

CONFIDENTIAL

**HYDROLOGICAL / HYDRAULIC STUDY  
OF NATAL ESTUARIES**

**DATA REPORT NO. 14  
MTWALUME NS 32**

SEDIMENT DYNAMICS DIVISION  
COASTAL ENGINEERING AND HYDRAULICS  
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY  
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

NRIO DATA REPORT D 8304

Stellenbosch, South Africa  
August 1983

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MTWALUME NS 32

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Natal.

*Location*

The Mtwalume River discharges into the Indian Ocean on the Natal South coast at 30°29'S, 30°38'E, and the 4 km reach under review extends from the old national road bridge to the mouth (see map inside back cover).

*Hydro data*

The M.A.R. from a catchment area of 565,0 km<sup>2</sup> is 71,7 x 10<sup>6</sup>m<sup>3</sup>. Of particular interest to this study is the nature of the run-off which is very erratic. This is quantified by the very high coefficient of variation (V%) for monthly run-off given in Table NS. 32/X. The wide spectrum of annual and monthly flows is clearly seen in Figures NS32/3 and 4. Figure NS32/5 shows the trends in the annual run-off for the period 1921 - 75.

Major floods occurred in April 1856, October 1917, March 1925, May 1959 and March 1976. The flood of the 17th May 1959 caused great damage and considerable siltation. Ten of the 21 spans of the old steel railway bridge were destroyed and the northern approach embankment was scoured away (Meineke, 1960 and Photo NS32/4). Orme (1974) estimated the 1959 flood level at the bridge to be +5m to MSL with a maximum scour depth to -12 m MSL.

For classification purposes, consideration must be given as to when the photographs were taken with regard to run-off. The following facts emerge regarding the six photographs studied and antecedent run-off conditions:

- (I) 30-4-1937 : below-average run-off for 3 months previous. 4th and 5th month previous well above average.
- (II) Jun/July '55: above-average run-off following a wet phase.
- (III) 23-5-1959 : above-average run-off following a major flood 17th May 1959. Prior to flood, 11 months of below-average run-off.

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- (IV) 6-6-1967 : below-average run-off following 2 months of above-average run-off : generally within a dry phase.
- (V) 17-6-1969: near-average run-off within a dry phase.
- (VI) 6-7-1976 : above-average run-off following a 5 month period of major flooding.

*River mouth*

Orme (1974) states that the mouth is commonly closed with littoral drift from the north. Most of the available aerial photographs, however, show the mouth to be open and therefore the 1969 photograph has been included, although very close in time to the 1967 photo, as an example of closed mouth conditions. The mouth position is variable for a variety of complex reasons. There is a basic pattern of the river discharging into the sea in a southerly position against rocks on the right bank during the dry winter seasons and dry phases. This was particularly common pre-1940 (Begg, 1978).

The dominant wave direction in the area is from the southerly sector. As a result the net longshore transport direction is from south to north along the coast. This generalization does not hold in the vicinity of rocky promontories, headlands and coastal structures. In the lee of such features reversal of the normal pattern occurs due to longshore variations in the wave set-up. (wave set-up  $\equiv$  difference between the actual water level inside the breaker zone and the still-water level). This leads to spit growth in the reverse direction which is frequently misinterpreted as meaning that the longshore drift is in the reverse direction. The headland south of the Mtwalume mouth serves as such a barrier for waves from the extreme southerly sector and accounts for the common southerly-extending spit.

During floods, the river adopts a more direct, northerly course to the sea and following major floods, a northerly-extending spit develops. This was particularly marked following the major May 1959 and March 1976 floods. Large amounts of fluvial-supplied off-shore sediment

...

are necessary for this spit growth. (Van Heerden, 1976).

The position is complicated further by human influences. Farming malpractices since the turn of the century (accelerated since the late 1930's) have caused aggradation. As a result, a lesser flood discharge than formerly can seemingly cause the breaching of the spit. The natural tendency for the Mtwalume to meander and flow against the higher ground along the left bank near the mouth has been strengthened by bridge building at the turn of the century, in 1961 and 1974. Embankments for the bridges on the right bank have confined the river to a more northerly course. The embankments and pier alignments of the new railway (1961) and freeway (1974) bridges which are close to the sea, also favour a more northerly position of the mouth, although the 1978 situation shows the mouth in the extreme south (see Figure NS32/2).

Prolonged dry spells will probably be required in present circumstances for the mouth to revert to its most southerly position against the rocks. The influence of mechanical breaching of the spit/bar should be noted, although it cannot be assessed as the frequency and positions are not known. Various mouth positions, bridges and embankments from 1937 to 1978 are shown in Figure NS32/2.

#### *Land-use*

Approximately 50% of the valley sides are under sugar cane. Cultivation on the flood plain increased from 23% to 83% between 1937 and 1955. Thereafter the figures appearing in the abstract (Table NS32/I) belie the true position as considerable areas under cultivation were covered with silt by the 1959 and 1976 floods and reclamation of land for agriculture was slow in the 1960s. Sometimes cultivation is to the channel edge. The remaining flood plain area is covered with bush/trees or swamps. The old national road (NR) bridge lies at the head of the reach and confines the flow. The old steel railway bridge with its embankments restricted the flow as also do the new railway and freeway bridges with their embankments across the flood plain.

### *Siltation*

Until the 1930s the river was estuarine up to the old NR bridge and near the old railway bridge the river was 6 m deep. At present the estuarine reach has been reduced to 25% of its previous length and the maximum depth is now unlikely to be more than 1,5 m (Begg, 1978). This marked aggradation is probably related to the expansion in sugar cane cultivation (late 1930s especially) in the whole catchment as well as the reach. Silt deposition near the bridge embankments can be seen in all photographs NS32/1 - 7 as well as in Figure NS32/2. Vast quantities of silt were transported by the major floods of 1959 and 1976 - particularly the 1959 flood which occurred after a long dry spell. Areas of the flood plain covered by silt, following these floods, may be seen in Photographs NS32/1, 4 and 7. For the lower reaches near the mouth, shown in Figure NS32/2, the following Table shows the increase in silt area following the two major floods:

Date	30-4-37	Jun/Jul'55	23-5-59	6-6-59	17-6-67	23-6-69	6-7-76
Silt area (ha)	20,1	21,0	28,9	22,6	15,8	15,28	27,1

The dramatic reduction in silt area after the 1959 and before the 1976 flood can be attributed to the removal of the old railway line which exposed the silt area D to erosion.

Silt area "A" (Figure NS32/2) extended after the May 1959 flood to incorporate an island area - resulting in a larger build-up of silt behind the railway embankment. Silt area "B" remained fairly constant for the period 1937 - 1969. After the March 1976 flood, siltation extended to area "C".

### *Stability*

The river flows along a deeply incised meander for the upper part of the reach under review and the flood plain is fairly narrow. The upper part of the reach has been fairly stable but the lower part (from section 7) has shifted laterally to a marked degree during the period 1937 - 1976 (Photo NS32/1). There is a high average displacement

of 138,5 m with a high average coefficient of variation of 38% (Table NS 32/IX) Thalweg displacement is shown in Figure NS32/1 and even allowing for the marked influence of the migration of the mouth, the lateral displacement is considerable. Changes in river widths and open water areas chiefly reflect the influence of major floods, and changes in sinuosity are largely a result of varying mouth conditions and positions. The reduction in estuarine length shows aggradation (vertical instability).

The Mtwalume has been unstable for the period under review.

ABBREVIATIONS/SYMBOLS USED IN THE TABLES

M.A.R.	Mean annual run-off
L.B.	Left bank
R.B.	Right bank
P	Perimeter
$\bar{x}$	Arithmetic mean
s	Standard deviation
V	Coefficient of variation $\frac{s}{\bar{x}}$
MSL	Mean sea level
R	River
d/s	Downstream
—	Maximum value
....	Minimum value
N.R.	No record

HUMAN INFLUENCES

Within the Reach

1. Land-use
  - (a) Cultivation: Valley sides = 50% under sugar cane
  - Flood plain 23%-83% under sugar cane (lands often covered with silt)
  - To channel edge Some years

- (b) Bridge building and embankments
  - old railway bridge 1km from mouth ( $\approx$  1900)
  - NR bridge at head of reach (1936)
  - new railway bridge 230 m from mouth (1961)
  - freeway bridge 500 m from mouth (1974)

- (c) Canals
  - nil

- (d) Urbanization/Industry
  - Built-up area higher up above RB of valley.

2. Breaching of sandbar  
 Dams opened artificially in 1930s by sugar cane farmers (Bogg, 1978).  
 No record of how frequently this has been done since.  
 Aerial photo of 12-6-76 shows channel cut in mid sand-spit but this was  
 evidently not successful judging by photo of 6-7-76.

3. Others
  - nil

Upstream of Reach

- (a) Dams in the catchment
  - nil
- (b) Building construction or canalization immediately upstream of reach
  - nil
- (c) Land-use malpractices/silt supply
  - Minic farming upstream and sugar cane farming downstream (some years to channel edge) cause severe bank erosion and siltation of river.

