Cooper and Mason (1987).

14. Estuary characteristics

The study area is described by Begg (1978) as being a true estuary as the system is generally mixed twice daily by the sea tide although river flow may briefly dominate during floods with the estuary taking on the characteristics of a river mouth. The estuary is rated by Begg (1978) to be in a fair environmental condition. The survey was confined to the lower estuary where the sediment is most dynamic. According to Begg (1978) tidal effects cease approximately 4 km from the mouth. Since the 1950's the estuary has suffered large amounts of sedimentation. Begg (1978) estimates the average depth at low tide in 1978 to be in the order of 2 m. Although the estuary was scoured out during Cyclone Domoina in 1984 and again during the September 1987 cut-off low flood, the estuary has again shallowed considerably with an average depth at low tide being approximately 1 m.

2. SEDIMENT COMPOSITION, TEXTURE AND DISTRIBUTION

2.1. Gravel fraction

Gravel (>2 mm diameter) is the coarsest sediment found throughout the study area (Fig.3.). The overall gravel fraction is extremely low (< 1%) comprising rounded to well-rounded quartz and rounded shell fragments. The gravel is found as a lag on the flood-tidal-delta, being reworked into the estuary from offshore. Remaining gravel is found as a deflation lag on the spits, the finer sand having been winnowed out by the wind.

2.2. Sand fraction

Sand is transported throughout the estuary by water and wind (Fig.4.). The sand fraction forms 4 differing populations.

1. Catchment-derived sand which includes reworked aeolian, lagoonal, estuarine and marine sand as well as fluvial sand.
2. Aeolian sand deposited into the estuary by north/south prevailing winds blowing over the barrier spits.
3. Marine sand deposited on the flood tide.
4. Bank erosion of the dune cordon (between the jetty and south spit) and surrounding estuarine deposits.

The catchment-derived sand comprises 95% rounded to well-rounded quartz, indicating an aeolian origin. The remaining 5% consists of heavy minerals, mica, nodular ferricrete and shell fragments (including foraminifera). The aeolian sand is typically 98% rounded to well-rounded quartz with < 1% heavy minerals and shell fragments. The marine sand contains approximately 95% angular to well-rounded quartz. Biogenic components (3%) include bivalve fragments, juvenile gastropods and ostracodes. Heavy minerals, garnet and pyroxene comprise the remaining 2%. The heavy mineral content is marginally higher than that entering the St. Lucia Estuary Mouth as the study area is closer to the heavy mineral rich dunes found just to the south of Mapelane.

The percentage sand distribution map (Fig.) shows the marine sand comprising > 90% sand forming the barrier environment (see Chapter 3). The marine sand enters the estuary on the flood-tide as a lobe forming emergent flood-tidal-deltas, terminating approximately 800 m up from the mouth. Observations from neighbouring St. Lucia Estuary Mouth indicate that most marine sand is transported as quick pulses when spring high tides coincide with storm swells. The changing tidal currents mix the marine sand with the

