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LATERAL STABILITY OF THE LOWER REACHES OF THE

MZUMBE RIVER, NATAL

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ABSTRACT

The Mzumbe river discharges into the Indian ocean on the Natal South coast at 30° 37' S, 30° 33' E. This paper examines the lateral stability of the lowest 3km of the Mzumbe river under two sets of conditions namely:

- A. normal run-off (\leq bankfull) from 1937-1979, using aerial photography; and
- B. major floods, such as May 1959 covering a period of about two days, based upon results from supplementary tests during a physical model study.

INTRODUCTION

Lateral stability of the lower reaches of the Mzumbe forms an important part of the hydrological/hydraulic study of the estuaries of Natal being done by NRIO for the Town & Regional Planning Commission, Natal. It was also a consideration during physical model tests for the hydraulic design of the Mzumbe freeway bridge. The latter model tests were carried out by NRIO during 1979-1981 for the consulting engineers, Nicholls & Van Wyk and Strydom, Newmark & Anthony (CSIR 1981).

MODUS OPERANDI

- A. Six time slices from 1937, 1955, 1959, 1966, 1976 and 1979 aerial photography were selected. The six aerial photographs were re-photographed and printed on a scale of 1:10 000 using tracings on transparent film of permanent features from the 1:10 000 orthophoto to obtain the best possible fit.

The film tracings were again used in conjunction with the 1:10 000 prints to outline the river courses for each time slice. The six tracings were then superimposed and an envelope of mobility was compiled.

A quantitative indication of the lateral stability was obtained by measuring distances from the maximum left bank position to mid-river at twelve stations. These stations were at approximately 300m intervals from the old South coast road steel bridge to the mouth. The sinuosity of the whole reach was also calculated and all measurements were made using a flat bed digitizer.

- B. Flow lines and surface velocities were recorded photographically by taking time exposures of white-painted cork floats spread over the model test area. The peak May 1959 flood was estimated to be $1320\text{m}^3 \cdot \text{s}^{-1}$ and changes in the flow lines with stage were recorded for various stages of the rising and falling river. The stage was recorded at a position 420m along the embankment from the left abutment of the NR bridge at the mouth. Changes of thalweg for various stages were derived from maximum flow lines.

BACK-UP/BACKGROUND DATA

Topographical surveys, cross-sections and HRU 9/81 simulated run-off data (Pitman et al 1981) were used to aid the interpretation of fluvial processes from both the aerial photography and the physical model.

A summary of pertinent hydro-geographical data is given below:

Area of catchment		536 km ²
River length		84 km
River gradient:	overall	1:90
	lowest 3km	1:310
M.A.P. (1921-1975)		905 mm
Simulated M.A.R.	mean	$71,03 \times 10^6 \text{ m}^3$
(1921-1975)	standard deviation	$48,26 \times 10^6 \text{ m}^3$
	coefficient of variation	68 %

RESULTS

- A. The six aerial photographs between 1937 and 1979 were taken, understandably, during good flying weather and therefore reflect conditions when the Mzumbe was confined within its channel (\leq bankfull, mean river width 54m). Over the 3km reach studied, the river was unstable during this 42-year period (average lateral displacement 121,7m, coefficient of variation 40,2%). On the following two pages are given a map showing how the lateral shift varies along the reach (Figure 1) and a table showing full details of the lateral stability (Table 1).

Reasons for the overall lateral instability, which is very marked in the lowest 1km, fall into two categories; (i) natural and (ii) human-influenced.

(i) Natural

The hinterland is youthfully incised and there is an abrupt transition from these conditions to the lowest 3km, there being no coastal plain. With an ample silt supply from the catchment, there is thus deposition in the lowest reaches where there is a marked check on river velocities. Furthermore, under natural conditions, the Mzumbe river course was diverted near the mouth by a long southerly-extending sand-spit behind which sedimentation occurred. Over the lowest reaches, therefore, the Mzumbe flows through and around a sub-aerial delta. There is no firmly established riverine vegetation and the banks are thus easily erodible. Controls to lateral shift are the valley spurs, and the bottom valley average width is 675m.