BASIC DATA / CALCULATIONS

Lateral displacement (1937 - 1976)	$\bar{x}$	138.45	m
Relative lateral stability (1937 - 1976)	$\bar{v}$	38	%
Area of catchment		565.0	km <sup>2</sup>
Area of flood plain		111.26	ha
Area of envelope of mobility		71.67	ha
Simulated M.A.R. (1921 - 1975)	$\bar{s}$	48.25	x 10 <sup>6</sup> m <sup>3</sup>
	$\bar{v}$	67.3	x 10 <sup>6</sup> m <sup>3</sup>

Dates of major floods: 1856, 1917, 24-3-25, 17-5-57, 21-3-76

MEASUREMENTS/CALCULATIONS FROM PHOTOGRAPHS

Date	30-4-37	1 Jun 55	6-6-59	17-6-67	23-6-69	6-7-76
Thalweg (m)	46.76	46.04	46.79	46.22	42.70	48.00
% Thalweg estuarine	100 (%)	?	?	?	?	35
Aerial D (m)	2906	2853	3041	3010	2863	3120
Sinuosity	1.61	1.61	1.54	1.54	1.49	1.54
$\bar{x}$ River width (m)	46.09	40.18	64.18	55.45	55.91	65.64
Open water area (ha)	27.5	20.9	36.6	32.8	29.2	35.3
% envelope of mobility	44	34	59	53	47	57
Bar/island area (ha)	9.0	1.1	nil	1.2	0.9	nil
River braided	—	partly	—	partly	partly	—
% Flood plain cultivated	23	83	20*	25*	35*	27*
Left valley side:						
% grass	—	—	—	—	—	—
% trees	40	65	56	53	56	50
% cultivated	60	35	44	47	44	50
% built up	—	—	—	—	—	—
Right valley side:						
% grass	—	—	—	—	—	—
% trees	25	40	45	51	50	55
% cultivated	75	60	55	49	50	45
% built up	—	—	—	—	—	—
L.B. % vegetated	51	52	27	53	49	41
R.B. % vegetated	35	33	25	23	43	18
Mouth open/closed (o/c)	0	0	0	0	C	0
Spit/bar:						
Direction (°)	907	918	90	99	220	99
Length (m)	690	475	550	720	710	715
$\bar{x}$ width (m)	73	77	67	56	63	60

\* values low due to silt deposition

RIVER Mtwalume, = 100 % ESTUARINE, REACH from NR bridge to mouth, 4 km from mouth. REF. DEA \_\_\_\_\_  
 AERIAL PHOTO DATE 30-4-37 SCALE 1:10 000 CATCHMENT AREA 565,0 km<sup>2</sup>, M.A.R. 71,76 m<sup>3</sup>x10<sup>6</sup>, No. of DAMS nil

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley			Valley Sides ( <del>Not</del> Well-defined)			
Terrain	Vegetation	Land-Use	Slumping	Vegetation and Land-Use	Left	Right
mountainous	almost none	none	✓ none	none		
✓ hilly	grass	scattered cultivation	occasional	grass		
undulating	✓ sparsely forested (0-25%)	partly cultivated	frequent	trees	40	25
plains	moderately forested (25-75%)	✓ mainly cultivated		cultivated	60	75
	heavily forested (75-100%)	✓ scattered settlement		built-up		
	swamp/bog	partly built-up				
		urbanised				

Comments \_\_\_\_\_

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 <u>4000</u> m	none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) <u>393</u> m	indefinite	not obviously degrading	✓ occasionally confined	lacustrine deposits
valley slope _____	✓ fragmentary	partly entrenched	frequently confined	fluvial deposits
height at head _____	continuous	entrenched	entrenched	aeolian
of reach _____ m to MSL		✓ aggrading		sand covered <u>nil</u> % area

Comments \_\_\_\_\_

River Mouth

Characteristics	Measurements	Comments
✓ 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 <u>207</u> °	
✓ outer bar	length of spit/bar <u>690</u> m	
✓ silt plume (fluvial)	length stabilized _____ m	
suspended sediment (marine)	width <u>73</u> m	

Comments \_\_\_\_\_

FLOOD PLAIN AND CHANNEL FEATURES

Description of Flood Plain	Vegetation	Forest Type	Land-Use
Presence			
none	almost none	not known/applicable	not cultivated, not built-up
indefinite	grass	riverine:	cultivated <u>23</u> % area
fragmentary	reed swamp <u>15</u> % area	main channel	crop/s <u>sugar cane</u>
✓ continuous	✓ sparsely forested	tributaries	partly built-up
	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 <u>4676</u> m	none	stagnant/still	none
sinuous	*sinuosity <u>1,61</u>	✓ occasional	✓ uniform water surface	✓ channel side bars
✓ irregular	*open water area <u>27,5</u> ha	frequent	uniform with rapid in reach	✓ point bars
regular meanders	perimeter <u>9952</u> 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 _____		✓ turbid	diamond bars
bifurcated	channel slope _____			diagonal bars
lake/s	channel width x _____ m s = _____ m			sand waves/large dunes
lagoon	river slope _____			
	river width x <u>46,09</u> m s = <u>27,2</u> m			

Comments \*whole reach \_\_\_\_\_

Obstructions/Constructions

Natural	Degree	Man-made	Degree of Obstruction/Constriction for Each	Position (from head of reach)
✓ none	none	✓ road bridge/s	<u>NR bridge</u>	<u>River confined</u>
logs	minor	✓ rail bridge/s	<u>old raily. br.</u>	<u>0 (at head)</u>
boulders	major	causeway		<u>3,5 km</u>
vegetation		weir/dam		
		fish traps		
		embankment/s		
		groynes		
		canals		
		drainage furrows		
		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 <u>51</u> %	
✓ irregular lateral activity	channel edge	right bank <u>35</u> %	
avulsion			

Comments \_\_\_\_\_

RIVER Mtivalume, ? ESTUARINE, REACH from NR bridge to mouth, 4 km from mouth. REF. DEA \_\_\_\_\_  
 AERIAL PHOTO DATE 23-6-69 SCALE 1:10 000 CATCHMENT AREA 565,0 km<sup>2</sup>, M.A.R. 71,67 m<sup>3</sup>x10<sup>6</sup>, No. of DAMS nil

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley			Valley Sides ( <del>Not</del> Well-defined)		
Terrain	Vegetation	Land-Use	Slumping	Vegetation and Land-Use	Left Right
mountainous	almost none	none	✓ none	none	- -
✓ hilly	grass	scattered cultivation	occasional	grass	- -
undulating	✓ sparsely forested (0-25%)	partly cultivated	frequent	trees	<u>56</u> <u>50</u>
plains	moderately forested (25-75%)	✓ mainly cultivated		cultivated	<u>44</u> <u>50</u>
	heavily forested (75-100%)	scattered settlement		built-up	- -
	swamp/bog	partly built-up			- -
		urbanised			- -

Valley Characteristics		Relation of Channel to Valley Bottom (Vertical)	Relation of Channel to Valley Sides or Resistant Terraces (Lateral)	Surface Geology
Measurements	Terraces			
valley length <u>4000</u> m	none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) <u>393</u> m	indefinite	not obviously degrading	✓ occasionally confined	lacustrine deposits
valley slope	fragmentary	partly entrenched	frequently confined	fluvial deposits
height at head	continuous	entrenched	entrenched	aeolian
of reach ___ m to MSL		✓ aggrading		sand covered <u>4</u> % area

River Mouth Characteristics	Measurements	Comments
✓ 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 <u>220</u> °	
outer bar	length of spit/bar <u>710</u> m	
silt plume (fluvial)	length stabilized _____ m	
suspended sediment (marine)	width <u>63</u> m	

FLOOD PLAIN AND CHANNEL FEATURES

Description of Flood Plain		Vegetation	Forest Type	Land-Use
Presence	Extent			
none	none	almost none	not known/applicable	not cultivated, not built-up
indefinite	average width <u>362</u> m	grass	riverine:	cultivated <u>35</u> % area
fragmentary	maximum width <u>410</u> m	reed swamp <u>10</u> % area	main channel	crop/✓ <u>sunni cane</u>
✓ continuous	aerial length <u>2950</u> m	sparsely forested	tributaries	partly built-up
	area <u>111,26</u> ha	moderately forested	✓ coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Channel Description	N.B. Estimate of flow stage: <u>LOW/NEAR-LONG TERM MEAN/HIGH</u>		Islands/Shoals	Type of Flow	Bar Type
Pattern	Measurements				
straight	thalweg <u>4270</u> m	none	none	stagnant/still	none
sinuous	* sinuosity <u>1,49</u>	occasional	occasional	uniform water surface	✓ channel side bars
✓ irregular	* open water area <u>29,2</u> ha	frequent	frequent	uniform with rapid in reach	✓ point bars
regular meanders	perimeter <u>10467</u> m	split**	split**	✓ irregular	channel junction bars
irregular meanders	lake/lagoon area _____ ha	braided**	braided**	pool & riffle sequence	mid-channel bars
tortuous meanders	river X-sections available			✓ turbid	✓ diamond bars
bifurcated	channel slope _____				diagonal bars
lake/s	channel width x _____ m s = _____ m				sand waves/large dunes
lagoon	river slope _____				
	river width x <u>55,9</u> m s = <u>57,6</u> m				

Obstructions/Constructions	Degree	Man-made	Degree of Obstruction/Constriction for Each	Position (from head of reach)
✓ none	none	road bridge/s	<u>NR bridge</u> River confined	<u>0 (at head)</u>
logs	minor	rail bridge/s	<u>New Railway br.</u> "	<u>3,9 km</u>
boulders	major	causeway		
vegetation		weir/dam		
		fish traps		
		embankment/s		
		groynes		
		canals		
		drainage furrows		
		others		

Lateral Channel 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 channel edge	left bank <u>49</u> %	
✓ irregular lateral activity			right bank <u>43</u> %	

RIVER Nitwalmu, ? % ESTUARINE, REACH from NR bridge to mouth, 4 km from mouth. REF. DEA \_\_\_\_\_  
 AERIAL PHOTO DATE 17-6-67 SCALE 1:10 000 CATCHMENT AREA 565,0 km<sup>2</sup>, M.A.R. 71,67 m<sup>3</sup>x10<sup>6</sup>, No. of DAMS nil

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	Vegetation	Land-Use	Slumping	Vegetation and Land-Use	Left	Right
mountainous	almost none	none	✓ none	none		
✓ hilly	grass	scattered cultivation	occasional	grass		
undulating	✓ sparsely forested (0-25%)	partly cultivated	frequent	trees	<u>53</u>	<u>51</u>
plains	moderately forested (25-75%)	✓ mainly cultivated		cultivated	<u>47</u>	<u>49</u>
	heavily forested (75-100%)	scattered settlement		built-up		
	swamp/bog	partly built-up				
		urbanised				