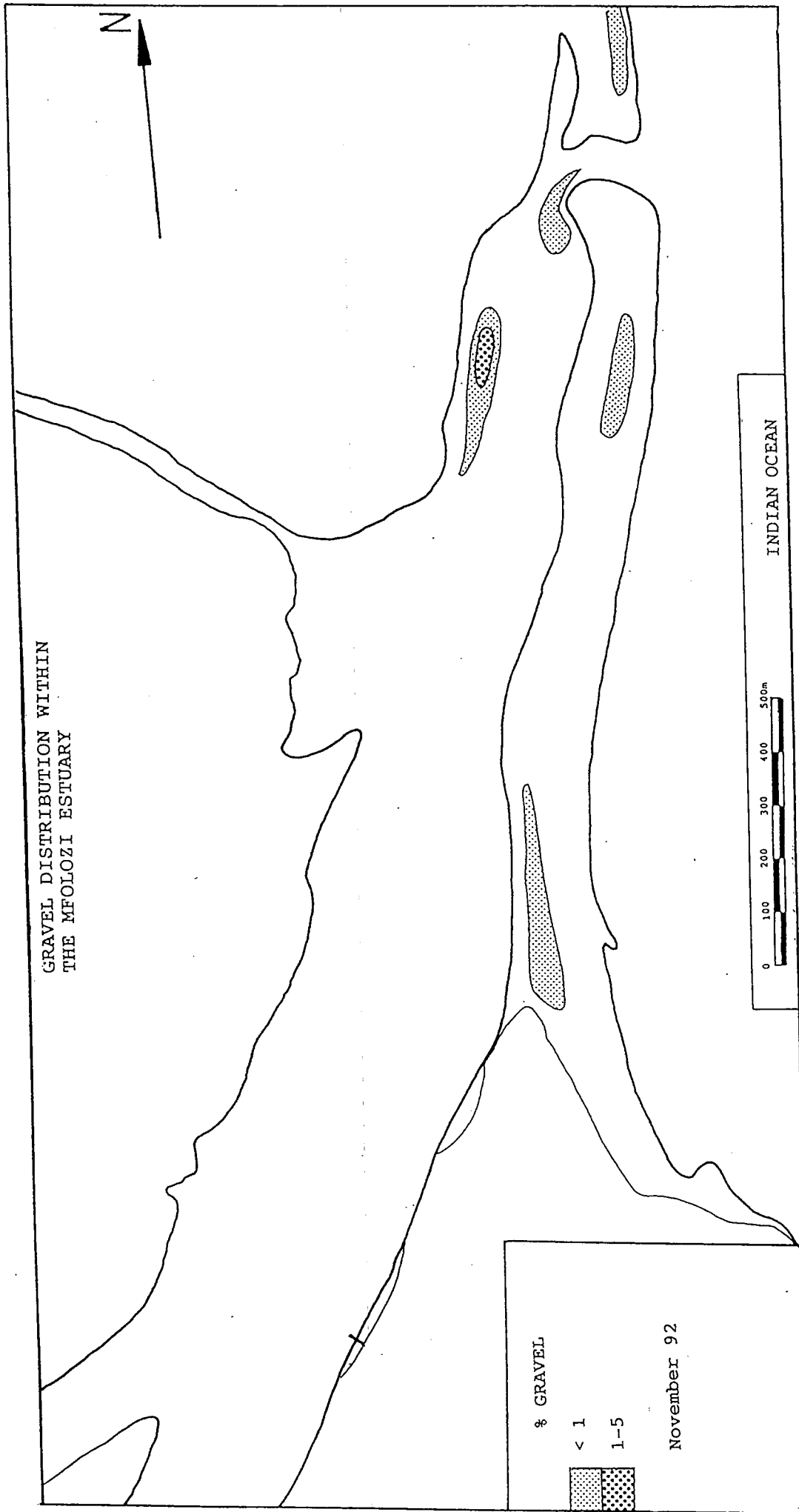


Fig.3.

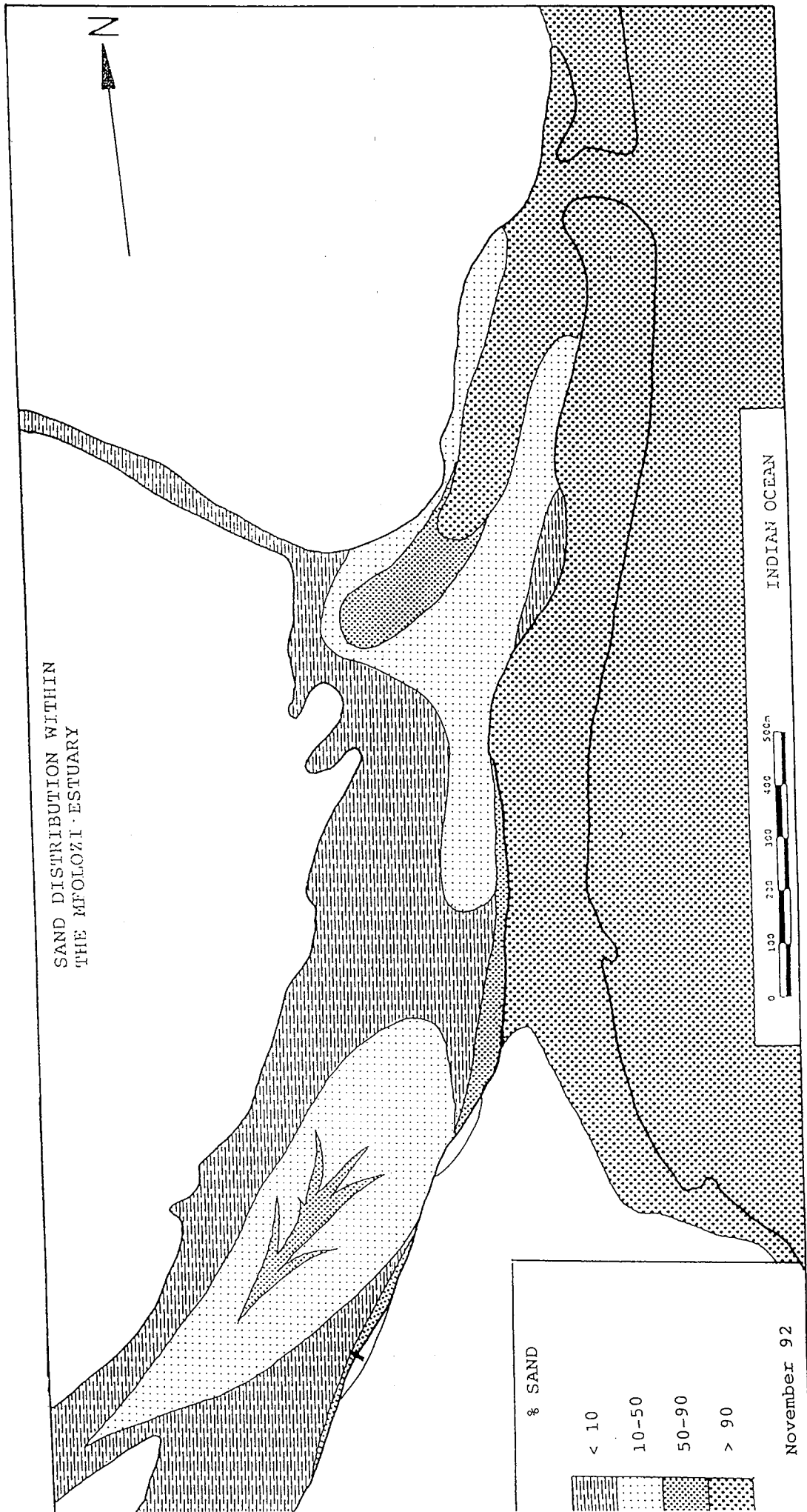


Fig.4.