Given the above geographical background, the run-off is the key natural factor influencing the Mzumbe's stability. It is very erratic. This is quantified by the high coefficients of variation for monthly run-off, ranging from 55 to 221% with a mean of 149%, and the differences between the often far higher mean and median run-off values (monthly and annual) resulting from the occasional major flood flows to which the Mzumbe is subject. The Mzumbe river has never been gauged and the aforementioned comments are based upon simulated run-off data for tertiary catchments (Pitman et al 1981). The wide spectrum of monthly and annual run-off is shown below in Figure 2 (page 6). Major floods this century are known to have occurred in October 1917, March 1925, May 1959 and March 1976. Under natural/near-natural conditions (ie. prior to 1955), during major floods, the spit would be breached. This allowed the Mzumbe to flow almost straight out to sea.

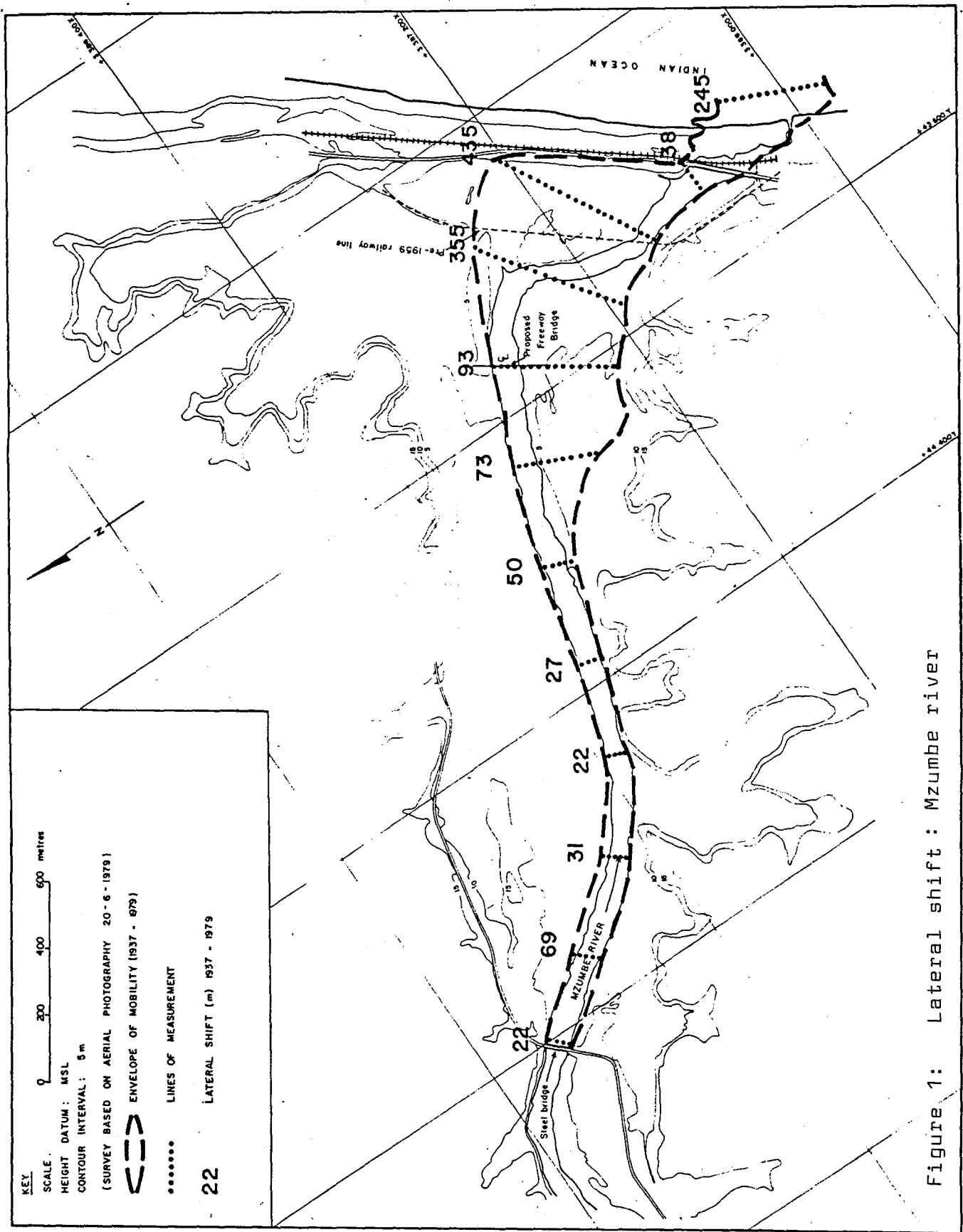


Figure 1: Lateral shift: Mzombe river

TABLE 2. Lateral stability of the Mzombe river.

