THE ESTUARIES OF NATAL: A METHOD OF CLASSIFICATION

by

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ABSTRACT

This poster paper describes a hydrological/hydraulic classification of the estuaries of Natal, based upon aerial photography. The modus operandi is outlined and although the study is in its early stages, some key factors (natural and man-made) are indicated together with the method by which they are quantified.

1. INTRODUCTION

A hydrological/hydraulic study, aimed at acquiring an understanding of the long-term functioning of the estuaries of Natal is being done by NRIO (CSIR) for the Natal Town and Regional Planning Commission. Special emphasis is given to the influence of man on the natural river régime. The investigation falls into three phases, namely, evaluation of available data, classification of the estuaries and examination of specific problems in particular estuaries. This poster paper is concerned with phase two, classification of the estuaries. As hydrological data are scarce, a method of study has been devised to make the maximum use of the main data source available which is aerial photography dating back to 1937.

2. PROCEDURE

2.1 Basis

For each of the 72 estuaries, a suitable reach of the river is selected to include at least the known estuarine area. The upstream limit is usually a road or railway bridge which provides a good control position but occasionally a river confluence has to be chosen. This reach is then identified on enlargements of six vertical aerial photographs from 1937 to 1980 and re-photographed. Prints are

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then made on a scale of 1:10 000 using tracings of permanent features from 1:10 000 orthophotos to obtain the best possible fit. The orthophoto itself is often used as one of the six photographs selected for study. Tracings of the river courses for the six years are made on transparent film (one for each year) and used to compile an envelope of mobility of the river. Within this envelope of mobility, lines of measurement are marked at regular 250 m to 300 m intervals from the upstream limit of the reach to the mouth together with a suitable datum line for measuring sand-spit lengths and directions. These items are transposed onto the six river course tracings together with an outline of the flood plain area (if present) which is assessed from the orthophoto. The remaining areas within the flood plain to be traced onto the six master river course film tracings are sand deposits, swamps and cultivation (from the 1:10 000 photographs).

2.2 Direct Observations and Measurements

The six aerial photographs are studied in detail with respect to:

(i) terrain above the valley,
(ii) valley characteristics,
(iii) river mouth,
(iv) flood plain, and
(v) the river course and its channel.

Several of the observations made are of a general descriptive and qualitative nature (e.g. terrain, land-use, settlement, relation of channel to valley bottom and sides, description of the river mouth, river pattern, lateral channel activity and man-made factors). Other observations require measurements. Some are done manually with a steel ruler or an opisometer, direct from the photographs: amongst these are vegetation and land-use on the valley sides and riverine vegetation. The remaining linear, areal and angular measurements are made using a flat-bed digitizer. These may be made direct from the photograph in the case of an orthophoto. Otherwise, for greater accuracy, they are made from the master film tracings - compilation of which is described in 2.1 above. Such linear and angular items measured include mid-valley lengths, thalwegs, valley widths, flood plain lengths and widths, wetted perimeters and sand-spit lengths, widths and directions. Areas measured on the digitizer include the flood plain, swamps, sand deposits, cultivation, open water and bars.

2.3 Indirect Measurements and Calculations

River widths are measured, averaged and the standard deviation calculated. If the channel widths (in this context synonomous with bank-full conditions) are markedly different from the river widths and clearly seen on the aerial photographs, these are also measured (across the same lines of measurement, marked at 250 m to 300 m intervals). The sinuosity for the whole reach is calculated. In order to quantify the lateral stability, distances are measured from the maximum left bank position to mid-river (along the selected lines of measurement on the six master film tracings). From these measurements, an average lateral displacement and an average coefficient of lateral stability is calculated for the time period under review.

2.4 Recording of Data

A table has been compiled (Table I) to facilitate the observation and recording of salient points. The basic idea for this tabular classification was taken from Kellerhals et al. (1976). Modifications were made to the initial table as the study progressed to include:

(a) local features of Natal rivers,

(b) estuarine conditions (e.g. river mouth characteristics), and

(c) particular needs of the study (e.g. man-made influences).

Data reports are prepared for each estuary. These contain the basic tabular classification forms for each photograph studied and tables showing river widths and lateral stability. Thalweg displacement is graphed. Other features selected for graphing vary from estuary to estuary, depending upon what is found to be pertinent. These may include open water areas (often found to be decreasing with time), thalweg changes, sinuosity changes and bar areas. Copies of the photographs used for classification are reproduced in the data reports together with a most recent aerial photograph onto which is superimposed the 1937 river course. The latter give a good visual indication of changes occurring in the estuaries over a period of approximately 40 years. Brief notes and an abstract of results are also prepared for each estuary. Data will be codified later and stored on computer for further analyses.