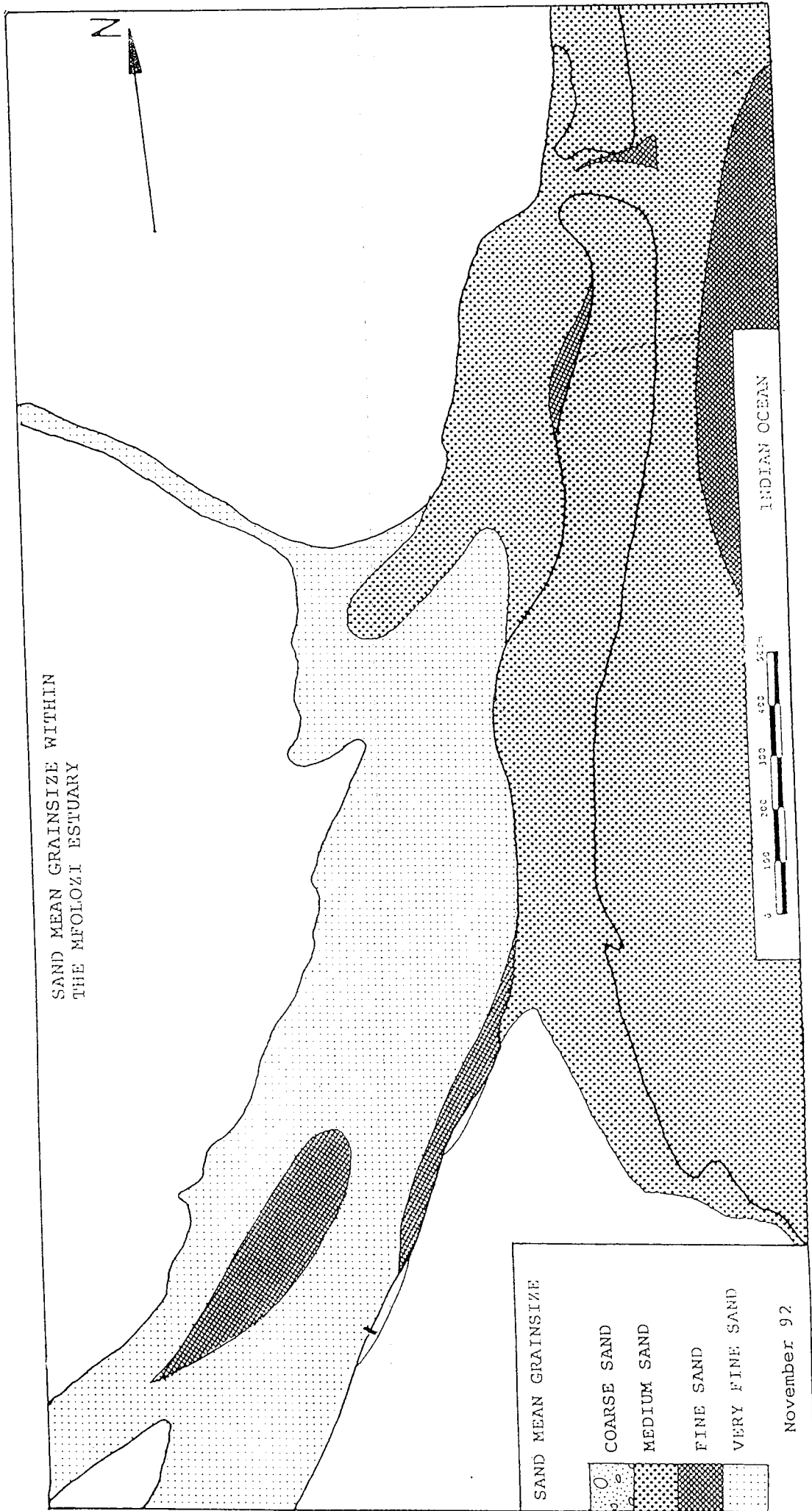
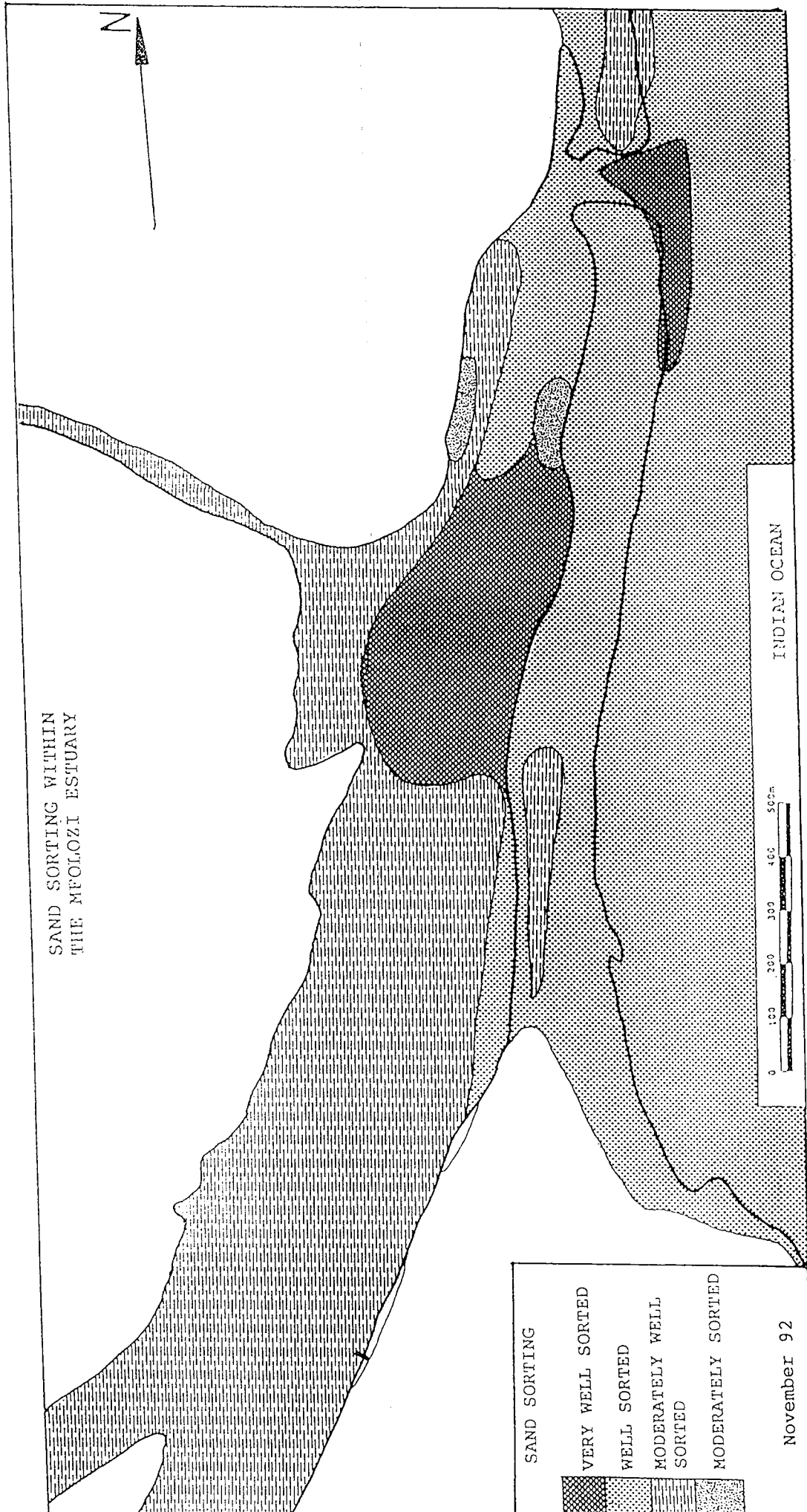