Station	Approx distance along 1979 R. course from steel bridge (m)	Distance from maximum observed L.D. position to mid-river (m)								Max-Min	\bar{x}	s	VZ
		Date											
		2-5-37	Jun/Jul, '55	6-6-59	10-6-66	6-7-76	20-6-79						
1	0	25	20	33	11	33	31	22	25,5	8,8	34,3		
2	300	75	11	70	80	38	45	69	53,2	26,7	50,2		
3	600	35	19	40	20	48	50	31	35,3	13,4	38,0		
4	900	30	18	40	27	31	33	22	29,8	7,3	24,3		
5	1 200	50	30	43	23	45	45	27	39,3	10,4	26,6		
6	1 500	80	75	35	30	35	60	50	52,5	22,1	42,1		
7	1 800	108	62	70	48	35	40	73	60,5	26,7	44,2		
8	2 100 (<i>C&E freeway</i>)	98	22	70	115	40	50	93	65,8	35,5	54,0		
9	2 400	262	82	60	415	310	205	355	222,3	136,2	61,3		
10	2 740	310	255	60	485	495	485	435	348,3	174,5	50,1		
11	2 980	50	88	60	65	60	65	38	64,7	12,7	19,6		
12	3 300 (mouth)	190	210	80	230	325	220	245	209,2	78,8	37,7		
\bar{x}		109,4	74,3	55,1	129,1	124,6	110,8	121,7	100,5		40,2		
s		94,5	79,4	16,1	162,2	158,4	134,5	142,4			12,7		
VZ		86,4	106,8	29,2	125,6	127,1	121,4	117,0			31,5		

