CONFIDENTIAL

HYDROLOGICAL/HYDRAULIC STUDY OF NATAL ESTUARIES

FORTY SECOND STEERING COMMITTEE MEETING MARINE DISPOSAL OF EFFLUENTS AND ESTUARINE INVESTIGATION COMMITTEE

PROGRESS REPORT NO. 5

Zinkwasi estuary

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

NRIO MEMORANDUM 8115

Stellenbosch, South Africa
March 1981

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FOREWORD

The aim of the study to be done over a five year period, is to obtain an understanding of the normal long-term functioning of the lagoon/estuary systems in Natal. The study will be done in three phases:

(i) the assessment of the available data and the needs of the sponsor;

(ii) the classification of the estuaries; and

(iii) the examination of specific problems in selected estuaries.

A Memorandum of Agreement between the Town and Regional Planning Commission, Natal and the CSIR for this hydrological/hydraulic study of Natal estuaries was signed by all parties concerned on 29 January 1979.

This report is one of a series of progress reports to the sponsor and was prepared by Mrs. J. Perry under the supervision of Dr. H. Swart of the Coastal Engineering and Hydraulics Division of NRIO.

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NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
COASTAL ENGINEERING AND HYDRAULICS DIVISION

NATAL ESTUARIES
PROGRESS REPORT NO. 5

1. GENERAL

Progress Report No. 5 is concerned with the Zinkwasi estuary (Reference NN 10) on the north coast of Natal. The study is part of phase two as outlined in clause 3(ii) of the Memorandum of Agreement between the Town and Regional Planning Commission, Natal and the CSIR, namely, '*The Classification of the Estuaries*'.

2. BASIC DATA

Contact prints of aerial photographs, on various scales, for the reach from the Tugela road bridge crossing to the mouth of the Zinkwasi taken on the following dates were available: 5 May 1937, September/October 1953, 6 June 1959, 3 May 1964, 21 August 1967 and 14 May 1976. A map (scale 1:5 000) from a survey on 11 March 1974 was also available. The basis used for scaling purposes was the orthophoto taken on 3 June 1973 (scale 1:10 000).

Additional data were available for the Zinkwasi estuary because since December 1976, the Zinkwasi Beach Health Committee (ZBHC) has been taking water level and rainfall readings. The position of the gauge plate and rain gauge are shown in the sketch map in Figure 1. ZBHC has also, since December 1976, kept a record of periods during which the Zinkwasi mouth was open to the sea. Huletts Sugar (Pty) Ltd. undertook a survey of the river mouth in June/July 1979; the detailed rock and sand contours are shown in Figure 2.

3. METHOD OF APPROACH

The method of study by tabular classification as previously evolved, was followed. Contact prints of the aerial photographs and the map were photographed and reprinted to obtain the best possible fit with the 1:10 000 orthophoto. All measurements of the area, river lengths and lateral displacement were made on a scale of 1:10 000. Three of the photographs used are reproduced in this report for comparison purposes, namely, those for 1937 (Photograph 1), 1959 (Photograph 2) and 1976 (Photograph 3). The orthophoto from 1973 is given in Photograph 4.

The basic tabular classification forms are given in Tables I to VIII. Table IX shows the river widths and Table X the lateral stability. Figures 11 to 18 show the river courses for the eight years under review on a reduced scale of 1:15 000 and an overlay of the envelope of mobility derived for the same period is shown in Figure 20 at the end of this report. A graph showing the thalweg displacement from 1937 to 1976 is given in Figure 19.

The water levels recorded by the ZBHC were in centimetres as read from their gauge plate which is marked in 5 cm intervals. The gauge zero was related to MSL (by Hulett's surveyor) and graphs of the water levels, reduced to MSL, are shown in Figures 3, 4, 5 and 6. The present gauge plate is very securely fixed but does not cover the full range of water levels; a gauge plate in use initially and to the same zero was even shorter. Rainfall, for the same period, was measured daily in inches at 08h00 and sometimes additional readings were taken at 14h00. These measurements were metricated and are shown with the water levels in Figures 3, 4, 5 and 6. The standard procedure of using the hydro-year (that is, from October to September) was followed. Monthly rainfall totals are given in Figures 7 to 10. On Figures 3 to 10 inclusive, a note has been made of when the Zinkwasi lagoon was open to the sea.

4. DISCUSSION OF RESULTS

(i) An abstract of results is given in Table XI.

(ii) The sinuosity range was low as was the lateral displacement. However, this 'apparent stability' is not the key factor representing natural and/or man-made influences over the period under review for an estuary such as the Zinkwasi which is closed to the sea for the greater part of the year.

(iii) The average width of the river/lagoon has gradually decreased from 93 m to 72 m. Deposition of soil in the river bed is shown clearly in the area marked A on Photographs 1 to 3. This was largely the result of a heavy storm in May 1959 which occurred soon after the lands had been ploughed.

An example of the gradual increase in the area of channel junction bars is shown in position B on Photographs 1 to 3.

(iv) In the area marked C on Photographs 1 to 3 the water depth as noted by long-standing local residents, has decreased from approximately 6 m to less than 1 m since the early 1930's.

(v) The reasons for (iii) and (iv) above are to be found in the decrease of riverine vegetation (of photographs 1 and 2) and the increase in lands bordering the flood plain cultivated with sugar cane (see 6 and 7 of Table XI). As the total area of riverine vegetation decreased from 17 ha to 2 ha, so the percentage swamp area in the flood plain has increased from 13 to 36 per cent.

(vi) The lagoon is closed to the sea for the greater part of the year. The direction of the sand-spit/sandbar remains constant (195°), as the result of marine rather than fluvial influences. Although the gauge plate does not cover the full range of water levels, the lagoon either breaches naturally or is breached artificially soon after the gauge plate is overtopped. This level is approximately +1,15 m to MSL.

The lagoon opens naturally at the southern end of the sandbar where the lowest level of the rock sill is of the order of -1,7 to -1,9 m below MSL (see Figure 2). Figure 2 shows a typical position at the Zinkwasi mouth, as viewed by the writer in September 1980. The river level is +0,39 m to

MSL, dammed behind a sand bar where the lowest level towards the south is in the form of a dry channel approximately +1 m to MSL. The main part of the sand bar is just over 2 m to MSL. If the bar is breached artificially, this is done by cutting a narrow channel about 1 m deep in the centre of the bar. The request for this action may be because of

a. health hazards arising from organic pollution
b. flooding of property or
c. flooding of cane fields.

The cane fields effected by flooding are situated both in and upstream of the reach examined in this study.

(vii) No comment will be made in this report on the rainfall patterns or totals as the recording period is too short.

5. CONCLUSIONS

(1) The deterioration of the Zinkwasi estuary/lagoon because of siltation appears to be a direct result of the destruction of riverine vegetation and the earlier bad farming practice of cultivation too near the water's edge, both in the reach under consideration and further upstream. Since the early 1960's, the ZBHC has been very active in its efforts to try to remedy the situation.

(2) Key factors therefore in the classification of this estuary, with its long periods of closure to the sea are

a. decrease in riverine vegetation
b. narrowing of the channel
c. increase in area of channel junction bars and
d. increase in swamp areas

all of which are inter-related.

(3) By keeping of accurate daily water-level and rainfall records and with the knowledge of rock levels at the mouth - all levels related to MSL - it should be possible to devise a suitable regulation programme for the opening of the lagoon to the sea bearing in mind health factors and the flooding of property and/or crops.

6. IMMEDIATE FUTURE PROGRAMME

(1) The next estuaries to be studied will be those under special consideration by Mr. Begg, namely; Siyai, Mahlongwa, Msimbasi, Mdloti, Manzimtoti, Mgeni, Mkomazi and Tongati.

(2) The first meeting of the Hydraulic/Hydrological Subcommittee has been called for Wednesday, 22 April 1981 at 14h00 in the offices of NRIO. This will be chaired by Mr. Pistorius and Messrs. Alexander and Hands, Prof. Rooseboom, Dr. Swart and Mrs. Perry will attend. A detailed appraisal of the method of study to date will take place in the light of the needs of the sponsor and the future programme. The need for water-level stations and general hydrological data such as catchment area rainfall will also be raised.

TABLE I

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

RIVER ZINKWASI REF. NN10 REACH from Tugela Road Br to Mouth, 2,5 km from mouth 100 % ESTUARINE

AERIAL PHOTO DATE 5-5-37 SCALE 1:10 000 CATCHMENT AREA 73* km² DAMS IN CATCHMENT NONE

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	Vegetation	Forest Type	Land Use
mountainous	almost none	not ~~applicable~~/known	none
hilly	✓grass	deciduous	scattered cultivation
✓undulating plains	sparsely forested (0-25%)	coniferous	✓partly cultivated → L. Flood Plain 69% R. " " 22%
	moderately forested (25-75%)		mainly cultivated
	heavily forested (75-100%)		✓scattered settlement
	swamp/bog		partly built-up
			urbanised

Comments * Average (Begg)

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 2220 m	✓none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) 260 m	indefinite	not obviously degrading	✓occasionally confined	lacustrine deposits
valley slope 1: 736 (straight-line)	fragmentary	partly entrenched	frequently confined	✓fluvial deposits
	continuous	entrenched	entrenched	aeolian
height at head of reach +2,5 m to MSL*		✓aggrading		sand covered ____ % area

Comments * estimate

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	✓sandspit: direction of growth	195	°
outer bar	length of ~~spit~~bar	280	m
silt plume (fluvial)	length stabilized	NIL	m
✓suspended sediment (marine)	width	50	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
indefinite	average width 260 m	✓grass	deciduous	cultivated NIL % area
fragmentary	maximum width 530 m	✓reed swamp 13 % area	coniferous	✓not built-up
✓continuous	aerial length 840 m	✓sparsely forested	✓riparian	partly built-up
	area 55 ha*	moderately forested	✓coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Comments * geomorph. flood plain 80 ha.