Fig.5.



SAND SORTING WITHIN
THE MFOLOZI ESTUARY

SAND SORTING

VERY WELL SORTED

WELL SORTED

MODERATELY WELL SORTED

MODERATELY SORTED

0 100 200 300 400 500m

INDIAN OCEAN

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Fig.6.

catchment sediments. The 50 - 90% lobe extending from the > 90% lobe is an abandoned flood-tidal-delta formed when the inlet mouth was located to the south of its present position. The 10 - 50% lobe of the middle ground bar formed when catchment sediments were deposited after the last flood. The sediment poured out of the Mfolozi River, into the large embayment, forming a delta. The delta has subsequently been modified by tidal and fluvial currents. The main channel is found between the jetty and middle ground bar. Wind-induced waves cause local erosion of the channel banks especially in the proximity of the dune.

2.3. Sand statistical parameters

The sand statistical parameters were determined using a computer-linked settling tube and were used to gain an idea of sediment provenance, movement and processes. Methods used are outlined by Cooper and Mason (1987).

2.3.1. Mean grainsize

No coarse-grained sand (0 - 1 Φ) was encountered throughout the study area (Fig.5). The medium-grained sand (1 - 2 Φ) makes up the bulk of marine sand. There are only limited amounts of fine-grained sand (2 - 3 Φ) found as deeper offshore marine deposits, part of the middle ground bar and where the estuary has cut into the vegetated dune causing slumping into the estuary. The vast majority of catchment-derived sediment has a very limited amount of sand (< 10%) which is very fine-grained (> 3 Φ) indicating a possible aeolian origin.

2.3.2. Sorting

The sand within the study area (Fig.6.) varies between very-well-sorted (< 0.35) to moderately-sorted (0.35 - 0.5) The marine sand is dominantly well-sorted (0.35 - 0.50) with only limited amounts of moderately-well-sorted sediment (> 0.70) occurring on the spits where wind action has winnowed some of the fine-grained sand. The catchment-derived sand is dominantly moderately-well-sorted indicating a mixing of fluvial, aeolian and marine sand. There are only two small lobes of moderately-sorted sand possibly caused by the mixing of the catchment and marine sands.