3. BACK-UP DATA

Hydrological data are scarce but simulated run-off is now available for tertiary catchments in Natal (H.R.U. Report 9/81). These data are an invaluable aid to interpreting the aerial photographs because wet and dry phases together with antecedent soil moisture conditions can be defined.

TABLE I — CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS — NRIO NS 41

RIVER LOVU, 24 % ESTUARINE, REACH from Sugar Mill Bridge to Mouth, 3,8 km from mouth. REF. DEA U 700 d

AERIAL PHOTO DATE 2-6-73 SCALE 1:10 000 CATCHMENT AREA 938 km², M.A.R. 115 m³x10⁶, No. of DAMS NIL

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	*Vegetation*	*Land-Use*
mountainous	✓ almost none	none
✓ hilly	grass	scattered cultivation
undulating	sparsely forested (0-25%)	partly cultivated
plains	moderately forested (25-75%)	✓ mainly cultivated
	heavily forested (75-100%)	scattered settlement
	swamp/bog	✓ partly built-up *
		urbanised

Valley Sides (~~Not~~ Well-defined)

Slumping	*Vegetation and Land-Use*	*Left*	*Right*
✓ none	none		
occasional	grass	NIL %	NIL %
frequent	trees	11 %	12 %
	cultivated	89 %	88 %
	built-up	NIL %	NIL %

Comments * near coast

Valley Characteristics

Measurements	*Terraces*	*Relation of Channel to Valley Bottom (Vertical)*	*Relation of Channel to Valley Sides or Resistant Terraces (Lateral)*	*Surface Geology*
valley length 3600 m	none	not applicable	✓ not applicable (no valley or free)	bedrock
bottom width (av.) 880 m	indefinite	not obviously degrading	occasionally confined	lacustrine deposits
valley slope ≏ 1:900	✓ fragmentary	partly entrenched	frequently confined	✓ fluvial deposits
height at head	continuous	entrenched	entrenched	aeolian
of reach + 4 m to MSL approx.		✓ aggrading		sand covered NIL % area

Comments

River Mouth

Characteristics	*Measurements*
✓ open/~~closed~~	right bank breakwater length ___ m
✓ natural/~~artificial~~	left bank breakwater length ___ m
canalized	rock sill level ___ m to MSL
✓ sandy	cliffs on right bank: height ___ m to MSL
✓ rocks on right bank	cliffs on left bank: height ___ m to MSL
rocks on left bank	spit/~~bar~~: direction of growth 205 °
outer bar	length of spit/~~bar~~ 640 m
silt plume (fluvial)	length stabilized 510 m
✓ suspended sediment (marine)	width 110 m

Comments

FLOOD PLAIN AND CHANNEL FEATURES

Description of Flood Plain

Presence	*Extent*	*Vegetation*	*Forest Type*	*Land-Use*
none	none	almost none	not known/applicable	✓ ~~not cultivated~~, not built-up
indefinite	average width 735 m	grass	riverine:	✓ cultivated 53 % area
fragmentary	maximum width 1300 m	reed swamp 19 % area	main channel	✓ crop/~~s~~ sugar cane
✓ continuous	aerial length 3419 m	sparsely forested	tributaries	partly built-up
	area 246 ha	moderately forested	✓ coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Comments

Channel Description

N.B. Estimate of flow stage: ~~LOW/NEAR LONG-TERM MEAN~~/HIGH **

Pattern	*Measurements*	*Islands/Shoals*	*Type of Flow*	*Bar Type*
straight	thalweg 3817 m	none	stagnant/still	none
sinuous	*sinuosity 1,12	occasional	✓ uniform water surface	channel side bars
irregular	*open water area 15,7 ha	frequent	uniform with rapid in reach	✓ point bars
regular meanders	perimeter 9159 m	split	irregular	channel junction bars
✓ irregular meanders	lake/lagoon area ___ ha	braided	pool & riffle sequence	mid-channel bars
tortuous meanders	✓ river X-sections available			diamond bars
bifurcated	channel slope ___			diagonal bars
lake/s	channel width $\bar{x}$ ___ m s = ___ m			sand waves/large dunes
lagoon	river slope ≏ 1:1388			
	river width $\bar{x}$ 37,4 m s = 47,5 m			

Comments *whole reach
** fairly high: fewer bars

Obstructions/Constructions

Natural	*Degree*
✓ none	none
logs	minor
boulders	major
vegetation	

Comments

Man-made	*Degree of Obstruction/Constriction for Each*	*Position (from head of reach)*
✓ road bridge/s	Sugar Mill + Natal Rd (NR) bridges. R. confined	Head + 3 km
✓ rail bridge/s	R. confined	3,8 km
✓ causeway	remains of 1959 causeway ? obstruction	≏ 3 km
weir/dam		
fish traps		
✓ embankment/s (2)	for NR + rlwy bridges	across L. flood plain
groynes		
✓ canal~~s~~	taking whole flow	0 - 1,2 km
✓ drainage furrows		widespread
✓ others		