Comments \_\_\_\_\_

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 _____ m	none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) _____ m	indefinite	not obviously degrading	✓ occasionally confined	lacustrine deposits
valley slope _____	✓ fragmentary	partly entrenched	frequently confined	fluvial deposits
height at head _____	continuous	entrenched	entrenched	aeolian
of reach _____ m to MSL		✓ aggrading		sand covered <u>17</u> % area

Comments \_\_\_\_\_

River Mouth

Characteristics	Measurements
✓ open/closed	right bank breakwater length _____ m
✓ natural/artificial	left bank breakwater length _____ m
canalized	rock sill _____ 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 <u>29</u> °
outer bar	length of spit/bar <u>750</u> m
silt plume (fluvial)	length stabilized _____ m
✓ suspended sediment (marine)	width <u>56</u> 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 <u>362</u> m	grass	riverine:	✓ cultivated <u>25</u> % area
fragmentary	maximum width <u>410</u> m	✓ reed swamp <u>12</u> % area	main channel	✓ crop/ <u>sugar cane</u>
✓ continuous	aerial length <u>2950</u> m	✓ sparsely forested	tributaries	partly built-up
	area <u>111,26</u> ha	moderately forested	✓ coastal dune/evergreen mangroves	mainly built-up
		heavily forested		

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 <u>4622</u> m	none	stagnant/still	none
sinuous	* sinuosity <u>1,54</u>	✓ occasional	uniform water surface	✓ channel side bars
✓ irregular	* open water area <u>32,8</u> ha	✓ frequent	uniform with rapid in reach	✓ point bars
regular meanders	perimeter <u>12548</u> 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		✓ turbid	✓ diamond bars
bifurcated	channel slope _____			diagonal bars
lake/s	channel width x _____ m s = _____ m			sand waves/large dunes
lagoon	river slope _____			
	river width x <u>55,45</u> m s = <u>38</u> m			

Comments \*whole reach

\*\* for short stretches in upper reach

Obstructions/Constructions

Natural	Degree	Man-made	Degree of Obstruction/Constriction for Each	Position (from head of reach)
✓ none	✓ none	✓ road bridge/s	<u>NR bridge</u>	<u>River confined</u>
logs	minor	✓ rail bridge/s	<u>New railw. br.</u>	<u>0 (at head)</u>
boulders	major	causeway		<u>3,9 km</u>
vegetation		weir/dam		
		fish traps		
		embankment/s		
		groynes		
		canals		
		drainage furrows		
		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 <u>53</u> %	
✓ irregular lateral activity	channel edge	right bank <u>23</u> %	
avulsion			

Comments \_\_\_\_\_

RIVER Mtwalume, ? % ESTUARINE, REACH from NR bridge to mouth, 4 km from mouth. REF. DEA  
 AERIAL PHOTO DATE 6-6-59 SCALE 1:10 000 CATCHMENT AREA 565,0 km<sup>2</sup>, M.A.R. 71,67 m<sup>3</sup>x10<sup>6</sup>, No. of DAMS nil

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Valley Sides (None Well-defined)

Terrain	Vegetation	Land-Use	Slumping	Vegetation and Land-Use	Left	Right
mountainous	almost none	none	✓ none	none		
✓ hilly	grass	scattered cultivation	occasional	grass		
undulating	✓ sparsely forested (0-25%)	partly cultivated	frequent	trees	<u>56</u>	<u>53</u>
plains	moderately forested (25-75%)	✓ mainly cultivated		cultivated	<u>44</u>	<u>47</u>
	heavily forested (75-100%)	scattered settlement		built-up		
	swamp/bog	✓ partly built-up urbanised				

Comments \_\_\_\_\_

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 <u>4000</u> m	none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) <u>393</u> m	indefinite	not obviously degrading	✓ occasionally confined	lacustrine deposits
valley slope _____	✓ fragmentary	partly entrenched	frequently confined	fluvial deposits
height at head _____	continuous	entrenched	entrenched	aeolian
of reach _____ m to MSL		✓ aggrading		sand covered <u>23</u> % 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 <u>20</u> °
✓ outer bar	length of spit/bar <u>550</u> m
✓ silt plume (fluvial)	length stabilized _____ m
suspended sediment (marine)	width <u>67</u> 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 <u>362</u> m	grass	riverine:	cultivated <u>20</u> % area
fragmentary		maximum width <u>410</u> m	reed swamp <u>15</u> % area	main channel	cropl <u>sugar cane</u>
✓ continuous		aerial length <u>2950</u> m	✓ sparsely forested	tributaries	partly built-up
		area <u>111,26ha</u>	moderately forested	✓ coastal dune/evergreen mangroves	mainly built-up

Comments \_\_\_\_\_

Channel Description N.B. Estimate of flow stage: LOW/NEAR LONG TERM MEAN/HIGH (major Flood 16/17-5-59)

Pattern	Measurements	Islands/Shoals	Type of Flow	Bar Type
straight	thalweg <u>4679</u> m	none	stagnant/still	none
sinuous	*sinuosity <u>1,54</u>	occasional <sup>xx</sup>	✓ uniform water surface	✓ channel side bars
✓ irregular	*open water area <u>36,6</u> ha	frequent	uniform with rapid in reach	✓ point bars
regular meanders	perimeter <u>10829</u> 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 _____		✓ turbid	diamond bars
bifurcated	channel slope _____			diagonal bars
lake/s	channel width x _____ m			sand waves/large dunes
lagoon	river slope _____			
	river width x <u>64,15</u> m			

Comments \*whole reach

<sup>xx</sup> near mouth

Obstructions/Constructions

Natural	Degree	Man-made	Degree of Obstruction/Constriction for Each	Position (from head of reach)
✓ none	none	✓ road bridge/s	<u>NR bridge</u> <u>River confined</u>	<u>0 (at head)</u>
logs	minor	✓ rail bridge/s	<u>old railw. br.</u> <u>supt away in flood</u>	<u>3,5 km</u>
boulders	major	causeway		
vegetation		weir/dam		
		fish traps		
		✓ embankment/s	<u>next to old railw. br.</u> <u>Diverts river</u>	<u>3,0 km</u>
		groynes		
		canals		
		drainage furrows		
		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 <u>27</u> %	
✓ irregular lateral activity	channel edge	right bank <u>25</u> %	
avulsion			

Comments \_\_\_\_\_

RIVER Natalume, ? ESTUARINE, REACH from NR bridge to mouth, 4 km from mouth. REF. DEA \_\_\_\_\_  
 AERIAL PHOTO DATE Jun/Jul '55 SCALE 1:10,000 CATCHMENT AREA 565.0 km<sup>2</sup>, M.A.R. 71.76 m<sup>3</sup>x10<sup>6</sup>, No. of DAMS nil

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	Vegetation	Land-Use	Slumping	Vegetation and Land-Use	Left	Right
mountainous	almost none	none	✓ none	none		
✓ hilly	grass	scattered cultivation	occasional	grass	—	—
undulating	✓ sparsely forested (0-25%)	partly cultivated	frequent	trees	40	25
plains	moderately forested (25-75%)	✓ mainly cultivated		cultivated	60	75
	heavily forested (75-100%)	scattered settlement		built-up	—	—
	swamp/bog	✓ partly built-up urbanised				

Comments \_\_\_\_\_

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 <u>4000</u> m	none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) <u>393</u> m	indefinite	not obviously degrading	✓ occasionally confined	lacustrine deposits
valley slope _____	✓ fragmentary	partly entrenched	frequently confined	fluvial deposits
height at head _____	continuous	entrenched	entrenched	aeolian
of reach _____ m to MSL		✓ aggrading		sand covered <u>1</u> % 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 <u>218</u> °
outer bar	length of spit/bar <u>475</u> m
silt plume (fluvial)	length stabilized _____ m
✓ suspended sediment (marine)	width <u>79</u> 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 <u>362</u> m	grass	riverine:	cultivated <u>1</u> % area
fragmentary	maximum width <u>410</u> m	reed swamp <u>1</u> % area	main channel	crop/ <u>sugar cane</u>
✓ continuous	aerial length <u>2750</u> m	✓ sparsely forested	tributaries	partly built-up
	area <u>111.2</u> ha	moderately forested	✓ coastal dune/evergreen mangroves	mainly built-up
		heavily forested		

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 <u>4604</u> m	none	stagnant/still	none
sinuous	*sinuosity <u>1.61</u>	occasional	uniform water surface	✓ channel side bars
✓ irregular	*open water area <u>20.7</u> ha	frequent	uniform with rapid in reach	point bars
regular meanders	perimeter <u>10454</u> 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 _____		✓ herbicid	diamond bars
bifurcated	channel slope _____			diagonal bars
lake/s	channel width x _____ m			sand waves/large dunes
lagoon	river slope _____			
	river width x <u>40.18</u> m			

Comments \*whole reach

\*\* for short stretches in upper reach

Obstructions/Constructions

Natural	Degree	Man-made	Degree of Obstruction/Constriction for Each	Position (from head of reach)
✓ none	none	road bridge/s	<u>NR bridge</u>	<u>River confined</u>
logs	minor	rail bridge/s	<u>old railw br.</u>	<u>0 (at head)</u>
boulders	major	causeway		<u>3.5 km</u>
vegetation		weir/dam		
		fish traps		
		embankment/s		
		groynes		
		canals		
		drainage furrows		
		others		

Comments \_\_\_\_\_

Lateral Channel Activity

Lateral Activity	Nature of Banks	Bank Vegetation	Lateral Stability
not detectable	alluvium (silt/sand)	none	stable
downstream progression	natural levees	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 channel edge	left bank <u>52</u> %	
✓ irregular lateral activity		right bank <u>33</u> %	
avulsion			

Comments \_\_\_\_\_

RIVER Mtunzume, 25 % ESTUARINE, REACH from NR bridge to north, 4 km from mouth. REF. DEA \_\_\_\_\_  
 AERIAL PHOTO DATE 6-7-76 SCALE 1:10 000 CATCHMENT AREA 565,0 km<sup>2</sup>, M.A.R. 71,67 m<sup>3</sup>x10<sup>6</sup>, No. of DAMS nil  
 (Orthophoto)