2.4. Mud fraction

The mud content of the estuary is determined as a dry weight percent. The entire area except for the barrier environment is dominated by mud (Fig.7.). The only other place besides the barrier environment that is not dominated by mud, is a small area of remnant catchment sand found on the middle ground bar. The mud is

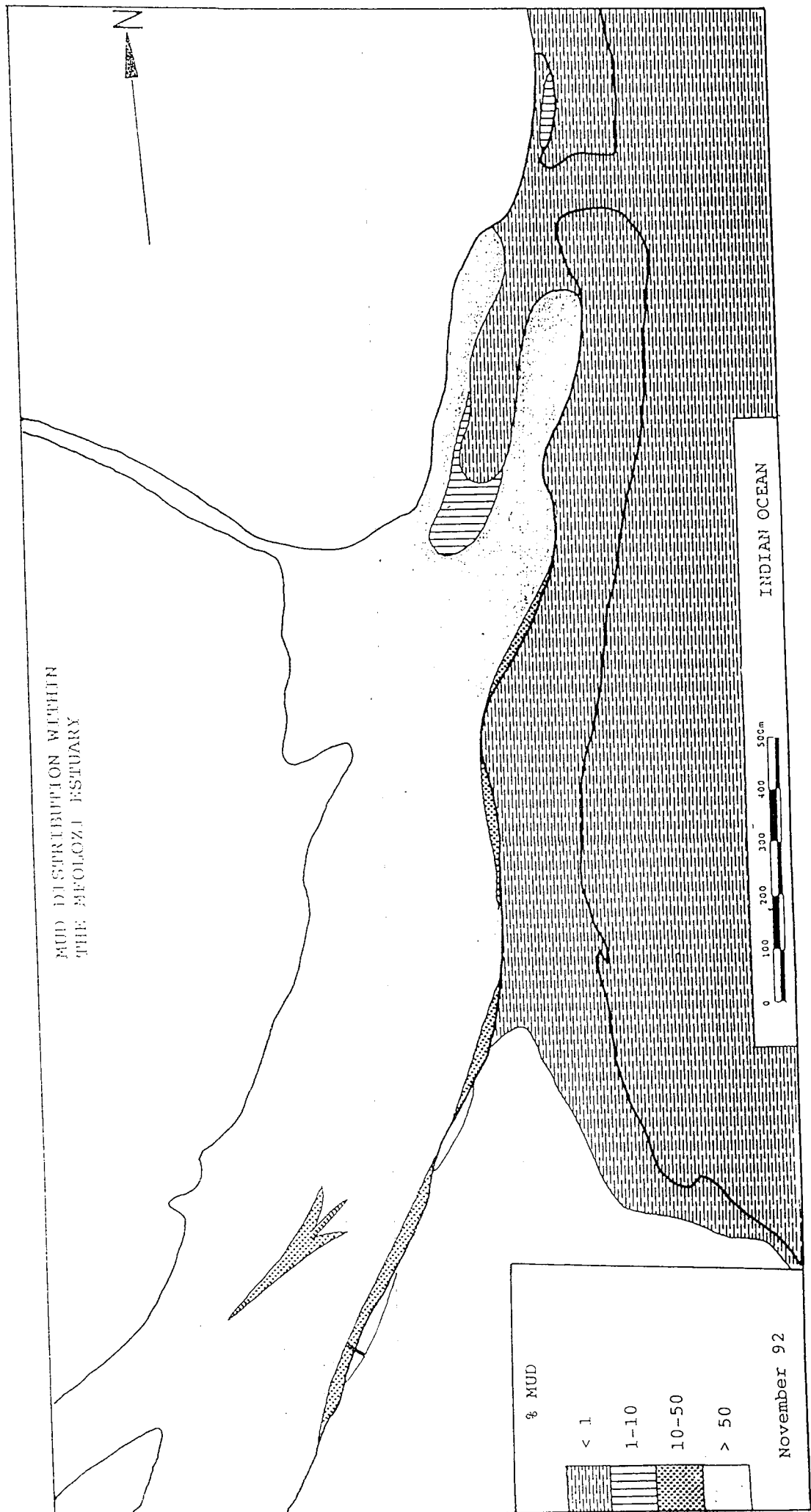


Fig.7.

transported down the catchment via the Mfolozi and Msunduzi Rivers. Upon reaching saline water the mud flocculates out of suspension and is deposited. Except for the main channel and flood-tidal-delta, mud has caused a large amount of sedimentation causing most areas to shallow. The mud is either very unconsolidated or consolidated depending on its age. Aeolian sand blowing into the estuary from the southern spit effectively buries the mud helping its consolidation. Sedimentation is aided by the large amounts of organic matter, including logs and reeds, transported down the catchment during floods. Tidal currents continually stir up the mud adding to the turbidity. The large volume of mud and the high turbidity indicates that the catchment is in a very poor state, having a detrimental effect on the estuary.

3. SEDIMENTARY ENVIRONMENTS

Few reports of sedimentary environments along the Natal/KwaZulu are available, although Cooper (1988) and Wright and Mason (1990) provide an insight into the Mgeni and St. Lucia Estuary Mouths. As with the St. Lucia Estuary Mouth, the Mfolozi Estuary Mouth changed a great deal after Cyclone Domoina and the September 1987 cut-off low flood event. During both floods (although Cyclone Domoina was about 4 times the magnitude of the 1987 flood) the estuary mouth was scoured wide open and vast amounts of sediment being moved offshore. The dynamics within the Mfolozi and St. Lucia Estuary directly after Cyclone Domoina have been well documented by Van Heerden and Swart (1986) and in the St. Lucia Estuary Mouth after the 1987 flood by Wright (1990). The Mfolozi Estuary behaved in a similar manner to the St. Lucia Estuary after both flood events. That is, marine sediment quickly re-entered the estuary causing progressive shallowing. The onset of drought conditions enhanced the shallowing by removing the scour mechanism. Bad catchment management ensured that large amounts of mud was still transported into the estuary by the remaining fluvial flow, compounding the shallowing. This simple flood-response has formed the two major sedimentary environments within the estuary.