Lateral Channel Activity

Lateral Activity	*Nature of Banks*	*Bank Vegetation*	*Lateral Stability*
not detectable	✓ alluvium (silt/sand)	none	stable
downstream progression	natural levées	✓ weak	slightly unstable
✓ progression & cut-offs	rock/boulders	good	✓ moderately unstable
mainly cut-offs	protected/stabilized	very strong	highly unstable
entrenched loop development	✓ cultivation to	left bank 8 %	
irregular lateral activity	channel edge	right bank NIL %	
avulsion			

Comments

Rainfall analyses of wet and dry periods, using exponentially filtered monthly rainfall data (Zucchini, 1975) are also very valuable - especially for smaller catchments for which no run-off data are available. When available, topographical surveys (for river gradients and cross-sections), physical model studies (for river flood behaviour), land-use studies for the whole catchment and archival data (old maps and cross-sections) are used to aid the study. For example, archival data has been used in one estuary to quantify river aggradation, making it possible to extend the period for which changes in the average river bed level could be calculated. At 21 estuaries, daily observations are made as to whether the mouth is open or closed. Water level stations are being established at 26 of the estuaries.

4. RIVER MOUTH AND SHORELINE FEATURES

Although this classification method highlights fluvial features which are dominant in the case of Natal's estuaries, the true quantitative picture of change is only revealed when viewed in conjunction with land-use and river mouth features. Table II gives a brief review of four important river mouth features:

(i) Mouth opening and closure is a dominant feature.

(ii) Rocks, rocky headlands and sills are very important because rocks to the south of an estuary afford protection from the dominant swell and allow a southerly extending spit to form where the general littoral drift is to the north.

(iii) Spits have an important effect on siltation. The prograding coastline north of the Tugela is dominated by long, northeasterly-extending spits causing river capture in one case and generally altering the courses of the rivers near the coast. For example the spit at Siaya has extended by 727 m in 40 years. South of the Tugela estuary the spits are generally southerly-extending.

(iv) Several man-made influences are apparent. Groynes affect littoral drift and the stabilization of spits inhibits the natural flood flows.

5. RESULTS

It has been found that major floods, riverine vegetation, swamp areas and sand-spits/bars at the mouth are the main natural factors influencing the behaviour of the estuaries. Man's influence is marked in land-use on the flood plain

TABLE II: SUMMARY OF MOUTH FEATURES

	Open/Closed			Rocks			Spit			Artificial
	Mostly									Including groynes, pipes, canals and spit stabilization
	O	C	O/C	→S	→N	N&S	→S	→N	Variable	
North Natal	10	7	3	7	0	1	8	7*	4	4
							* one shows spit →S after major floods			
South Natal	12	36	4	34	3	6	41**	7	3	36***
							** six - maybe more show spit →N after major floods			*** 30 of these have road/rail bridge embankments - often involving spit stabilization

The above table gives the number of estuaries to the north and south of Durban showing the features as itemized. It is based upon "The Estuaries of Natal" by G W Begg (1978) and a study of aerial photographs.

and in the whole catchment area, the construction of embankments and bridges, groynes and breakwaters, dams in the catchment, the drainage of swamps, the removal of riverine vegetation, canalization and the stabilization of formerly mobile sand-spit and bar areas. Instability is clearly shown by sinuosity index fluctuations, large lateral thalweg displacements with a high coefficient of variation and longer thalwegs (behind prograding sand-spits). The converse may not mean stability, however. "Apparently stable" estuaries often show marked deterioration through decreased open water areas, narrowing river widths, increased bar areas and general aggradation. Some examples of lateral stability are given below:

Estuary	Av. lateral displacement (m)	$\overline{V}$%	Notes
Mtamvuna	19	11	Stable
Mzumbe	122	40	Unstable
Mahlongwa	4	12	*Apparently stable
Mkomazi	22	17	*Apparently stable
Lovu	95	42	Unstable
Mgeni	53	16	*Apparently stable
Mdloti	62	42	Unstable
Tongati	30	35	Unstable
Zinkwasi	7	8	*Apparently stable
Siaya	14	47	Unstable (esp. 1953+)
Mhlatuze (Richards Bay)	1 255	66	Unstable

* These estuaries show instability in other ways e.g.

(i) loss of open water areas
(ii) aggradation with loss of tidal influence.

6. CONCLUSION

This interpretation of fluvial features, based upon aerial photographs over a period of 40 years, is expected to provide a key to the natural functioning of the estuaries of Natal and the estuarine responses to human influences. Thereby, this study will also facilitate conservation measures and/or planned development of estuarine resources by the Town and Regional Planning Commission, Natal.

7. FOOTNOTE

Readers are invited to contact the author direct for further information on specific estuaries.

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