Average lateral displacement 1937-79 = 121,7 m

Average coefficient of variation 1937-79 = 40,2%

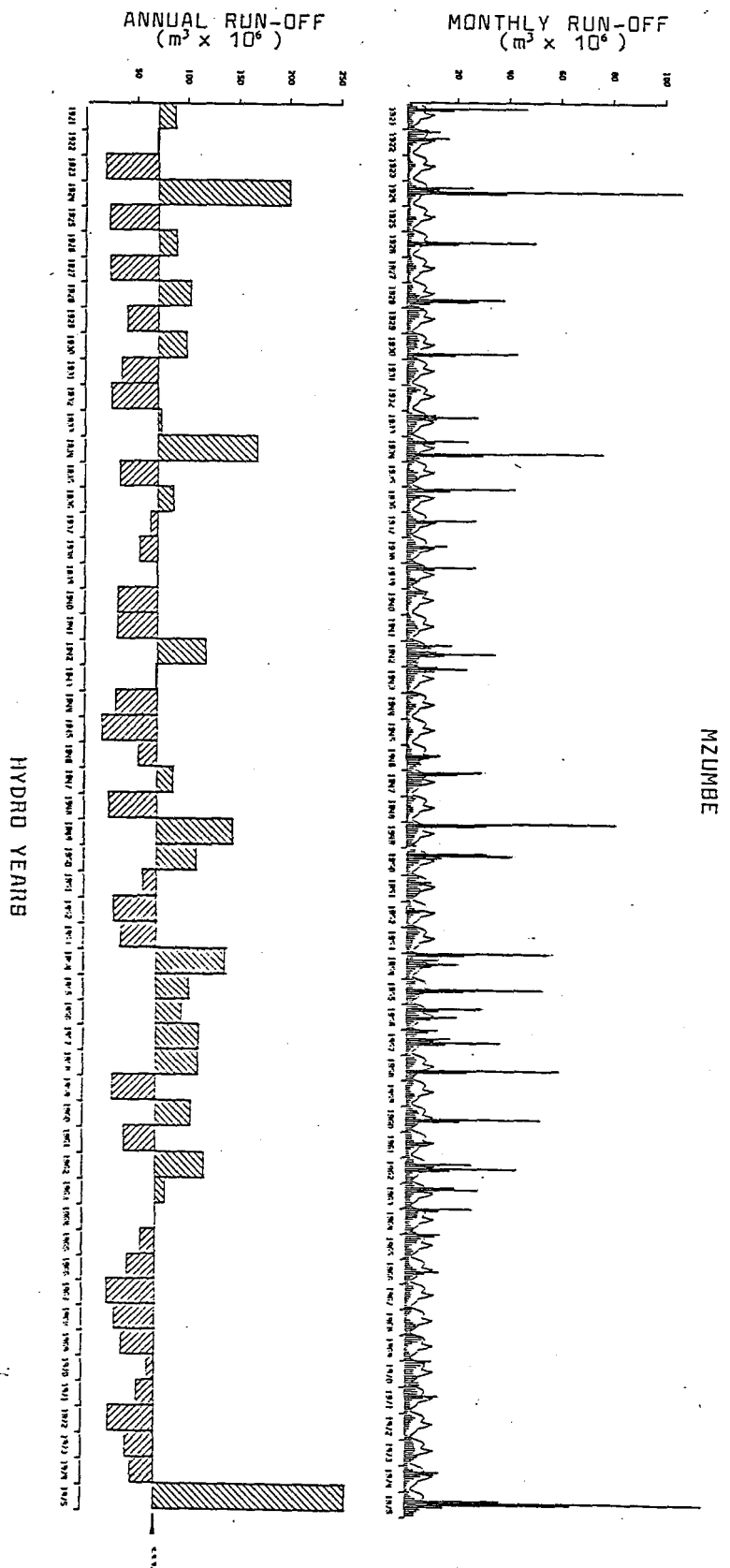


Figure 2. Simulated run-off (from HRU 9/81 data)

The river would then return to a more sinuous course and the mouth would gradually migrate towards the south until it reached rocks along the right bank. The floods often break long periods of drought (eg. 1960's early and late 1970's) during which time the Mzumbe is laterally stable with a very low flow.

The mouth remains open for 90% of the year and sinuosity for the 3km reach varied from 1,15 to 1,25 for the six time slices studied from 1937 to 1979.

(ii) Human-influenced

Human-influenced factors affecting the stability of the Mzumbe are very important and include land-use, bridges and embankments, stabilization of the spit and canalization.

The catchment is 84% Kwazulu where land-use practices on easily erodible soils lead to an ample silt supply. In the lowest reaches there is a little cultivation of sugar cane to the river banks.

A dominant factor in the lateral stability of the lower reaches of the Mzumbe has been bridge building, with the accompanying embankments across the flood plain. The steel bridge of the old South coast road was built in the 1930's, the National road bridge near the mouth in 1955 (and a new freeway bridge will be built in the late 1980's). The old railway bridge was built at the turn of the century with three spans, modified in 1932 to two spans. This was replaced by a new bridge at the mouth in 1954. The positions of these bridges are shown in Figure 1. The river course is thus restricted at these positions and upstream of their associated embankments the Mzumbe has gradually adjusted its sinuosity to the new conditions during seasonal minor floods. During major floods the old railway line bridges still allowed the Mzumbe to straighten its course and flow straight out to sea as described in (i). However, with the stabilization of the spit in the mid 1950's to accommodate national road and railway line, natural flood flow has been inhibited (see Section 8 below for details of major flood flows). The May 1959 flood did nevertheless breach the northern approach embankment over a distance of 162m from the road bridge abutment, following which the stabilization was reinforced.

After the May 1959 flood, near the mouth, the river flowed straight towards the stabilized spit and then turned through almost 90° flowing alongside the embankment to the road and rail bridges. This represented the furthest left-bank position of the river (see time slice 6-6-59 measurements in Table 1) and sinuosity for the whole reach was then 1,25.

In an effort to divert the river flow directly towards the road and rail bridges, a canal was built, approximately 800m upstream of the road bridge, reducing the sinuosity to 1,15. By mid-1961 however the canal was silted up and since then the river has gradually been trying to re-establish its natural more northerly course over the lowest 1km. This accounts mostly for the large lateral shift seen in this area (Figure 1) and the high instability of the lowest 1km recorded in Table 1.