1. Barrier-associated sedimentary environment.
2. Estuarine/Lagoonal sedimentary environment.

3.1. Barrier-associated sedimentary environment.

As with the St. Lucia Estuary Mouth (Wright & Mason, 1990), the barrier environment comprises (Fig's. 2 & 8) a tidal inlet channel, inlet beach face, flood-tidal-delta, ebb-tidal-delta, spits, backspit and aeolian dune.

The tidal inlet channel varies in width due to the large fluctuation in flow. Tidal flow causes the inlet channel to fluctuate from approximately 40 m at low tide to 130 m at high tide. Fluvial floods may cause the channel to widen drastically. The tidal inlet channel splits into ebb and flood-dominated channels.

The inlet beach face varies in width reaching widths of up to 200 m and is more dominant on the south side of the inlet channel.

The emergent flood-tidal-delta is the prominent feature contributing most of the marine sediment into the estuary. The position of the flood-tidal-delta depends upon the position of the inlet channel. Thus an abandoned flood-tidal-delta is found just to the south west of the present one (Fig. 2), being formed when the inlet channel was located approximately 700 m south of its present position.

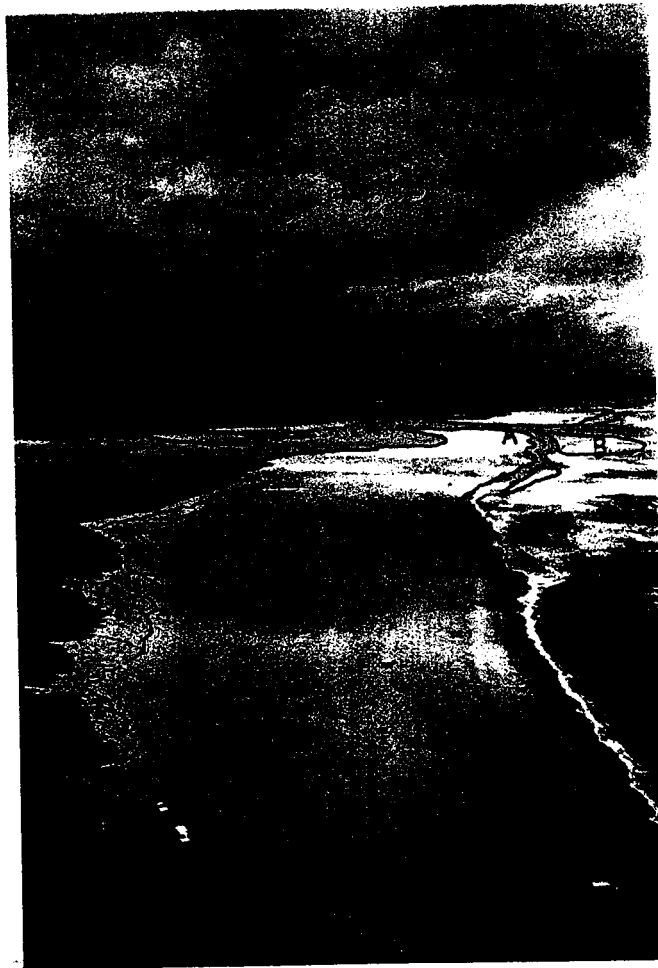


Fig.8. Oblique photo showing The Barrier Environment including; A) the tidal inlet channel and inlet beach face, B) ebb-tidal-delta, C) flood-tidal-delta, D) main flood-channel, E) south spit, F) backspit and prograding foredune,(4).

The Mfolozi/St. Lucia system differs from most other estuaries in Natal/KwaZulu as they share a common ebb-tidal-delta. Permanent ebb-tidal-deltas are fairly rare along the coast due to the high wave energy. The dominantly medium-grained ebb-tidal delta is the morphological key of both the Mfolozi and St. Lucia estuary geometry as it focuses the dominant southeasterly swell regime by causing wave refraction. This, in turn, sets up longshore currents which are responsible for sediment transport.

The barrier environment is dominated by the 1 700 m long southern spit separating the sea from the estuarine environment. The southern spit is in places over 300 m wide and well over 2 m high. The 320 000 m² area is vulnerable to the prevailing north/south winds which have initiated minor foredune growth along the west side of the southern part of the south spit. Logs and reeds deposited as a spring high tide line have aided the dune growth. Wind action is causing the west side of the south spit to prograde over the estuarine mud deposits. To the north of the inlet channel is another area of open sand, the northern spit, separating the Mfolozi inlet channel from the St. Lucia channel. The area between the two channels is approximately 50 000 m² from where the prevailing winds move sand into both inlet channels. Aeolian sand movement is partially restricted by the flood debris deposited.

The backspit environment is a sheltered area formed from an abandoned channel where the Mfolozi occasionally flows into the St. Lucia Estuary Mouth on a spring high tide. This flow has cut into the old dredge spoil site which has been colonised by a Casuarina plantation causing the trees to slump onto the backbeach.

The Natal Parks Board buildings are sited on a vegetated dune complex. The dune cordon has been locally eroded between the jetty and southern spit causing slumping into the estuary. It should be noted that only a thin barrier (20-30 m) separates the campsites from the estuary which may be under threatened during the next major flood. The foredune sited in front of the vegetated hummocky dune is locally prograding onto the southern spit.