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Valley Sides (Not Well-defined)

Terrain	Vegetation	Land-Use	Slumping	Vegetation and Land-Use	Left	Right
mountainous	almost none	none	✓ none	none	—	—
✓ hilly	grass	scattered cultivation	occasional	grass	—	—
undulating	✓ sparsely forested (0-25%)	partly cultivated	frequent	trees	<u>50</u>	<u>55</u>
plains	moderately forested (25-75%)	✓ mainly cultivated		cultivated	<u>50</u>	<u>45</u>
	heavily forested (75-100%)	scattered settlement		built-up	—	—
	swamp/bog	✓ partly built-up urbanised			—	—

Comments \_\_\_\_\_

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 <u>4000</u> m	none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) <u>393</u> m	indefinite	not obviously degrading	✓ occasionally confined	lacustrine deposits
valley slope <u>1:400</u>	✓ fragmentary	partly entrenched	frequently confined	fluvial deposits
height at head of reach <u>10</u> m to MSL	continuous	entrenched	entrenched	aeolian
		✓ aggrading		sand covered <u>57</u> % area

Comments \_\_\_\_\_

River Mouth

Characteristics	Measurements	Comments
✓ 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 <u>29</u> °	
outer bar	length of spit/bar <u>715</u> m	
silt plume (fluvial)	length stabilized _____ m	
suspended sediment (marine)	width <u>60</u> 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 <u>362</u> m	grass	riverine:	cultivated <u>27</u> % area
fragmentary	maximum width <u>470</u> m	reed swamp <u>7</u> % area	main channel	crop/✓ <u>sugar cane</u>
✓ continuous	aerial length <u>2950</u> m	sparsely forested	tributaries	partly built-up
	area <u>111,26</u> 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 <u>4178</u> m	✓ none	stagnant/still	none
sinuous	*sinuosity <u>1,44</u>	occasional	✓ uniform water surface	✓ channel side bars
✓ irregular	*open water area <u>35,3</u> ha	frequent	uniform with rapid in reach	✓ point bars
regular meanders	perimeter <u>10724</u> m	split	irregular	channel junction bars
irregular meanders	lake/lagoon area _____ ha	braided	pool & riffle sequence	✓ mid-channel bars
contortuous meanders	river X-sections available _____		✓ turbid	diamond bars
bifurcated	channel slope _____			diagonal bars
lake/s	channel width x _____ m s = _____ m			sand waves/large dunes
lagoon	river slope _____			
	river width x <u>68,64</u> m s = <u>34,6</u> m			

Comments \*whole reach \_\_\_\_\_

Obstructions/Constructions

Natural	Degree	Man-made	Degree of Obstruction/Constriction for Each	Position (from head of reach)
✓ none	none	✓ road bridge/s	<u>NR bridge</u>	<u>0</u> (at head)
logs	minor	✓ rail bridge/s	<u>Freeway bridge</u>	<u>3,6</u> km
boulders	major	causeway	<u>New railw. br.</u>	<u>3,9</u> km
vegetation		weir/dam		
		fish traps		
		embankment/s		
		groynes		
		canals		
		drainage furrows		
		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 channel edge	left bank <u>41</u> %	
✓ irregular lateral activity		right bank <u>18</u> %	

Comments \_\_\_\_\_

Station	Approx. distance along 1976 R. NR bridge (m)	River widths (m)								$\bar{x}$	s	V%
		Date										
		30.04.37	J/J 55	06.06.59	17.06.67	23.06.69	06.07.76					
1	0	33	15	37	65	65	87			50,33	26,46	52,57
2	400	15	12	45	23	45	50			31,67	16,92	53,43
3	800	40	13	37	28	36	50			34,00	12,51	36,79
4	1 200	34	25	58	37	30	40			37,33	11,41	30,57
5	1 600	25	25	66	50	32	50			41,33	16,61	40,19
6	2 000	40	27	37	25	15	55			33,17	13,95	42,06
7	2 400	77	45	70	63	53	63			61,83	11,50	18,60
8	2 800	90	45	68	55	45	75			63,00	17,94	28,48
9	3 200	57	27	70	112	77	135			79,67	38,72	48,60
10	3 600	84	193	193	137	217	125			158,17	50,87	32,16
11	4 000	12	15	25	15	0	25			15,33	9,31	60,73
$\bar{x}$		46,09	40,18	64,18	55,45	55,91	68,64			55,08		
s		27,21	51,97	45,65	38,39	57,59	34,56					
V%		59,04	129,34	71,13	69,23	103,00						

LATERAL STABILITY

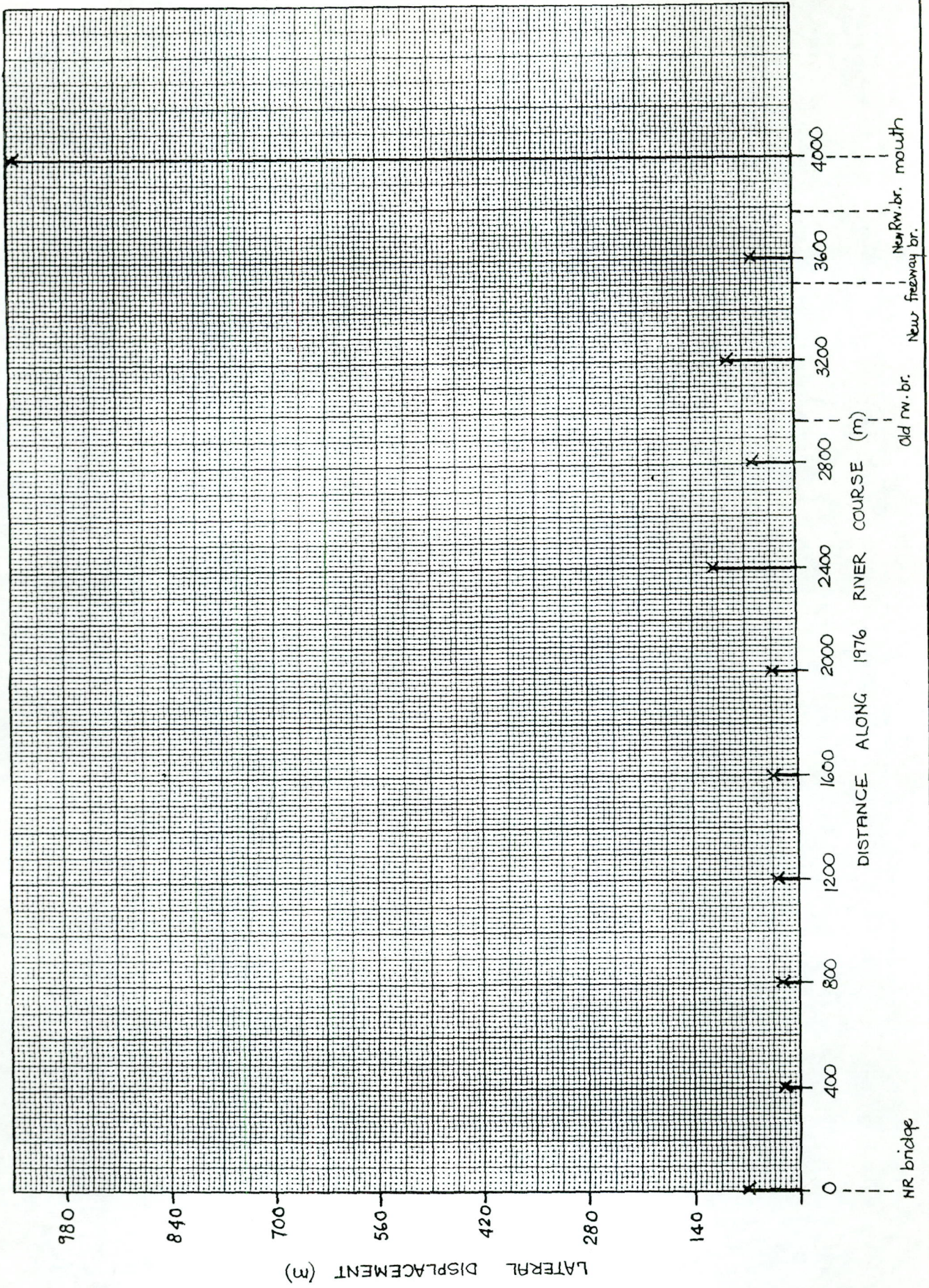
TABLE NS32/IX

Station	Approx. distance along 1976 R. course from NR bridge (m) 30.04.37	Distance from maximum observed L.B. position to mid-river (m)				Max - Min	$\bar{x}$	s	V%
		Date							
		J/J 55	06.06.59	17.06.67	23.06.69				
1	30	30	63	35	40	55	42,17	13,79	32,70
2	35	25	36	22	30	25	28,83	5,78	20,04
3	40	48	43	29	46	40	41,00	6,69	16,33
4	25	15	32	20	40	35	27,83	9,50	34,12
5	15	15	45	25	30	25	25,83	11,14	43,14
6	55	60	60	50	42	25	48,67	13,44	27,62
7	86	83	125	140	120	25	96,50	41,62	43,13
8	53	35	43	90	80	60	60,17	21,27	35,36
9	37	17	35	55	100	80	54,00	31,02	57,45
10	153	145	110	107	135	94	124,00	23,61	19,04
11	1 070	860	215	345	N.R.	15	501,00	445,81	88,98
$\bar{x}$	145,36	121,18	73,36	83,45	66,30	43,55	88,87		37,99
s	309,04	248,07	56,20	95,22	39,37	25,60			20,83
V%	212,60	204,71	76,61	114,10	59,38	58,78			54,83

Average lateral displacement 1937-1976 = 138,45 m  
 Average coefficient of variation 1937-1976 = 38%.

TABLE NS 32X SIMULATED RUN-OFF FOR MTWALUME CATCHMENT AREA= 565.050.KM. SM.A.R.