Channel Description

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

Pattern	Measurements	Islands/~~Sandbanks~~	Type of Flow	Bar Type
straight	meander belt width ____ m	✓none *	stagnant/still	none
sinuous	meander wave length ____ m	occasional	✓uniform water surface	✓channel side bars
✓irregular	sinuosity (whole reach) 1,47	frequent	uniform with rapid in reach	point bars
regular meanders	thalweg 2700 m	split	irregular	✓channel junction bars
irregular meanders	lake/lagoon area ____ ha	braided	pool & riffle sequence	mid-channel bars
tortuous meanders	inundated			diamond bars
bifurcated	channel slope $\bar{x}$ ____			diagonal bars
lake/s	channel width $\bar{x}$ ____ m s = ____ m			sand waves/large dunes
lagoon	river slope $\bar{x}$			
	river width $\bar{x}$ 93,3 m s = 47,8 m			

Comments * formerly one.

Obstructions/Constructions

Natural	Degree
✓none	✓none
logs	minor
boulders	major
vegetation	

Comments ____

Man-made	Degree of Obstruction/Construction for Each
road bridge/s	1 at head of reach. R. continues
rail bridge/s	
causeway	
weir/dam	
fish traps	
embankment/s	
groynes	
canals	
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 25 %	
✓irregular lateral activity		right bank 36 %	
avulsion			

Comments ____

TABLE II

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

RIVER ZINKWASI REF. NN 10 REACH from Tugela Road Br. to Mouth, 2,5 km from mouth 100 % ESTUARINE

AERIAL PHOTO DATE Sept/Oct'53 SCALE 1: 10 000 CATCHMENT AREA 73* km² DAMS IN CATCHMENT NONE

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	*Vegetation*	*Forest Type*	*Land Use*
mountainous	almost none	not applicable/known	none
hilly	✓grass	deciduous	scattered cultivation
✓undulating	✓sparsely forested (0-25%)	coniferous	partly cultivated
plains	moderately forested (25-75%)		✓mainly cultivated → L. Flood Plain 88% R. " " 63%
	heavily forested (75-100%)		✓scattered settlement
	swamp/bog		partly built-up
			urbanised

Comments *Average (Begg)

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 2220 m	✓none	not applicable	not applicable (no valley or free)	bedrock
bottom width(av.) 260 m	indefinite	not obviously degrading	✓occasionally confined	lacustrine deposits
valley slope 1:736	fragmentary	partly entrenched	frequently confined	✓fluvial deposits
(straight-line)	continuous	entrenched	entrenched	aeolian
height at head		✓aggrading		sand covered NIL % area
of reach +2,5 m to MSL*				

Comments * estimate

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	sandspit: direction of growth	195°
outer bar	~~epi~~bar length	280 m
silt plume (fluvial)	length stabilized	NIL m
✓suspended sediment (marine)	width	50 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
indefinite	average width 260 m	✓grass	deciduous	cultivated NIL % area
fragmentary	maximum width 530 m	✓reed swamp 27 % area	coniferous	✓not built-up
✓continuous	aerial length 640 m	✓sparsely forested	✓riparian	partly built-up
	area 55 ha*	moderately forested	✓coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Comments * geomorph. flood plain 80 ha

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

Pattern	*Measurements*	*Islands/Shoals*	*Type of Flow*	*Bar Type*
straight	meander belt width ____ m	✓none *	stagnant/still	none
sinuous	meander wave length ____ m	occasional	✓uniform water surface	✓channel side bars
✓irregular	sinuosity(whole reach) 1,52	frequent	uniform with rapid in reach	point bars
regular meanders	thalweg 2500 m	split	irregular	✓channel junction bars
irregular meanders	lake/lagoon area ____ ha	braided	pool & riffle sequence	mid-channel bars
tortuous meanders	inundated			diamond bars
bifurcated	channel slope			diagonal bars
lake/s	channel width $\bar{x}$ ____ m s = ____ m			sand waves/large dunes
lagoon	river slope			
	river width $\bar{x}$ 83,6 m s = 55,1 m			

Comments * Currently one

Obstructions/Constructions

Natural	*Degree*	*Man-made*	*Degree of Obstruction/Construction for Each*
✓none	✓none	road bridge/s	1 at head of reach. R. confined
logs	minor	rail bridge/s	
boulders	major	causeway	
vegetation		weir/dam	
		fish traps	
		embankment/s	
		groynes	
		canals	
		others	

Comments

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 22 %	
✓irregular lateral activity	channel edge	right bank 32 %	
avulsion			

Comments

TABLE III

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

RIVER ZINKWASI REF. NN 10 REACH from Tugela Road Br to Mouth. 2,5 km from mouth 100 % ESTUARINE

AERIAL PHOTO DATE 6-6-59 SCALE 1: 10 000 CATCHMENT AREA 73* km² DAMS IN CATCHMENT NONE

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	Vegetation	Forest Type	Land Use
mountainous	almost none	not ~~applicable~~/known	none
hilly	✓grass	deciduous	scattered cultivation
✓undulating plains	✓sparsely forested (0-25%)	coniferous	partly cultivated
	moderately forested (25-75%)		✓mainly cultivated → L. Flood Plain 89% R. Flood Plain 82%
	heavily forested (75-100%)		scattered settlement
	swamp/bog		✓partly built-up
			urbanised

Comments * Average (Begg)

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 2220 m	✓none	not applicable	not applicable (no valley or free)	bedrock
bottom width(av.) 260 m	indefinite	not obviously degrading	✓occasionally confined	lacustrine deposits
valley slope 1:136 (straight-line)	fragmentary	partly entrenched	frequently confined	✓fluvial deposits
	continuous	entrenched	entrenched	aeolian
height at head of reach 2,5 m to MSL *		✓aggrading		sand covered NIL % area

Comments * estimate.

River Mouth

Characteristics	Measurements	
open/~~almost~~	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	sandspit: direction of growth	195°
outer bar	length of spit	200 m
✓silt plume (fluvial)	length stabilized	NIL m
suspended sediment (marine)	width	50 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
indefinite	average width 260 m	✓grass	deciduous	cultivated 12 % area **
fragmentary	maximum width 530 m	✓reed swamp 27 % area	coniferous	✓not built-up
✓continuous	aerial length 1780 m	✓sparsely forested	✓riparian	partly built-up
	area 55 ha*	moderately forested	✓coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Comments * geomorph. flood plain 80 ha
** on Fomat Island

Channel Description

N.B. Estimate of flow stage: ~~LOW/MEDIUM/HIGH~~/HIGH

Pattern	Measurements	Islands/Shoals	Type of Flow	Bar Type
straight	meander belt width ___ m	✓none	stagnant/still	none
sinuous	meander wave length ___ m	occasional	✓uniform water surface	✓channel side bars
irregular	sinuosity(whole reach) 1,49	frequent	uniform with rapid in reach	point bars
regular meanders	thalweg 2650 m	split	irregular	✓channel junction bars
✓irregular meanders	lake/lagoon area ___ ha	braided	pool & riffle sequence	mid-channel bars
tortuous meanders	inundated			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 82,8 m s = 47,2 m			

Comments * formerly one

Obstructions/Constructions

Natural	Degree	Man-made	Degree of Obstruction/Construction for Each
✓none	✓none	road bridge/s	1 at head of reach. R. confined
logs	minor	rail bridge/s	
boulders	major	causeway	
vegetation		weir/dam	
		fish traps	
		embankment/s	
		groynes	
		canals	
		others	

Comments ___

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 22 %	
✓irregular lateral activity	channel edge	right bank 31 %	
avulsion			

Comments ___

TABLE IV

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

RIVER ZINKWASI REF. NN 10 REACH from Tugela Road Br to Mouth. 2,5 km from mouth 100 % ESTUARINE

AERIAL PHOTO DATE 3-5-64 SCALE 1:10 000 CATCHMENT AREA 73* km² DAMS IN CATCHMENT NONE

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	*Vegetation*	*Forest Type*	*Land Use*
mountainous	✓almost none	not ~~applicable~~/known	none
hilly	grass	deciduous	scattered cultivation
✓undulating plains	✓sparsely forested (0-25%)	coniferous	partly cultivated
	moderately forested (25-75%)		✓mainly cultivated → L. Flood Plain 89% R. Flood Plain 82%
	heavily forested (75-100%)		scattered settlement
	swamp/bog		✓partly built-up urbanised

Comments *Average (Begg)

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 2220 m	✓none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) 260m	indefinite	not obviously degrading	occasionally confined	lacustrine deposits
valley slope 1:736 (straight-line)	fragmentary	partly entrenched	frequently confined	✓fluvial deposits
height at head of reach +2,5 m to MSL*	continuous	entrenched	entrenched	aeolian
		✓aggrading		sand covered NIL % area

Comments * estimate

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	sandspit: direction of growth	195°	
outer bar	length of ~~spit~~bar	280	m
silt plume (fluvial)	length stabilized	NIL	m
✓suspended sediment (marine)	width	50	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
indefinite	average width 260 m	✓grass	deciduous	cultivated NIL % area
fragmentary	maximum width 530 m	✓reed swamp 27 % area	coniferous	✓not built-up
✓continuous	aerial length 1795 m	✓sparsely forested	✓riparian	partly built-up
	area 55 ha*	moderately forested	✓coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Comments * geomorph flood plain 80 ha.