3.2. Estuarine/Lagoonal environment.

Four estuarine environments have been recognised (Fig's.2 & 9):

1. subtidal estuarine main channel;
2. middle ground bar;
3. old dredge channel;
4. tidal mudflats. These back-barrier environments are dominated by catchment mud.



Fig.9. Oblique photo showing the Estuarine/lagoonal Environment comprising: A) the subtidal main channel, B) middle ground bar, C) abandoned dredge channel and D) tidal mudflats. Note the hummocky dune complex with NPB buildings. The campsites sited within the vegetation below the letter B are susceptible to flooding.

The main channel (Fig.9) is a modified flood relic, formed during the last major flood. Flood-tidal currents have since modified this channel maintaining it as the deepest channel within the estuary, having an average depth of 1.5 m. Flood tidal currents transport medium-grained sand approximately 800 m up the channel where they are mixed with estuarine mud and sand.

The middle ground bar was originally deposited as a delta, within the large embayment which formed after the last flood. The bar comprises catchment-derived sand and mud which has been reworked by tidal currents. Large amounts of flood debris on the bar, mostly tree trunks, act as sediment traps.

The old abandoned dredge channel (Fig.9) used to link the St. Lucia Estuary with the Mfolozi Estuary in the 1970's (Orme, 1975), for transport of materials to the Mfolozi River. Tranquil conditions have since then allowed large amounts of mud to be deposited causing shallowing. With time this channel will completely fill and be vegetated, forming a marsh.

The tidal mudflats dominate the western side of the estuary. These thick muds have been deposited during the tranquil conditions prevailing after the last major flood. Tidal effects are limited and have insufficient energy to remove the sediment, although tidal channels do penetrate well into the surrounding wetlands.

The estuarine/lagoonal environment exhibits a fining upward sequence of sediments typical of a post-flood event. Marine sands deposited into the estuary after the flood are progressively overlain by finer sediments as the flood waters recede. The reduction of fluvial flow enables catchment mud to be deposited. This sequence will be repeated after the next major flood.

4. DISCUSSION.

The Mfolozi Estuary has been drastically altered since bad catchment management, starting in the 1950's, changed the sedimentological characteristics. Huge amounts of catchment mud dominate the estuarine environment, causing shallowing. The dynamic barrier complex is dominated by medium-grained sand. During periods of low catchment flow the inlet channel migrates to the north, eroding Casuarina stands. Periods of increased catchment flow will cause the inlet channel to move south, eroding the south spit. Drastic increases (a flood) will cause the south spit to breach fairly close to the vegetated dune cordon. The Mfolozi and St. Lucia Estuaries have a very similar sedimentology except for the greater mud content of the Mfolozi. The dynamics of both systems are interlinked as they share a common ebb-tidal-delta.

4.1. Management recommendations.

The Natal Parks Board policy of least interference should still be followed. The only time the south spit should be breached is if the Mfolozi and St. Lucia Estuary Mouths should join. This is not desirable as large amounts of mud from the Mfolozi Estuary will be transported into the St. Lucia Estuary thus repeating conditions prevalent in the late 1950's.

Extreme care should be taken in siting new camp sites/accommodation as various areas within the vegetated hummocky dune area are susceptible to flood damage. Indeed, only a thin relic-dune barrier separates the estuary from the present campsites.

4.2. Future research.

There is an enormous amount of sedimentological/geomorphological information that needs to be collected before a more complete understanding of the system can be obtained. Research targets to this end should include:

1. A literature survey of previous work needs to be carried out to ascertain the exact state of knowledge.
2. A detailed study of the sedimentology of the whole Mfolozi System, including the inland catchment, floodplain and continental shelf so that modern and ancient rates of sedimentation can be calculated. This project could involve seismics, drilling, vibracoring and sediment sampling.
2. Determining the coastal equilibrium. That is, whether the coastline is prograding or retreating and

at what rate. Taking into account predicted sealevel rises, future changes can then be predicted.

3. Conditions under which the Mfolozi and St. Lucia Estuaries would rejoin and the after effects of this event.
4. A detailed study of the sediment dynamics of the Mfolozi Estuary including a sediment budget so that rates can be compared with work undertaken by Wright (1990). Particular attention should be paid to the rate and volume of mud entering the system.
5. A study of past and present channel migrations of the Mfolozi and Msunduzi Rivers with a particular aim of mapping the floodline of the 1984 and 1987 floods and comparing them with dated older floodlines: That is working out the palaeoflood hydrology.