B. Results from flow velocity tests for a 1320 cumec flood give a clear picture of the Mzumbe's flow patterns over the lowest 1,5km during both rising and falling stages under stabilized spit conditions. Stage (in m to MSL) was measured at a position 420m along the spit from the NR bridge left abutment. It was found that the Mzumbe started to overtop its banks at stage +3,4 with a discharge of $150\text{m}^3 \cdot \text{s}^{-1}$. Major floods inundate the whole valley and the thalwegs vary with stage as shown in the maps on the following two pages (Figures 3 and 4). Conditions in relation to stage may be summarized as follows:

- i) +3,5 to +6,4. The Mzumbe gradually straightens its course towards the stabilized spit, then turns through almost 90° flowing alongside the spit to the sea through the road and rail bridges.
- ii) +6,4 to +7,3 (full spate). The cushioning effect of dammed-up waters behind the spit becomes marked and the Mzumbe adopts a smooth curve approach to the bridges.
- iii) +7,3 to +3,5. During the falling river stages, the Mzumbe gradually reverts to a more sinuous course and, near the mouth, flows alongside the stabilized spit. Shift of the main impact on the stabilized spit with stage is shown in Figure 5 below.

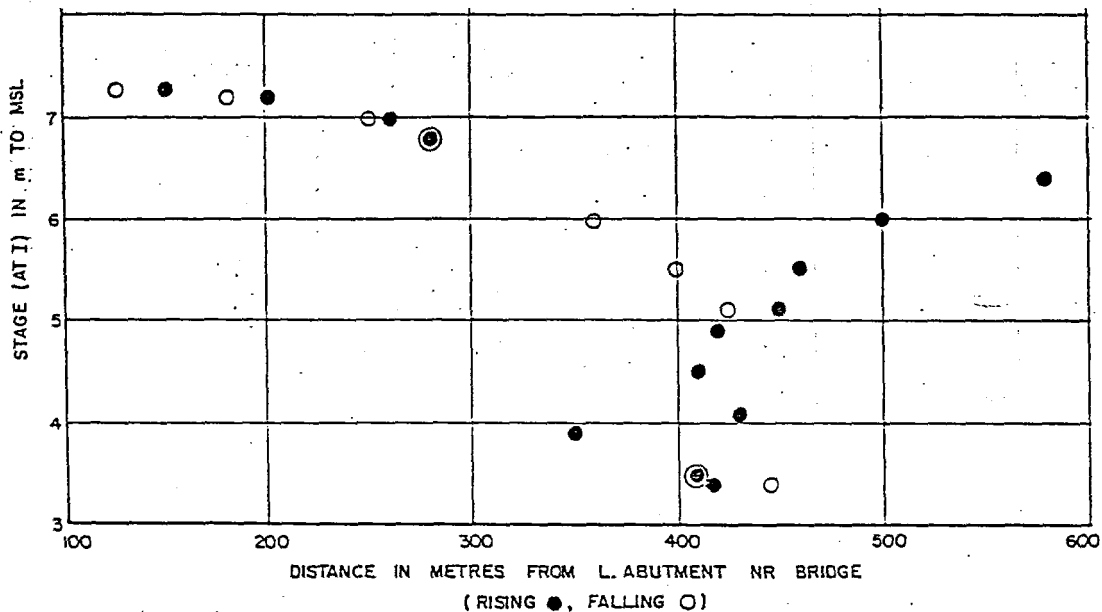


Figure 5 Shift of Main Impact on the Stabilized Spit

CONCLUSIONS

1. The above studies of the Mzumbe under both normal flow and major flood conditions give a quantitative assessment of the lateral stability of the lower reaches of the river from 1937 to 1979.
2. As the Mzumbe is typical of many Natal South Coast rivers, understanding of its behaviour under natural and human-influenced conditions provides a useful tool for regional planners.
3. The lower reaches of the Mzumbe are laterally unstable (highly unstable near the mouth). The Mzumbe demonstrates a river with a youthfully incised hinterland, no coastal plain and an erratic run-off trying to adjust to the human influences of bridge building, stabilization of the sand-spit at the mouth and canalization.

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