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

Pattern	*Measurements*		*Islands/Shoals*	*Type of Flow*	*Bar Type*
straight	meander belt width	____ m	✓none *	stagnant/still	none
sinuous	meander wave length	____ m	occasional	✓uniform water surface	✓channel side bars
irregular	sinuosity (whole reach)	1,47	frequent	uniform with rapid in reach	point bars
regular meanders	thalweg	2600 m	split	irregular	✓channel junction bars
✓irregular meanders	lake/lagoon area	____ ha	braided	pool & riffle sequence	mid-channel bars
tortuous meanders	inundated				diamond bars
bifurcated	channel slope	____			diagonal bars
lake/s	channel width $\bar{x}$	____ m s = ____ m			sand waves/large dunes
lagoon	river slope	____			
	river width $\bar{x}$	78,1 m s = 45,6 m			

Comments * formerly one

Obstructions/Constructions

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

Comments ____

Man-made	*Degree of Obstruction/Construction for Each*
road bridge/s	1 at head of reach. R. confined
rail bridge/s	
causeway	
weir/dam	
fish traps	
embankment/s	
groynes	
canals	
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 16 %	
✓irregular lateral activity		right bank 19 %	
avulsion			

Comments ____

TABLE V

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

RIVER ZINKWASI REF. NN 10 REACH from Tugela Road Bl to Mouth, 2,5 km from mouth 100 % ESTUARINE

AERIAL PHOTO DATE 21-8-67 SCALE 1:10 000 CATCHMENT AREA 73 km² DAMS IN CATCHMENT NONE

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain
- mountainous
- hilly
- ✓ undulating plains

Vegetation
- ✓ almost none
- grass
- ✓ sparsely forested (0-25%)
- moderately forested (25-75%)
- heavily forested (75-100%)
- swamp/bog

Forest Type
- not ~~applicable~~/known
- deciduous
- coniferous

Land Use
- none
- scattered cultivation
- partly cultivated
- ✓ mainly cultivated → L. Flood Plain 89%, R. Flood Plain 82%
- scattered settlement
- ✓ partly built-up
- urbanised

Comments * Average (Begg)

Valley Characteristics

Measurements
- valley length 2220 m
- bottom width (av.) 260 m
- valley slope 1:736 (straight-line)
- height at head of reach +2,5 m to MSL *

Terraces
- ✓ none
- indefinite
- fragmentary
- continuous

Relation of Channel to Valley Bottom (Vertical)
- not applicable
- not obviously degrading
- partly entrenched
- entrenched
- ✓ aggrading

Relation of Channel to Valley Sides or Resistant Terraces (Lateral)
- not applicable (no valley or free)
- ✓ occasionally confined
- frequently confined
- entrenched

Surface Geology
- bedrock
- lacustrine deposits
- ✓ fluvial deposits
- aeolian
- sand covered NIL % area

Comments * estimate

River Mouth

Characteristics
- ~~open~~/closed
- natural/~~artificial~~
- canalized
- sandy
- ✓ rocks on right bank
- rocks on left bank
- outer bar
- silt plume (fluvial)
- ✓ suspended sediment (marine)

Measurements
- right bank breakwater length ____ m
- left bank breakwater length ____ m
- ✓ rock sill level ____ m to MSL
- cliffs on right bank: height ____ m to MSL
- cliffs on left bank: height ____ m to MSL
- sandspit: direction of growth 195°
- length of spit 280 m
- length stabilized NIL m
- width 50 m

Comments

FLOOD PLAIN AND CHANNEL FEATURES

Description of Flood Plain

Presence
- none
- indefinite
- fragmentary
- ✓ continuous

Extent
- none
- average width 260 m
- maximum width 530 m
- aerial length 1840 m
- area 55 ha *

Vegetation
- almost none
- ✓ grass
- ✓ reed swamp 29 % area
- ✓ sparsely forested
- moderately forested
- heavily forested

Forest Type
- not known/~~applicable~~
- deciduous
- coniferous
- ✓ riparian
- ✓ coastal dune/evergreen
- mangroves

Land Use
- not cultivated
- cultivated NIL % area
- ✓ not built-up
- partly built-up
- mainly built-up

Comments * geomorph. flood plain 80 ha

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

Pattern
- straight
- sinuous
- irregular
- regular meanders
- ✓ irregular meanders
- tortuous meanders
- bifurcated
- lake/s
- lagoon

Measurements
- meander belt width ____ m
- meander wave length ____ m
- sinuosity (whole reach) 1,48
- thalweg 2680 m
- lake/lagoon area inundated ____ ha
- channel slope ____
- channel width x̄ ____ m s = ____ m
- river slope ____
- river width x̄ 78,2 m s = 46,7 m

Islands/Shoals
- ✓ none *
- occasional
- frequent
- split
- braided

Type of Flow
- stagnant/still
- ✓ uniform water surface
- uniform with rapid in reach
- irregular
- pool & riffle sequence

Bar Type
- none
- ✓ channel side bars
- point bars
- ✓ channel junction bars
- mid-channel bars
- diamond bars
- diagonal bars
- sand waves/large dunes

Comments * formerly one

Obstructions/Constructions

Natural ____ *Degree*
- ✓ none
- logs
- boulders
- vegetation

Degree
- ✓ none
- minor
- major

Comments

Man-made ____ *Degree of Obstruction/Construction for Each*
- road bridge/s 1 at head of reach. R. confined
- rail bridge/s
- causeway
- weir/dam
- fish traps
- embankment/s
- groynes
- canals
- others

Lateral Channel Activity

Lateral Activity
- not detectable
- downstream progression
- progression & cut-offs
- mainly cut-offs
- entrenched loop development
- ✓ irregular lateral activity
- avulsion

Nature of Banks
- ✓ alluvium (silt/sand)
- natural levées
- rock/boulders
- protected/stabilized
- cultivation to channel edge

Bank Vegetation
- none
- ✓ weak
- good
- very strong
- left bank 15 %
- right bank 17 %

Lateral Stability
- ✓ stable
- slightly unstable
- moderately unstable
- highly unstable

Comments

TABLE VI

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

RIVER ZINKWASI REF. NN 10 REACH from Tugela Road Br to Mouth, 2,5 km from mouth 100 % ESTUARINE

AERIAL PHOTO DATE 3-6-73 SCALE 1:10 000 CATCHMENT AREA 73* km² DAMS IN CATCHMENT NONE
orthophoto

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	Vegetation	Forest Type	Land Use
mountainous	✓almost none	not ~~applicable~~/known	none
hilly	grass	deciduous	scattered cultivation
✓undulating plains	✓sparsely forested (0-25%)	coniferous	partly cultivated
	moderately forested (25-75%)		✓mainly cultivated → L. Flood Plain 89%b
	heavily forested (75-100%)		scattered settlement R. Flood Plain 82%b
	swamp/bog		✓partly built-up
			urbanised

Comments * Average (Reach)

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 2220 m	✓none	not applicable	not applicable (no valley or free)	bedrock
bottom width(av.) 260 m	indefinite	not obviously degrading	✓occasionally confined	lacustrine deposits
valley slope 1:736	fragmentary	partly entrenched	frequently confined	✓fluvial deposits
(straight-line)	continuous	entrenched	entrenched	aeolian
height at head of reach +2,5 m to MSL *		✓aggrading		sand covered ____ % area

Comments * estimate

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	sandspit: direction of growth	195	°
outer bar	length of spit	280	m
silt plume (fluvial)	length stabilized	NIL	m
✓suspended sediment (marine)	width	50	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
indefinite	average width 260 m	✓grass	deciduous	cultivated NIL % area
fragmentary	maximum width 530 m	✓reed swamp 29 % area	coniferous	✓not built-up
✓continuous	aerial length 1805 m	✓sparsely forested	riparian	partly built-up
	area 55 ha*	moderately forested	coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Comments * geomorph flood plain 80ha

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

Pattern	Measurements		Islands/Shoals	Type of Flow	Bar Type
straight	meander belt width	____ m	✓none *	stagnant/still	none
sinuous	meander wave length	____ m	occasional	✓uniform water surface	✓channel side bars
irregular	sinuosity(whole reach)	1,50	frequent	uniform with rapid in reach	point bars
regular meanders	thalweg	2706 m	split	irregular	✓channel junction bars
✓irregular meanders	lake/lagoon area inundated	____ ha	braided	pool & riffle sequence	mid-channel bars
tortuous meanders	channel slope	____			diamond bars
bifurcated	channel width $\bar{x}$	____ m s = ____ m			diagonal bars
lake/s	river slope	____			sand waves/large dunes
lagoon	river width $\bar{x}$	74,3 m s = 43,3 m			

Comments * formerly one

Obstructions/Constructions

Natural	Degree
✓none	✓none
logs	minor
boulders	major
vegetation	

Comments ____

Man-made	Degree of Obstruction/Construction for Each
road bridge/s	1 at head of reach. R. Confined
rail bridge/s	
causeway	
weir/dam	
fish traps	
embankment/s	
groynes	
canals	
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 15 %	
✓irregular lateral activity		right bank 22 %	
avulsion			

Comments ____

TABLE VII

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

RIVER ZINKWASI REF. NN 10 REACH from Tugela Road Br to Mouth, 2,5 km from mouth 100 % ESTUARINE

~~AERIAL PHOTO~~ MAP DATE 11-3-74 SCALE 1:5 000 CATCHMENT AREA 73 km² DAMS IN CATCHMENT NONE

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	*Vegetation*	*Forest Type*	*Land Use*
mountainous	almost none	not ~~applicable~~/known	none
hilly	grass	deciduous	scattered cultivation
✓ undulating	sparsely forested (0-25%)	coniferous	partly cultivated
plains	moderately forested (25-75%)		✓ mainly cultivated
	heavily forested (75-100%)		scattered settlement
	swamp/bog		✓ partly built-up
			urbanised