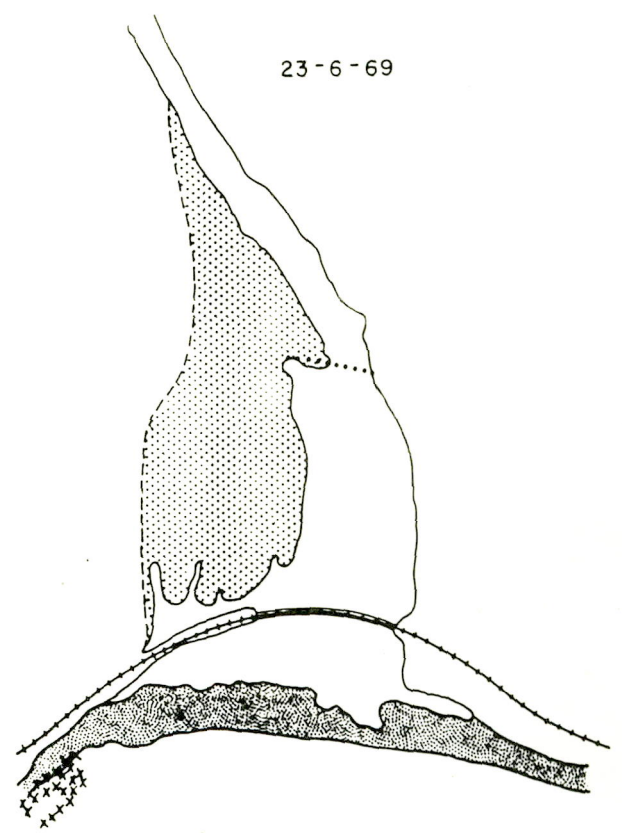
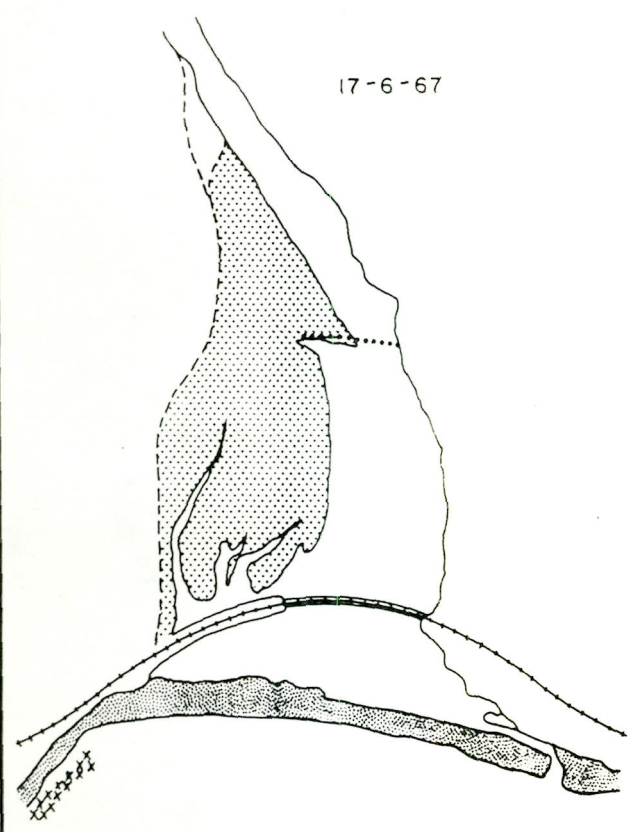
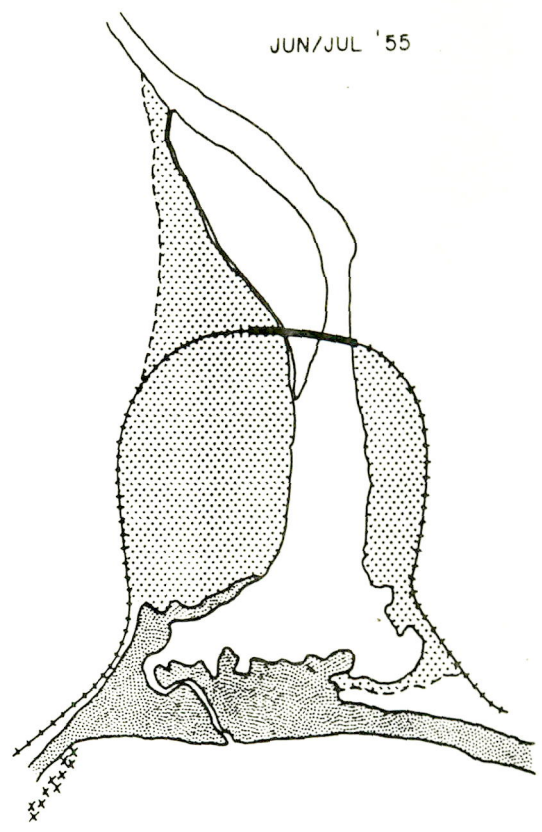
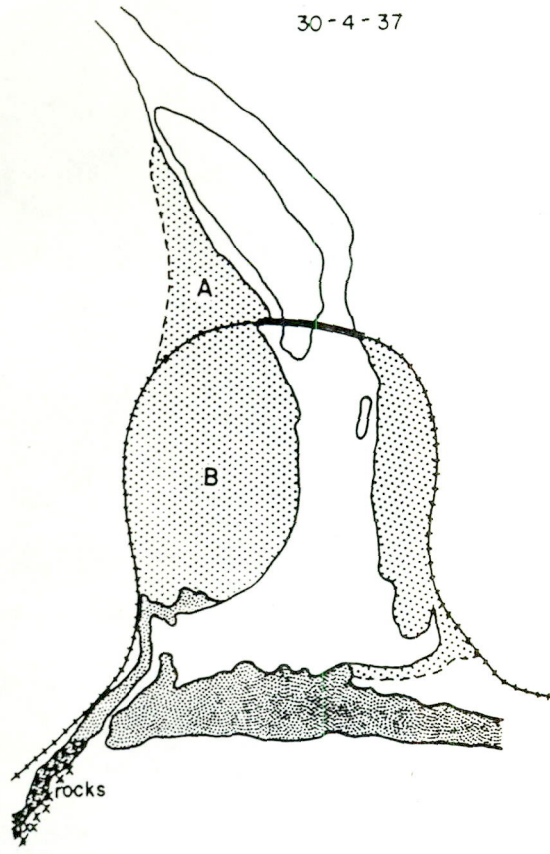
YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	SM.A.R.
1921	2.20	3.93	46.92	18.54	3.11	2.02	1.53	1.89	2.38	2.15	1.99	2.03	88.69	123.75
1922	8.55	12.94	6.80	4.04	16.41	9.30	4.04	2.34	1.41	1.41	1.44	1.06	69.85	97.46
1923	1.17	1.25	1.56	2.17	3.14	3.04	2.11	1.41	.98	.74	.75	1.06	19.40	27.07
1924	1.34	1.95	3.52	26.19	12.92	107.00	39.19	3.54	2.07	1.55	1.25	1.08	201.59	281.28
1925	1.37	1.59	1.37	1.23	1.50	3.37	3.74	2.47	2.05	1.84	1.33	1.34	23.24	32.42
1926	2.42	2.96	2.58	1.84	1.84	50.31	20.09	2.94	1.74	1.19	1.22	1.34	90.26	125.94
1927	1.80	1.91	2.21	2.71	3.51	3.60	2.57	1.70	1.14	.83	.84	1.01	23.87	33.31
1928	1.51	2.14	2.31	2.22	2.06	3.60	4.99	4.38	38.39	28.04	9.25	5.41	104.29	145.52
1929	6.87	6.35	4.59	4.85	3.07	3.07	2.18	1.65	1.48	1.55	1.58	2.41	41.13	57.39
1930	3.79	4.13	4.33	4.86	4.09	4.22	4.27	2.87	2.89	2.14	1.49	1.22	100.56	140.31
1931	3.49	3.05	2.75	2.90	3.88	4.64	3.80	3.23	2.89	2.14	1.49	1.22	35.49	49.52
1932	1.75	3.72	5.09	3.88	2.23	1.77	1.83	1.57	1.12	.93	.85	.82	25.58	35.69
1933	.86	2.25	11.66	28.27	12.05	4.27	3.76	3.24	2.32	2.35	2.46	1.91	75.40	105.20
1934	1.55	2.42	24.07	11.37	3.72	3.39	3.44	4.03	76.68	30.04	5.40	3.94	170.07	237.30
1935	2.80	1.98	1.16	1.22	2.70	4.28	3.60	4.13	4.76	3.45	2.12	1.70	33.91	47.32
1936	2.02	42.47	17.35	3.59	6.94	5.55	3.14	1.81	1.16	.98	1.27	1.47	87.77	122.46
1937	1.71	1.97	2.65	3.85	27.26	11.80	3.76	3.43	2.12	1.84	1.92	3.29	53.49	74.63
1938	1.88	2.79	3.54	3.77	15.75	9.31	4.33	2.94	2.12	1.84	1.92	3.29	53.49	74.63
1939	5.29	6.05	27.21	11.24	1.94	1.34	1.39	3.31	5.04	4.03	2.53	1.03	32.37	45.16
1940	1.41	8.46	6.86	4.05	2.31	1.94	2.06	1.53	1.01	.85	.83	1.03	32.37	45.16
1941	1.43	1.89	1.84	3.12	3.80	4.39	4.71	3.67	2.37	1.49	1.48	1.87	32.08	44.76
1942	2.98	5.18	18.04	9.53	4.04	11.94	34.64	15.08	5.03	4.08	4.89	4.66	120.10	167.57
1943	12.11	23.76	11.09	4.48	3.37	3.37	3.14	2.20	1.61	1.44	1.22	2.19	69.98	97.64
1944	4.53	4.49	2.55	1.44	1.79	3.59	3.83	2.78	1.94	1.42	1.09	.86	30.32	42.30
1945	1.37	1.60	1.17	1.09	1.53	2.39	2.59	1.93	1.26	.88	.68	.61	17.11	23.87
1946	.85	1.62	2.14	2.03	2.25	12.98	8.62	4.93	5.40	5.58	4.08	2.77	53.25	74.30
1947	2.14	28.93	19.80	7.79	5.99	6.17	5.95	4.58	2.77	1.66	1.13	.89	87.78	122.49
1948	2.55	3.61	2.76	1.93	1.69	2.28	2.79	2.35	1.54	1.06	.87	.97	24.38	34.02
1949	2.67	81.26	31.08	4.97	4.68	4.07	3.26	3.06	2.61	2.23	3.27	3.92	147.07	205.22
1950	3.56	3.30	31.17	40.02	13.66	5.19	4.55	2.80	1.62	1.07	1.51	2.79	111.23	155.20
1951	4.96	4.83	4.01	9.31	6.85	4.62	5.25	6.03	4.93	3.31	2.25	1.71	58.06	81.01
1952	1.55	1.78	2.27	3.39	5.99	4.82	2.68	1.60	1.06	.79	1.24	2.34	29.52	41.19
1953	3.39	4.50	5.21	4.56	3.42	3.16	2.67	2.28	2.16	1.78	1.44	1.92	36.51	50.94
1954	54.27	22.28	3.63	12.31	8.13	18.70	9.64	3.60	3.43	2.68	1.28	1.70	139.66	194.88
1955	2.63	3.47	3.39	2.01	2.52	52.15	22.05	4.92	3.43	2.68	2.45	2.65	104.37	145.63
1956	3.46	4.56	28.91	12.78	4.14	5.37	19.36	9.70	3.31	1.99	1.51	2.42	97.50	136.05
1957	12.10	8.57	4.38	3.81	17.07	9.36	36.53	15.27	2.96	1.83	1.31	1.26	114.45	159.70
1958	1.78	3.98	3.99	3.55	3.22	2.45	1.71	59.17	23.71	4.10	3.55	3.10	113.71	158.66
1959	3.03	3.06	2.54	1.90	1.68	2.15	3.33	3.62	2.64	1.81	1.41	1.44	28.63	39.94
1960	1.93	2.80	4.57	5.17	3.96	4.19	52.14	21.06	3.92	2.95	2.27	1.99	106.94	149.21
1961	2.10	2.59	2.56	2.54	3.29	10.68	6.93	3.41	2.09	1.34	1.37	1.47	40.36	56.32
1962	1.90	3.43	3.66	25.64	11.54	43.05	17.42	2.87	1.83	2.89	3.55	2.70	120.46	168.08
1963	2.92	3.74	19.11	28.22	10.98	3.44	2.56	1.98	2.19	2.61	2.19	1.90	81.83	114.19
1964	25.74	12.70	4.93	4.74	4.47	3.09	1.80	1.44	2.28	3.02	3.42	4.45	72.08	100.57
1965	13.50	11.69	6.19	4.98	4.57	2.90	1.91	2.46	2.98	2.46	1.85	1.63	57.10	79.68
1966	1.44	1.69	1.85	2.17	3.22	4.59	13.13	7.41	3.07	2.29	1.81	1.32	44.04	61.45
1967	1.57	3.06	3.32	2.68	2.26	2.31	2.26	1.71	1.15	.81	1.17	1.93	24.22	33.80
1968	2.62	2.64	1.99	1.17	1.05	2.39	3.26	4.26	4.33	3.20	2.56	2.42	31.88	44.48
1969	4.33	6.19	6.86	5.09	3.09	1.67	.90	1.06	1.88	2.19	2.45	3.03	38.74	54.05
1970	10.09	8.08	6.17	4.74	3.81	3.69	3.65	4.53	4.30	3.79	5.41	5.88	64.16	89.53
1971	5.30	4.83	5.25	5.18	12.80	7.38	3.00	2.15	2.15	2.30	2.16	1.58	54.07	75.45
1972	1.31	3.04	4.21	3.48	2.59	2.12	2.17	1.87	1.22	.87	1.15	2.07	26.09	36.40
1973	2.76	3.37	3.70	3.47	4.19	4.23	3.62	4.47	5.01	3.76	2.42	1.66	43.06	60.09
1974	1.46	1.82	3.64	13.17	11.51	6.45	3.77	2.26	1.43	.98	.74	1.22	48.45	67.60
1975	1.89	1.84	2.65	4.18	37.06	114.65	64.13	15.15	6.18	4.79	3.89	3.65	260.06	362.87
MEAN	4.66	7.27	7.98	7.09	6.33	11.16	8.65	5.13	4.94	3.86	2.45	2.16	71.67	101.67
S	8.01	12.65	9.76	8.24	6.71	22.27	13.11	8.42	11.41	7.51	4.73	1.23	48.25	67.32
VR	172.10	173.93	172.19	116.29	106.10	192.54	151.56	164.18	231.09	194.60	111.62	56.93	67.32	101.67
MEAN ANNUAL RUN-OFF=	71.67 MILLION CUBIC METRES. COMPILED FROM HRU REPORT NO.9/81 DATA													