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6. APPENDICES

Sample no	%>VCS	%VCS	% CS	% MS	% FS	%VFS	%Mud
MF44	0.1	8.4	8.5	49.4	7.9	25.7	0.0
MF14	0.0	0.0	0.0	0.0	0.7	2.3	97.0
MF46	0.0	0.0	0.0	30.3	67.4	2.3	0.0
MF11	0.0	0.0	0.0	0.0	0.0	4.0	96.0
MF29	0.0	0.0	0.0	3.0	8.0	89.0	0.0
MF5	0.0	0.5	2.2	10.8	21.6	4.9	60.0
MF10	0.0	0.0	0.2	0.4	3.3	14.1	82.0
MF45	0.0	0.0	51.9	44.0	5.8	0.0	0.0
MF19	0.0	0.0	0.6	2.9	9.8	21.9	65.0
MF43	0.0	0.0	3.3	44.9	53.3	0.0	0.0
MF41	0.2	3.9	44.1	45.3	6.3	0.2	0.0
MF36	0.1	0.0	17.9	76.0	5.7	0.3	0.0
MF4	1.0	2.2	26.1	32.5	38.2	0.0	0.0
MF15	0.0	0.1	0.4	9.3	52.4	7.9	30.0
MF30	0.0	0.7	1.1	21.6	68.5	8.0	0.0
MF38	0.0	0.5	7.1	86.8	5.9	0.0	0.0
MF23	0.6	1.4	34.9	57.6	5.4	0.2	0.0
MF7	0.0	0.9	24.4	60.9	12.1	1.8	0.0
MF16	0.0	0.0	0.7	19.5	11.5	4.2	64.0
MF42	0.0	0.6	1.8	34.6	32.0	0.0	31.0
MF39	0.0	1.6	23.3	64.4	10.7	0.0	0.0
MF39	0.0	0.0	37.7	30.0	14.0	18.3	0.0
MF31	0.0	0.0	0.0	73.7	19.5	6.9	0.0
MF44	0.1	0.9	16.4	76.7	5.9	0.0	0.0
MF40	0.0	0.0	8.4	87.6	5.0	0.0	0.0
MF260	0.0	0.0	27.5	62.9	5.2	4.4	0.0
MF18	0.0	1.0	9.6	29.7	12.0	10.6	37.0
MF6	0.0	2.0	12.1	84.5	0.0	1.9	0.0
MF25	0.0	0.1	24.0	58.6	17.3	0.0	0.0
MF27	0.0	0.0	3.4	55.9	33.9	0.0	7.0
MF27	0.0	0.0	0.0	4.2	14.3	53.1	29.0
MF21	0.0	0.2	0.7	43.9	55.1	0.1	0.0
MF12	0.0	0.0	0.2	9.7	9.0	4.1	77.0
MF35	0.2	1.0	39.0	51.5	8.9	0.0	0.0
MF34	0.0	0.1	7.4	63.2	28.4	0.8	0.0
MF32	1.0	0.2	3.8	47.4	44.3	3.3	0.0
MF33	0.0	0.3	7.1	57.8	34.0	0.7	0.0
MF20	0.0	0.0	0.0	0.0	0.4	5.5	94.0
MF8	0.0	0.0	0.0	0.3	0.9	8.8	90.0
MF1	0.1	0.1	6.8	49.9	41.5	1.6	0.0
MF24	0.0	0.8	35.4	57.7	5.8	0.2	0.0
MF22	0.0	0.3	15.8	75.8	8.0	0.1	0.0
MF28	0.0	0.0	3.1	56.9	39.3	0.7	0.0
MF2	0.0	0.0	7.0	76.8	16.3	0.0	0.0

Sample no	Med.	Mean	mm Mn	Sort	Ske.
MF44	1.69	1.46	0.363	0.61	-0.38
MF14	3.50	3.36	0.097	0.41	-0.35
MF46	2.19	1.96	0.257	0.58	-0.41
MF11	3.91	3.88	0.068	0.09	-0.32
MF29	3.17	2.98	0.127	0.80	-0.24
MF5	2.39	2.24	0.212	0.71	-0.22
MF10	3.22	3.08	0.119	0.32	-0.43
MF45	1.00	1.03	0.491	0.19	0.16
MF19	3.13	2.84	0.140	0.53	-0.54
MF43	2.02	1.97	0.256	0.40	-0.14
MF41	1.03	1.08	0.474	0.64	0.08
MF36	1.42	1.39	0.383	0.42	-0.07
MF4	1.67	1.48	0.359	0.82	-0.24
MF15	2.39	2.40	0.190	0.37	0.01
MF30	2.41	2.34	0.197	0.50	-0.13
MF38	1.52	1.49	0.355	0.30	-0.09
MF23	1.19	1.18	0.441	0.54	-0.01
MF7	1.44	1.39	0.382	0.57	-0.09
MF16	1.95	2.12	0.229	0.55	0.32
MF42	1.97	1.90	0.268	0.37	-0.19
MF39	1.23	1.25	0.421	0.41	0.04
MF39	1.19	1.93	0.263	1.21	0.62
MF31	1.70	1.79	0.288	0.31	0.32
MF44	1.64	1.44	0.368	0.49	-0.40
MF40	1.54	1.46	0.363	0.32	-0.24
MF260	1.34	1.34	0.394	0.52	0.01
MF18	1.80	1.60	0.330	0.62	-0.33
MF6	1.59	1.48	0.359	0.41	-0.29
MF25	1.37	1.45	0.365	0.59	0.13
MF27	1.86	1.86	0.275	0.42	-0.00
MF27	3.23	3.19	0.109	0.31	-0.12
MF21	2.03	2.00	0.250	0.28	-0.12
MF12	2.05	2.42	0.187	0.62	0.59
MF35	1.17	1.18	0.441	0.61	0.02
MF34	1.79	1.72	0.304	0.45	-0.16
MF32	1.98	1.97	0.255	0.47	-0.01
MF33	1.85	1.79	0.290	0.50	-0.12
MF20	3.47	3.46	0.091	0.27	-0.03
MF8	3.55	3.49	0.089	0.27	-0.24
MF1	1.92	1.80	0.287	0.46	-0.27
MF24	1.16	1.20	0.434	0.49	0.09
MF22	1.51	1.44	0.368	0.44	-0.16
MF28	1.92	1.88	0.271	0.36	-0.10
MF2	1.62	1.60	0.329	0.40	-0.06