Comments * Average (Reag)

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 2220 m	none	not applicable	not applicable (no valley or free)	bedrock
bottom width (av.) 260 m	indefinite	not obviously degrading	✓ occasionally confined	lacustrine deposits
valley slope 1:736	fragmentary	partly entrenched	frequently confined	fluvial deposits
(straight-line)	continuous	entrenched	entrenched	aeolian
height at head		aggrading		sand covered ____ % area
of reach +2,5 m to MSL *				

Comments * estimate

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	sandspit: direction of growth	1950
outer bar	length of spit	280 m
silt plume (fluvial)	length stabilised	Nil m
suspended sediment (marine)	width	40 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
indefinite	average width 260 m	grass	deciduous	cultivated ____ % area
fragmentary	maximum width 530 m	reed swamp ____ % area	coniferous	✓ not built-up
✓ continuous	aerial length 1770 m	sparsely forested	riparian	partly built-up
	area 55 ha *	moderately forested	coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Comments * geomorph. flood plain 80 ha

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

Pattern	*Measurements*	*Islands/Shoals*	*Type of Flow*	*Bar Type*
straight	meander belt width ____ m	✓ none *	stagnant/still	none
sinuous	meander wave length ____ m	occasional	uniform water surface	channel side bars
irregular	sinuosity (whole reach) 1,53	frequent	uniform with rapid in reach	point bars
regular meanders	thalweg 2700 m	split	irregular	✓ channel junction bars
✓ irregular meanders	lake/lagoon area ____ ha	braided	pool & riffle sequence	mid-channel bars
tortuous meanders	inundated			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 79,2 m s = 47,8 m			

Comments * one formerly

Obstructions/Constructions

Natural	*Degree*	*Man-made*	*Degree of Obstruction/Construction for Each*
✓ none	✓ none	road bridge/s	1 at head of reach. R. confined
logs	minor	rail bridge/s	
boulders	major	causeway	
vegetation		weir/dam	
		fish traps	
		embankment/s	
		groynes	
		canals	
		others	

Comments ____

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 ____ %	
✓ irregular lateral activity	channel edge	right bank ____ %	
avulsion			

Comments ____

TABLE VIII

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

RIVER ZINKWASI REF. NN 10 REACH from Tugela Road Br to Mouth, 2,5 km from mouth 100 % ESTUARINE

AERIAL PHOTO DATE 14-5-76 SCALE 1:10 000 CATCHMENT AREA 73 km² DAMS IN CATCHMENT NONE

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain	*Vegetation*	*Forest Type*	*Land Use*
mountainous	✓almost none	not ~~applicable~~/known	none
hilly	grass	deciduous	scattered cultivation
✓undulating	✓sparsely forested (0-25%)	coniferous	partly cultivated
plains	moderately forested (25-75%)		✓mainly cultivated → L. Floodplain 89% R. Floodplain 82%
	heavily forested (75-100%)		scattered settlement
	swamp/bog		✓partly built-up
			urbanised

Comments * Average (Begg)

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 2220 m	✓none	not applicable	not applicable (no valley or free)	bedrock
bottom width(av.) 260 m	indefinite	not obviously degrading	✓occasionally confined	lacustrine deposits
valley slope 1:136 (straight-line)	fragmentary	partly entrenched	frequently confined	✓fluvial deposits
height at head of reach +2,5 m to MSL	continuous	entrenched	entrenched	aeolian
		✓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	sandspit: direction of growth	195°
outer bar	length of spit	280 m
silt plume (fluvial)	length stabilized	NIL m
✓suspended sediment (marine)	width	50 m

Comments * from -0,31 to -1,71 m to MSL according to June 1979 survey

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
indefinite	average width 260 m	grass	deciduous	cultivated NIL % area
fragmentary	maximum width 530 m	reed swamp 36 % area	coniferous	✓not built-up
✓continuous	aerial length 1740 m	sparsely forested	riparian	partly built-up
	area 55 ha*	moderately forested	coastal dune/evergreen	mainly built-up
		heavily forested	mangroves	

Comments * geomorph floodplain 80 ha

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

Pattern	*Measurements*	*Islands/Shoals*	*Type of Flow*	*Bar Type*
straight	meander belt width ____ m	✓none *	stagnant/still	none
sinuous	meander wave length ____ m	occasional	✓uniform water surface	✓channel side bars
irregular	sinuosity(whole reach) 1,50	frequent	uniform with rapid in reach	point bars
regular meanders	thalweg 2610 m	split	irregular	✓channel junction bars
✓irregular meanders	lake/lagoon area ____ ha	braided	pool & riffle sequence	mid-channel bars
tortuous meanders	inundated			diamond bars
bifurcated	channel slope ____			diagonal bars
lake/s	channel width x ____ m s = ____ m			sand waves/large dune
lagoon	river slope ____			
	river width x 72,1 m s = 51,0 m			

Comments * formerly one

Obstructions/Constructions

Natural	*Degree*	*Man-made*	*Degree of Obstruction/Construction for Each*
✓none	✓none	road bridge/s	1 at head of reach. R. confined
logs	minor	rail bridge/s	
boulders	major	causeway	
vegetation		weir/dam	
		fish traps	
		embankment/s	
		groynes	
		canals	
		others	

Comments

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 16 %	
✓irregular lateral activity		right bank 30 %	
avulsion			

Comments

TABLE IX: RIVER WIDTHS (in metres)

Station	Distance along mid-channel from Tugela Road Bridge (m)	DATE								$\bar{x}$	s	v%
		5.5.37	Sept/Oct '53	6.6.59	3.5.64	21.8.67	3.6.73 (orthophoto)	11.3.74 (map)	14.5.76			
1	0	43,0	41,0	40,0	40,0	41,0	41,0	41,0	40,0	40,9	1,0	2,4
2	278	45,0	36,0	38,0	42,0	40,0	35,0	34,5	37,0	38,4	3,7	9,5
3	556	99,0	80,0	68,0	68,0	68,0	69,0	67,5	62,0	72,7	11,8	16,2
4	834	60,0	60,0	58,0	49,0	50,0	56,0	56,0	45,0	54,3	5,6	10,3
5	1 112	94,0	80,0	67,0	50,0	50,0	50,0	52,5	50,0	61,7	17,1	27,7
6	1 390	88,0	90,0	70,0	70,0	72,0	72,0	65,5	62,0	73,7	10,1	13,6
7	1 668	129,0	124,0	119,0	110,0	110,0	105,0	107,5	110,0	114,3	8,6	7,5
8	1 946	135,0	135,0	125,0	122,0	120,0	120,0	122,5	122,0	125,2	6,3	5,0
9	2 224	191,0	190,0	188,0	180,0	185,0	165,0	190,0	182,0	183,9	8,6	4,7
10	2 502	49,0	0	55,0	50,0	46,0	30,0	55,0	11,0	37,6	21,7	57,6
	$\bar{x}$	93,3	83,6	82,8	78,1	78,2	74,3	79,2	72,1	80,2		
	s	47,8	55,1	47,2	45,6	46,9	43,3	47,8	51,0			
	v%	51,2	65,9	57,0	58,3	60,0	58,2	60,4	70,8			

where $\bar{x}$ = the arithmetic mean

s = the standard deviation and

v = the coefficient of variation $\frac{s}{\bar{x}}$

TABLE X: LATERAL STABILITY

Station	Distance along mid-channel from Tugela Road Bridge (m)	Distance from maximum observed L.B. position to mid-channel (in metres) DATE								$\bar{x}$	s	v%	Max-Min
		5.5.37	Sept/Oct '53	6.6.59	3.5.64	21.8.67	3.6.73 (orthophoto)	11.3.74 (map)	14.5.76				
1		21,5	20,5	20,0	20,0	21,0	20,5	20,5	20,0	20,5	0,5	2,6	1,5
2		40,0	35,0	40,0	21,0	42,0	40,0	42,0	39,0	37,4	7,0	18,6	21,0
3		70,0	50,0	48,0	34,0	50,0	50,0	55,0	50,0	50,9	9,9	19,4	36,0
4		35,0	30,0	30,0	25,0	32,0	32,0	30,0	32,0	30,8	2,9	9,3	10,0
5		47,0	40,0	51,0	35,0	45,0	47,0	40,0	46,0	43,9	5,1	11,7	12,0
6		44,0	45,0	38,0	25,0	36,0	40,0	36,0	40,0	39,3	3,7	9,5	10,0
7		64,5	72,0	60,0	65,0	65,0	63,0	65,0	75,0	66,2	4,9	7,4	15,0
8		77,5	68,0	75,0	75,0	60,0	65,0	71,0	75,0	70,8	6,1	8,5	17,5
9		95,5	95,5	100,0	100,0	93,0	100,0	100,0	100,0	98,0	2,9	2,9	4,5
10		25,5	N.R.	38,0	35,0	22,0	30,0	32,0	50,0	33,2	9,2	27,6	28,0
	$\bar{x}$	52,1	50,7	50,0	44,5	46,6	48,8	49,2	52,7	49,2		11,8	15,6
	s	24,0	23,7	23,4	26,6	21,8	22,8	23,9	23,9				10,5
	v%	46,1	46,8	46,8	59,7	46,9	46,8	48,6	45,3				67,8

where $\bar{x}$ = the arithmetic mean
s = the standard deviation and
v = the coefficient of variation $\frac{s}{\bar{x}}$