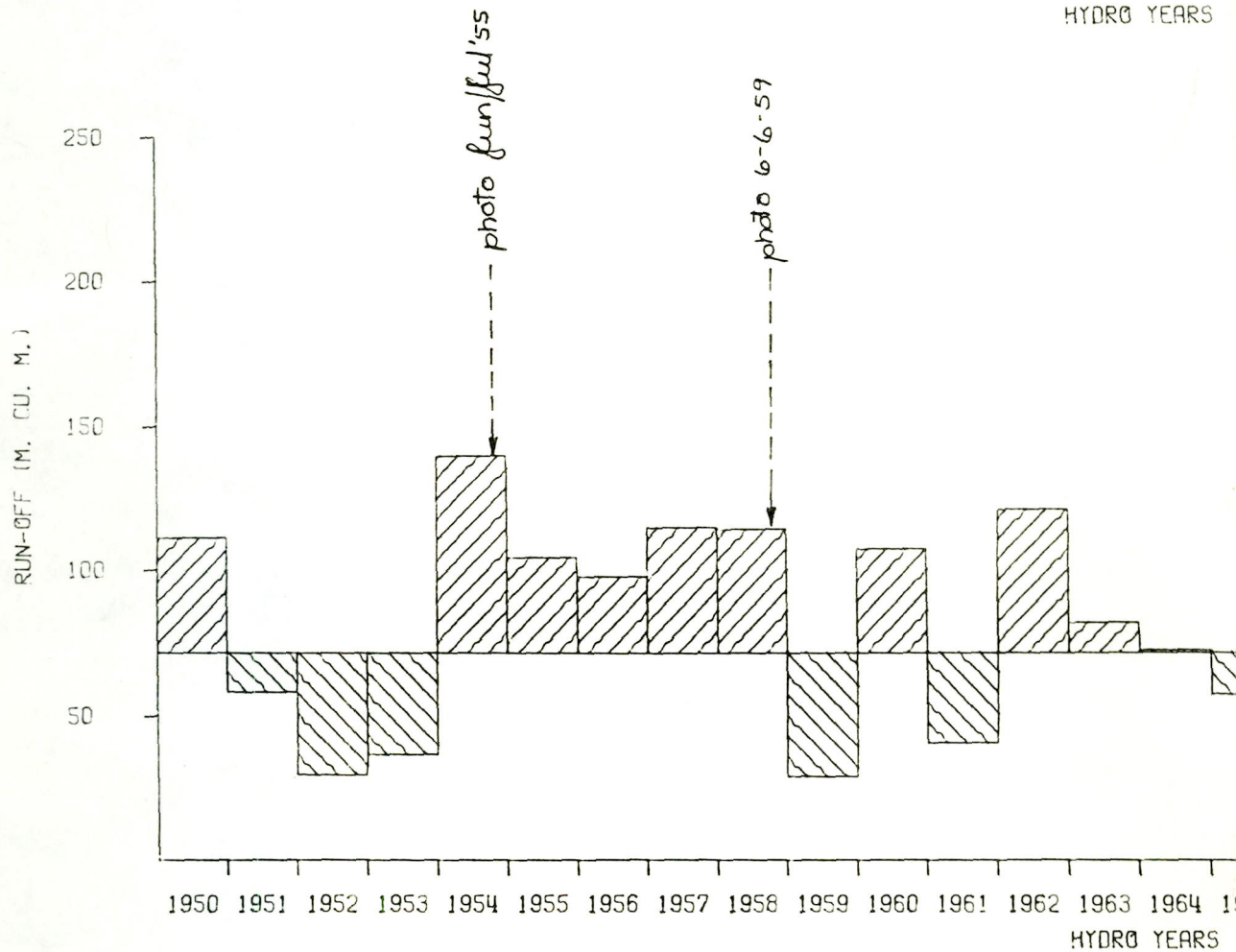
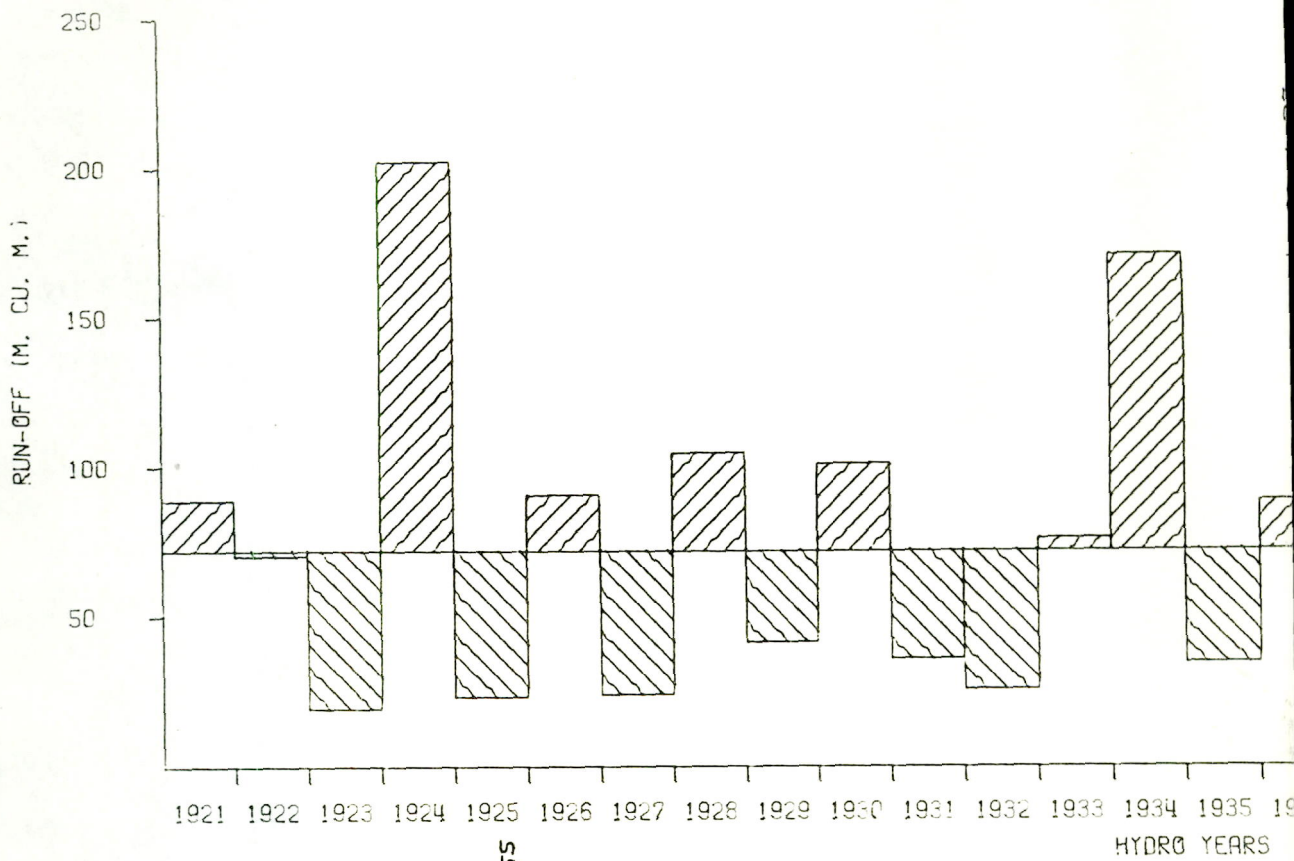
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 DATE  
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NATAL ESTUARIES: MTWALUME  
 THALWEG DISPLACEMENT: 1937-1976