Average lateral displacement 1937 - 76 = 16 m

Average coefficient of variation 1937 - 76 = 12 per cent

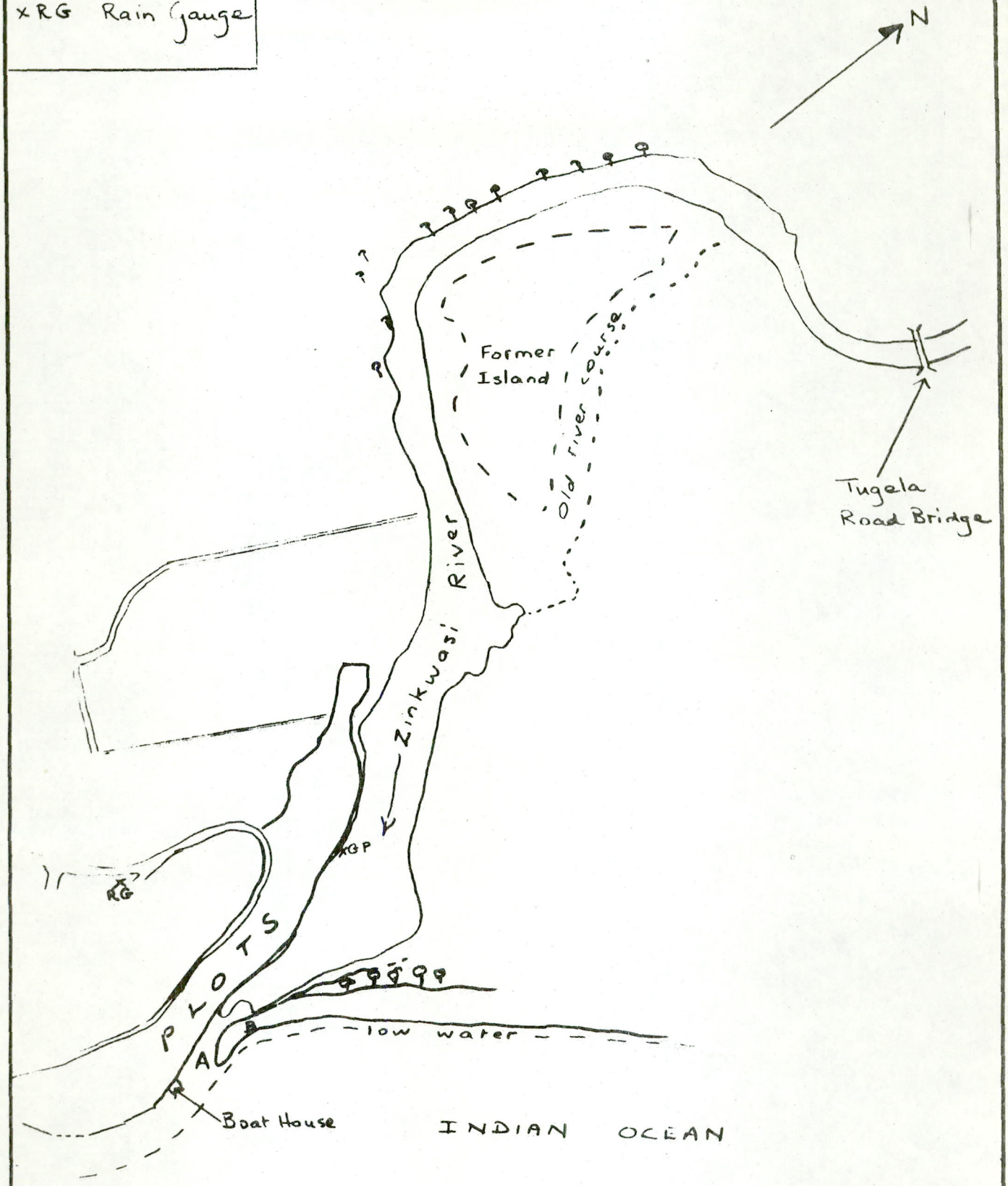
TABLE XI: ABSTRACT

ZINKWASI	1931 - 1976
1. Sinuosity	Range 1,47 - 1,53
2. River width	$\bar{x}$ Range 93 m - 72 m
3. Lateral displacement	$\bar{x}$ = 16 m
Average coefficient of variation $\frac{s}{\bar{x}}$% = 12	
4. River length	2 500 - 2 700 m
5. Flood plain area	
(i) % cultivated (≃ 1959 only)	12%
(ii) % swamp	13% → 36%
6. Riverine vegetation	
(i) Left bank	25% → 16%
(ii) Right bank	36% → 17%
(iii) Total area (main river and tributaries within reach)	17 ha → 2 ha
7. Lands bordering flood plain cultivated with sugar	
(i) Left bank	69% → 89%
(ii) Right bank	22% → 82%
8. Rainfall	
1977/78	1 083 mm
1978/79	1 049 mm
1979/80	948 mm
9. Number of days the mouth was open	
1977/78	102
1978/79	53
1979/80	22
10. Man's influence during 1937 - 76	
(i) Decrease in riverine vegetation (increase of 2 - 9% from 1937 - 76 due to re-establishment of vegetation on former island)	
(ii) Increase in area under sugar cane to the edge of flood plain	
(iii) Since detailed records were kept (that is, from 6.2.77) the mouth has been opened artificially on ten occasions.	

KEY

× GP Gauge Plate

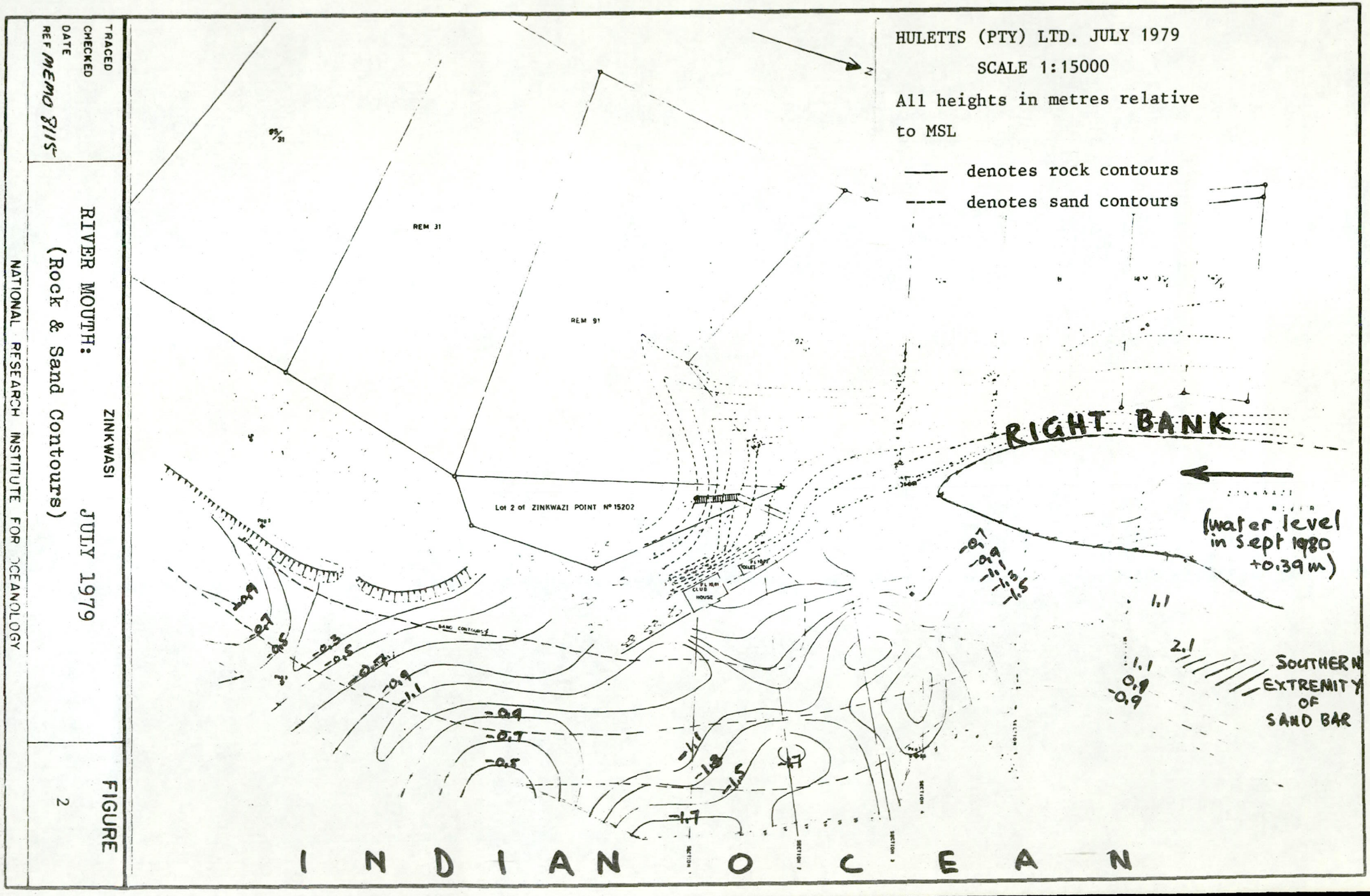
× RG Rain Gauge

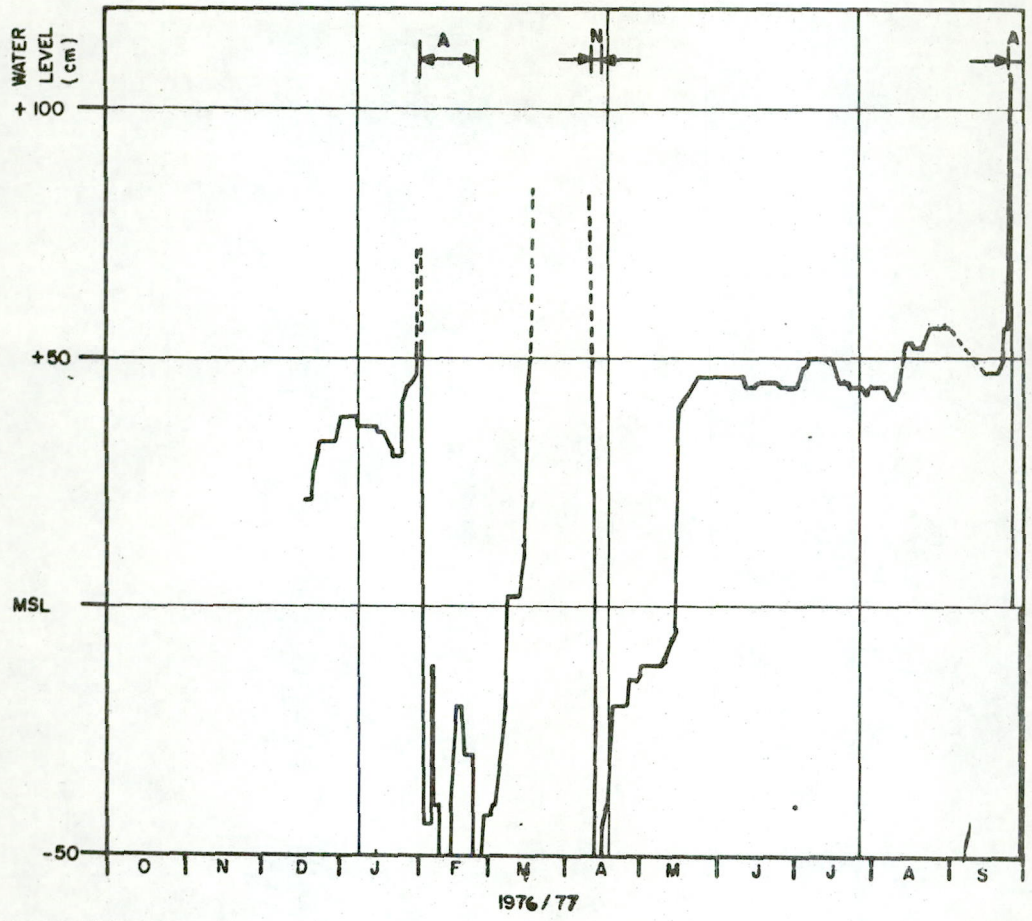


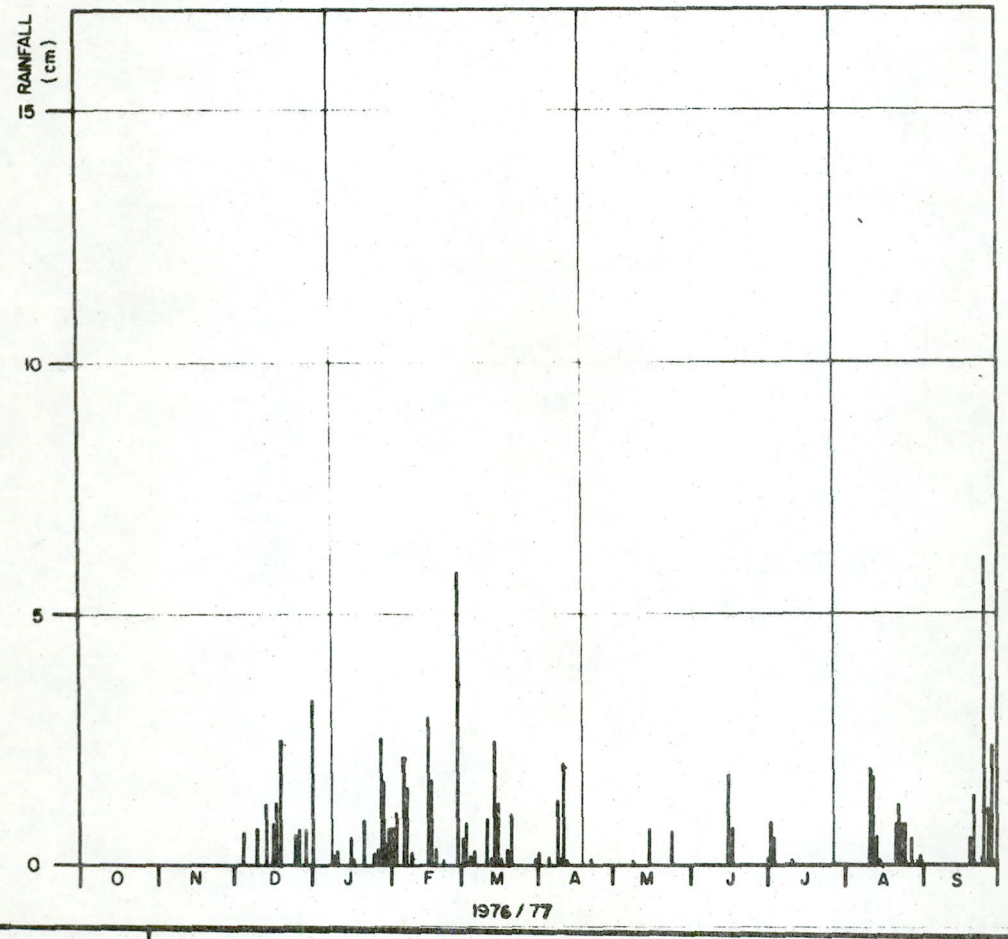
Scale 1:10 000

PACED CHECKED DATE REF MEMO 8115	ZINKWASI SKETCH MAP	FIGURE 1

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY


HULETTS (PTY) LTD. JULY 1979
SCALE 1:15000
All heights in metres relative to MSL
—— denotes rock contours
---- denotes sand contours
REM 31
REM 91
Lot 2 of ZINKWAZI POINT Nº 15202
RIGHT BANK
(water level in Sept 1980 +0.39 m)
SOUTHERN EXTREMITY OF SAND BAR
INDIAN OCEAN
TRACED
CHECKED
DATE
REF MEMO 815
ZINKWASI
RIVER MOUTH:
(Rock & Sand Contours)
JULY 1979
FIGURE
2
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY





TRACED CHECKED DATE REF MEMO 8115	ZINKWASI WATER LEVELS & RAINFALL : 1976/77	FIGURE 3

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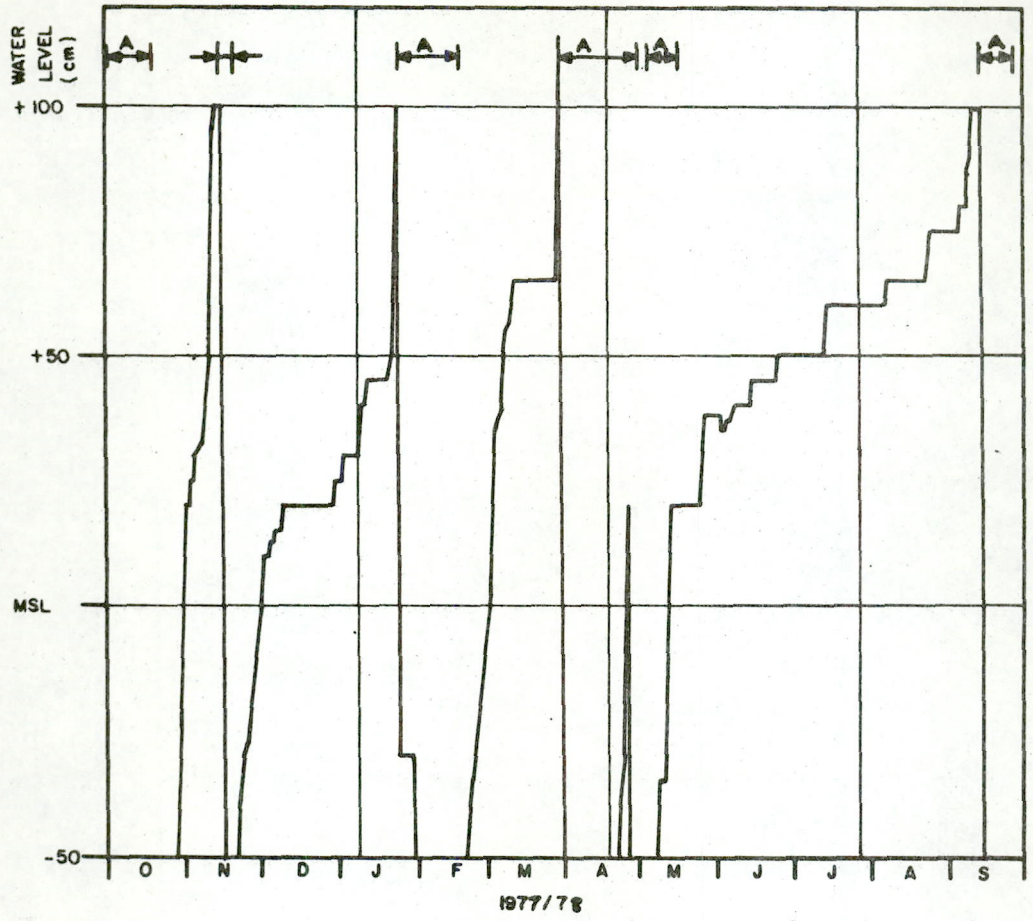