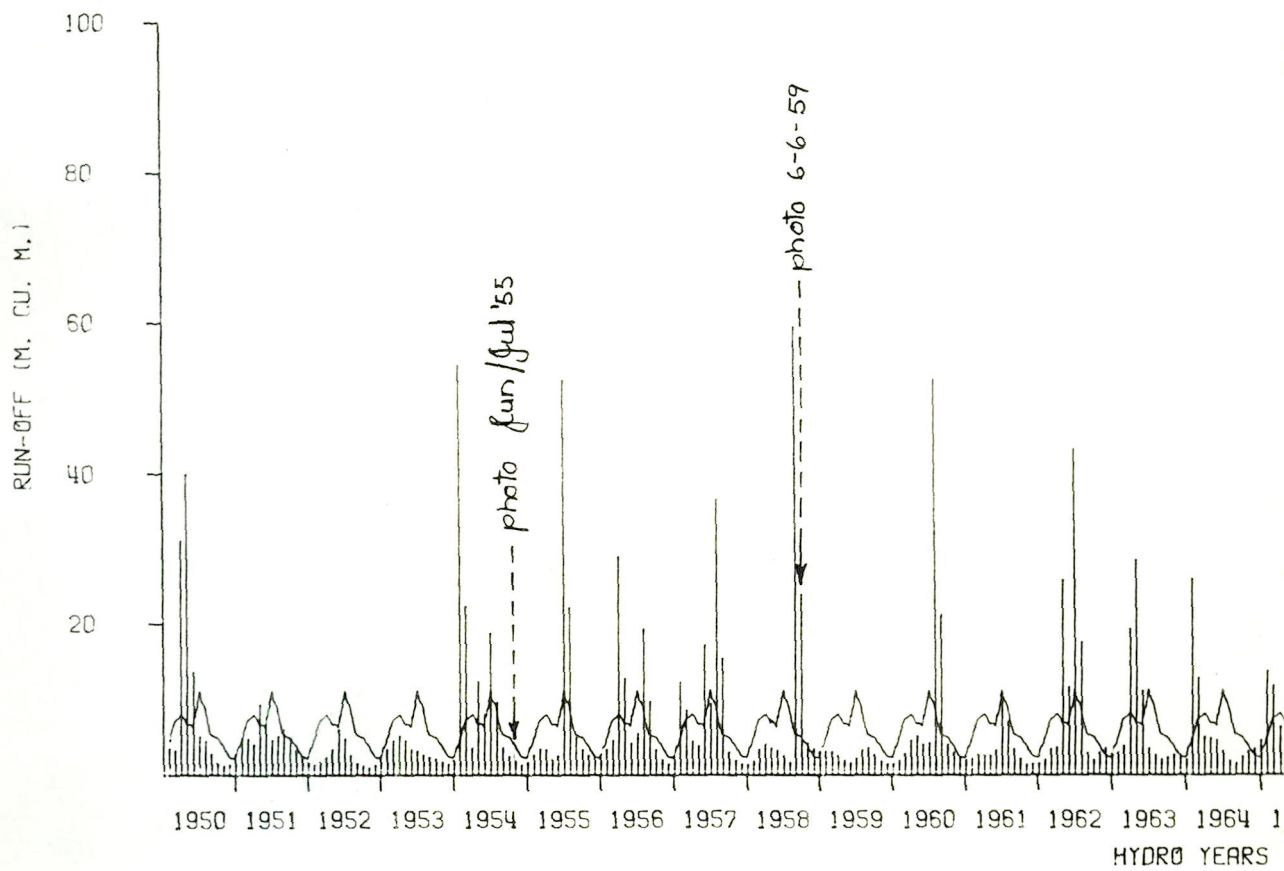
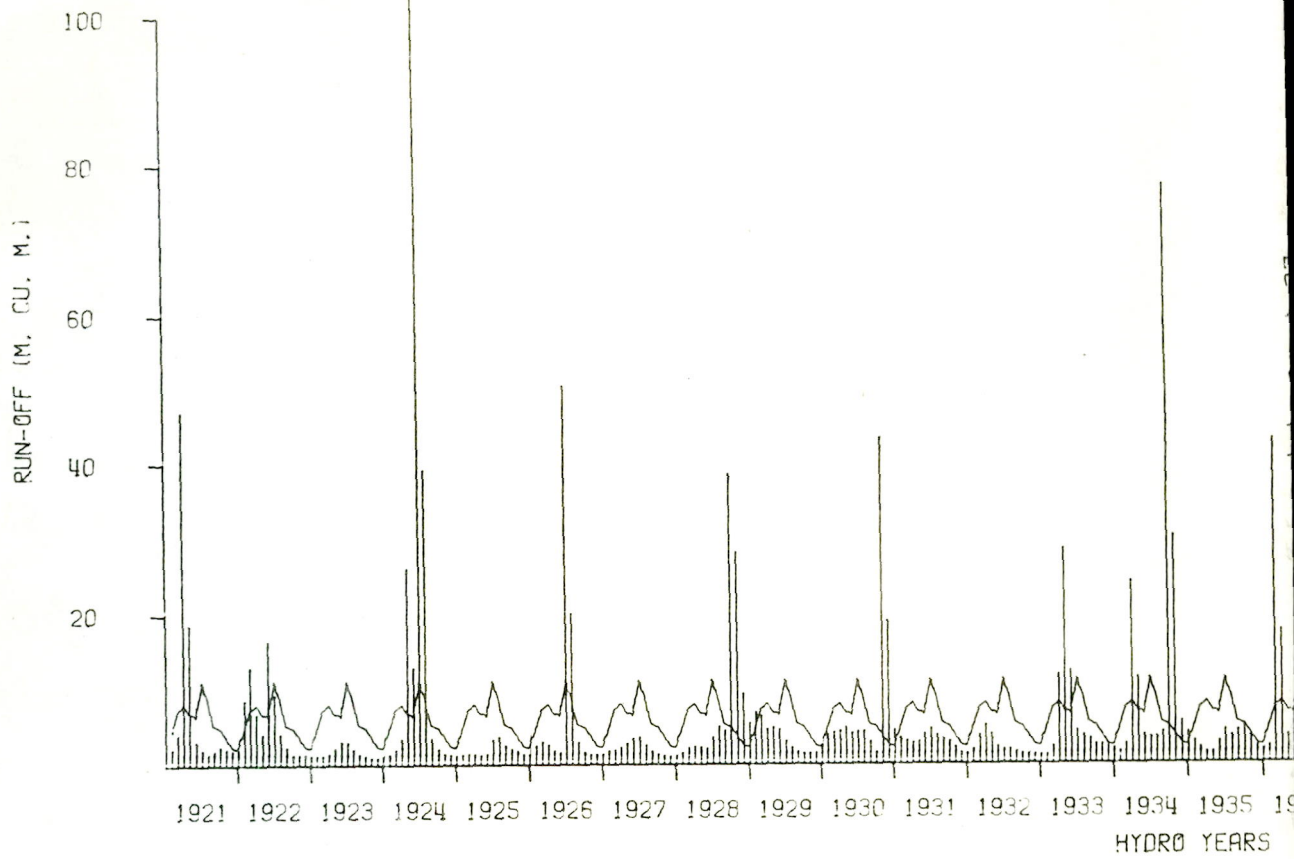
FIGURE  
 NS 32/1



<p>TRACED: DD          CHECKED:          DATE:          REF.:</p>	<p>NATAL ESTUARIES: MTWALUME</p> <p>MOUTH POSITIONS: 1937-1978</p>	<p>FIGURE          NS 32/2</p>
<p>NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY</p>		