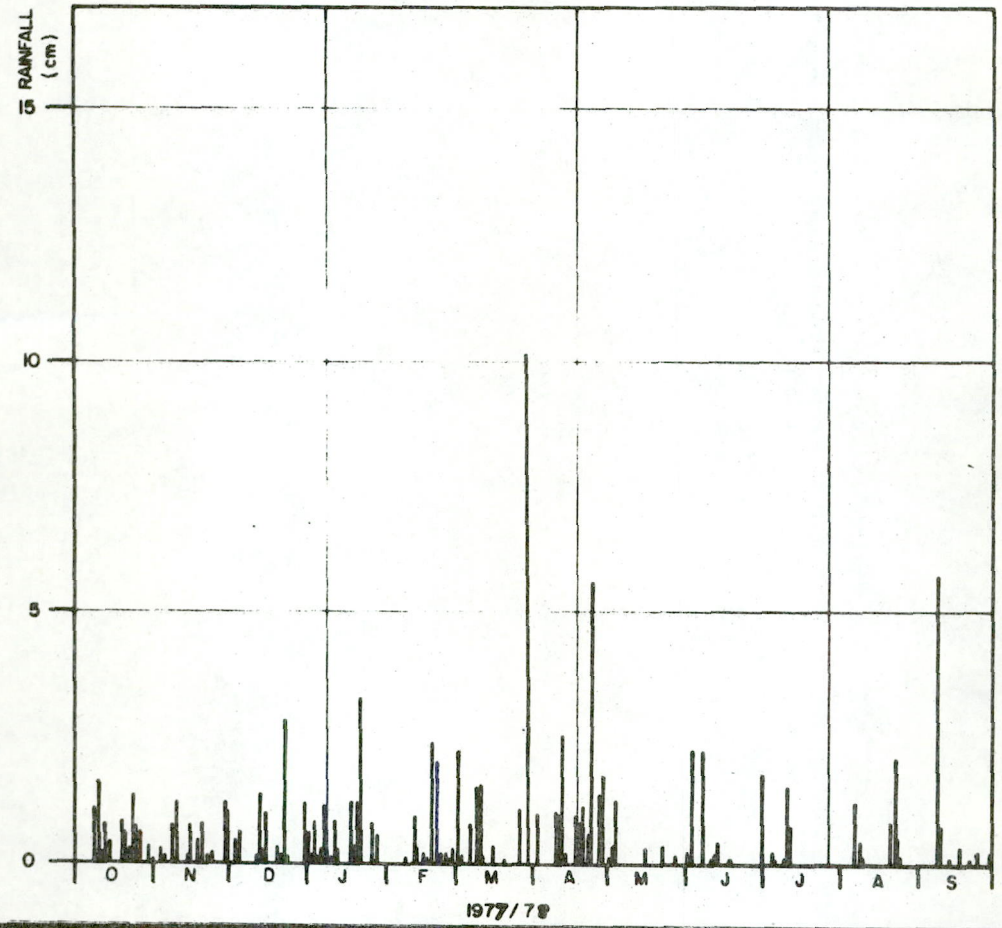

TRACED
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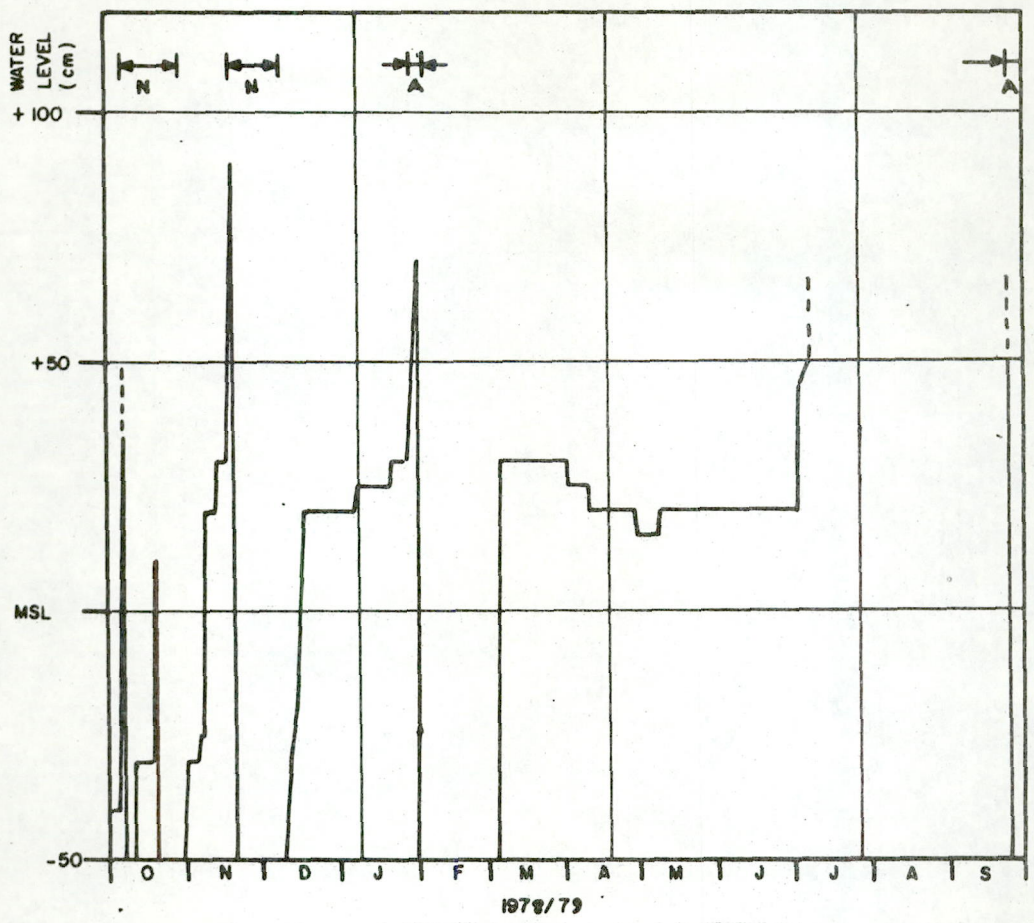
DATE:
REF. MEMO 8/15