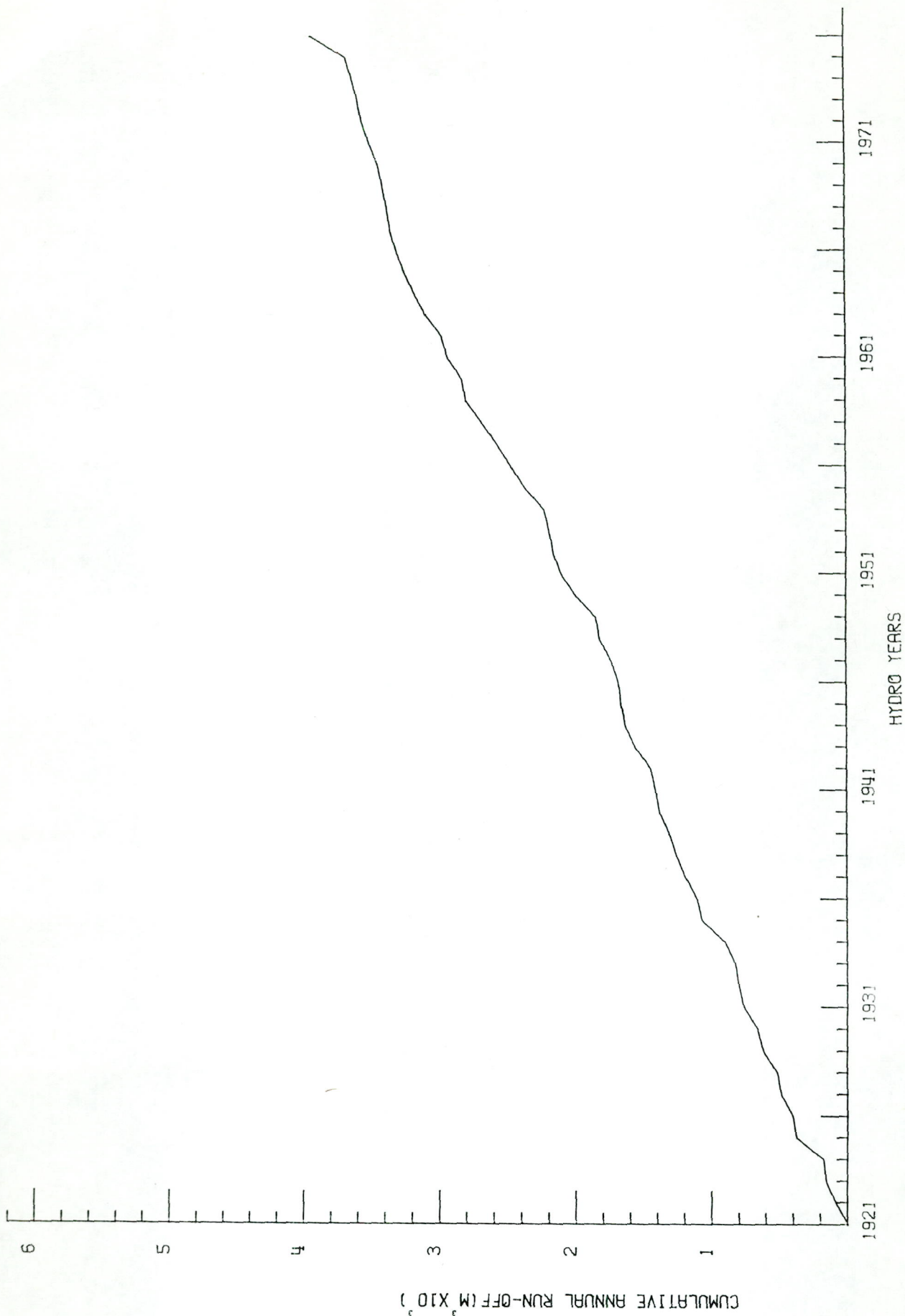
TRACED : COMPILOT CHECKED : DATE : REF. :	NATAL ESTUARIES : MTWALUME SIMULATED ANNUAL RUN-OFF 1921-1975	FIGURE NS 32/3
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY		



TRACED : COMPLETE  
 CHECKED :  
 DATE :  
 REF :

NATAL ESTUARIES : MTHALUME  
 SIMULATED MONTHLY RUN-OFF  
 1921-1975

FIGURE  
 NS 32/4



TRACED : COM PLOT  
 CHECKED:  
 DATE :  
 REF. :

NATAL ESTUARIES: MTWALUME  
 CUMULATIVE ANNUAL RUN-OFF

FIGURE  
 NS 32/5



SCALE: 1:14 000 approx

TRACED JGAN  
CHECKED:  
DATE:  
REF

NATAL ESTUARIES: MTWALUME  
6-7-76 (13h58)  
30-4-37 RIVER COURSE SUPERIMPOSED

PHOTOGRAPH  
NS 32/1

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY



SCALE 1:14 000 approx

TRACED JGAN  
CHECKED  
DATE  
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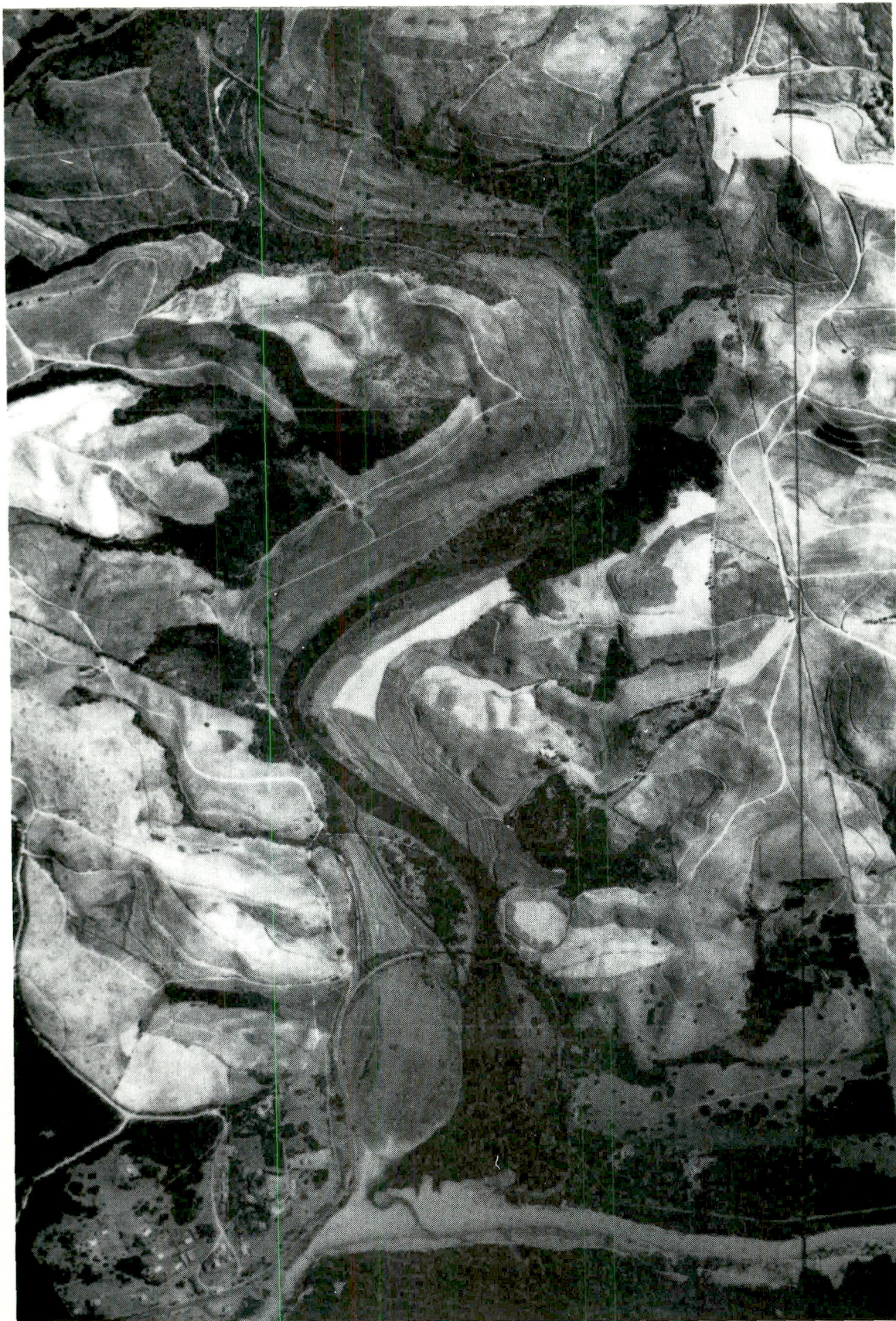
NATAL ESTUARIES MTWALUME

30-4-37 (12h20)

PHOTOGRAPH

NS 32/2

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SCALE: 1:14 000 approx

TRACED JGAN  
CHECKED  
DATE  
REF

NATAL ESTUARIES: MTWALUME

JUN / JUL 1955 (11h30)

PHOTOGRAPH

NS 32/3



SCALE 1:14 000 approx

TRACED JGAN  
CHECKED  
DATE  
REF

NATAL ESTUARIES : MTHALUME

6-6-59 (13h07)

PHOTOGRAPH

NS 32/4

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY



SCALE: 1 : 14 000 approx.

TRACED JGAN  
CHECKED  
DATE:  
REF

NATAL ESTUARIES : MTWALUME

17-6-67 (13h25)

PHOTOGRAPH

NS 32/5

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SCALE: 1 : 14 000 approx

TRACED JGAN  
CHECKED  
DATE  
REF

NATAL ESTUARIES : MTWALUME  
23-6-69 (10h18)

PHOTOGRAPH  
NS 32/6

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SCALE 1:14 000 approx

TRACED JGAN  
CHECKED  
DATE  
REF

NATAL ESTUARIES MTWALUME

6-7-76 (ORTHOPHOTO)

PHOTOGRAPH

NS 32/7

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