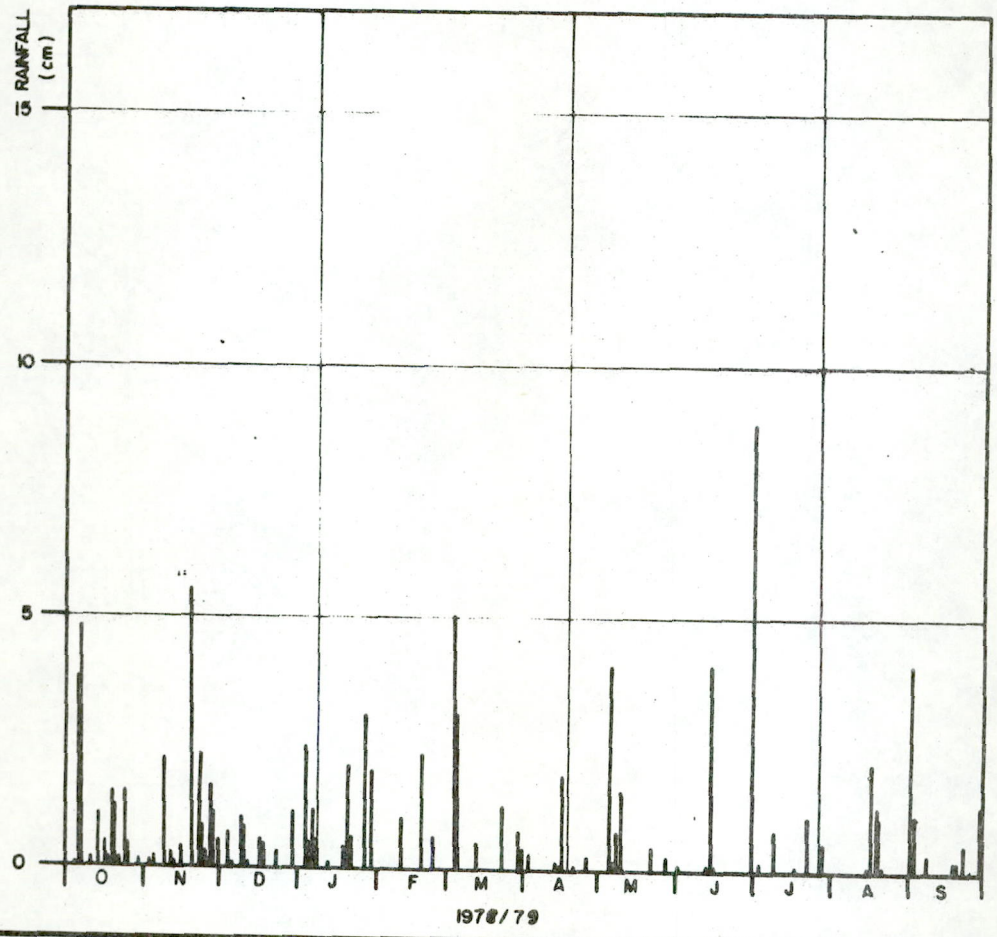
ZINKWASI

WATER LEVELS & RAINFALL : 1977/78

FIGURE 4

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY





TRACED JOAN
CHECKED
DATE
REF MEMO 8115

ZINKWASI

WATER LEVELS & RAINFALL : 1978/79

FIGURE 5

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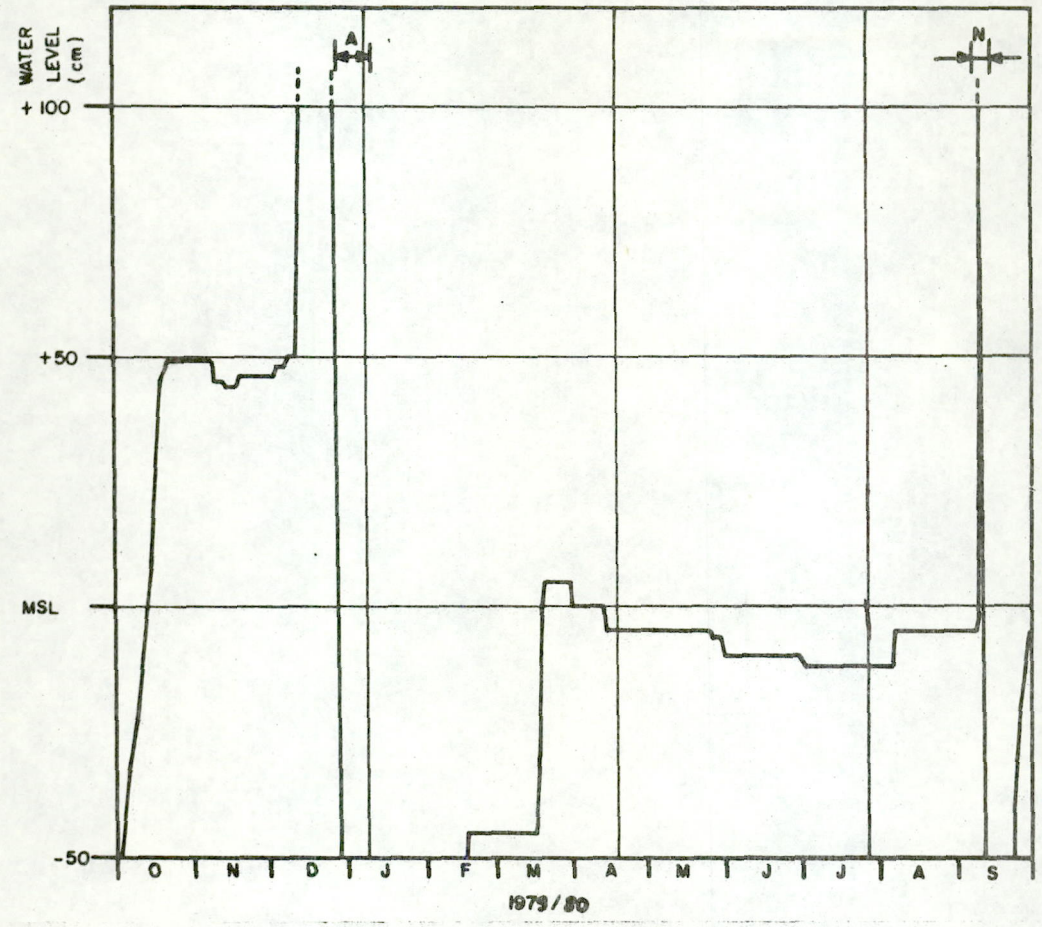

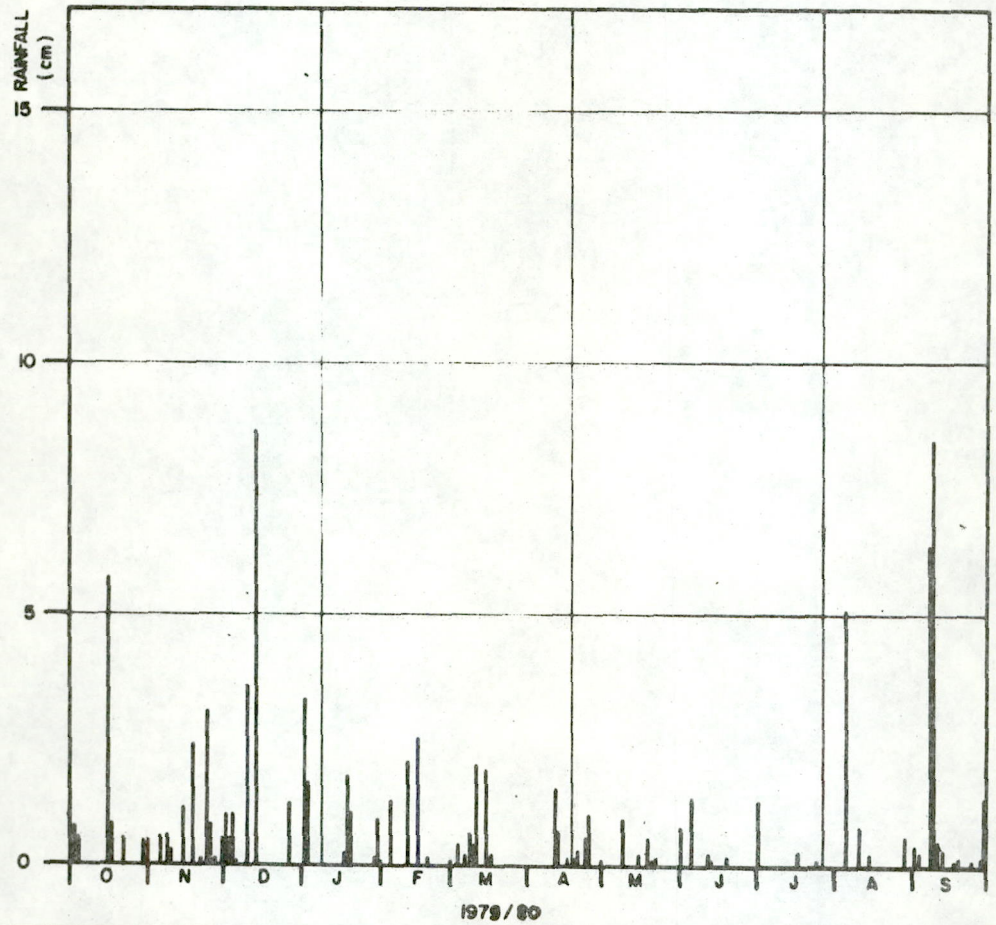

TRACED CHECKED DATE REF MEMO 8/15	ZINKWASI WATER LEVELS & RAINFALL : 1979/80	FIGURE 6

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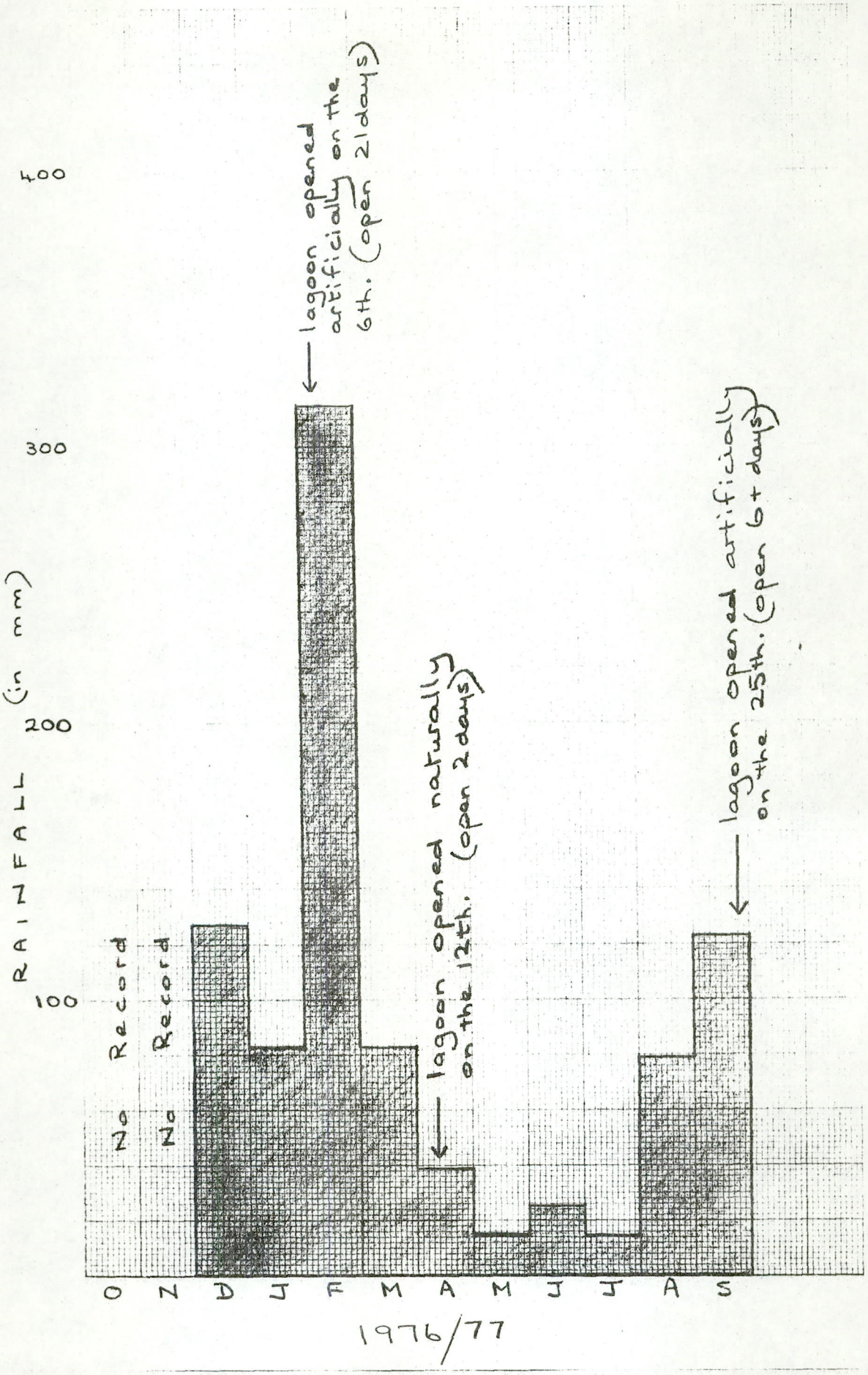

TRACED CHECKED : DATE : REF MEMO 8/15	ZINKWASI MONTHLY RAINFALL 1976/77	FIGURE 7

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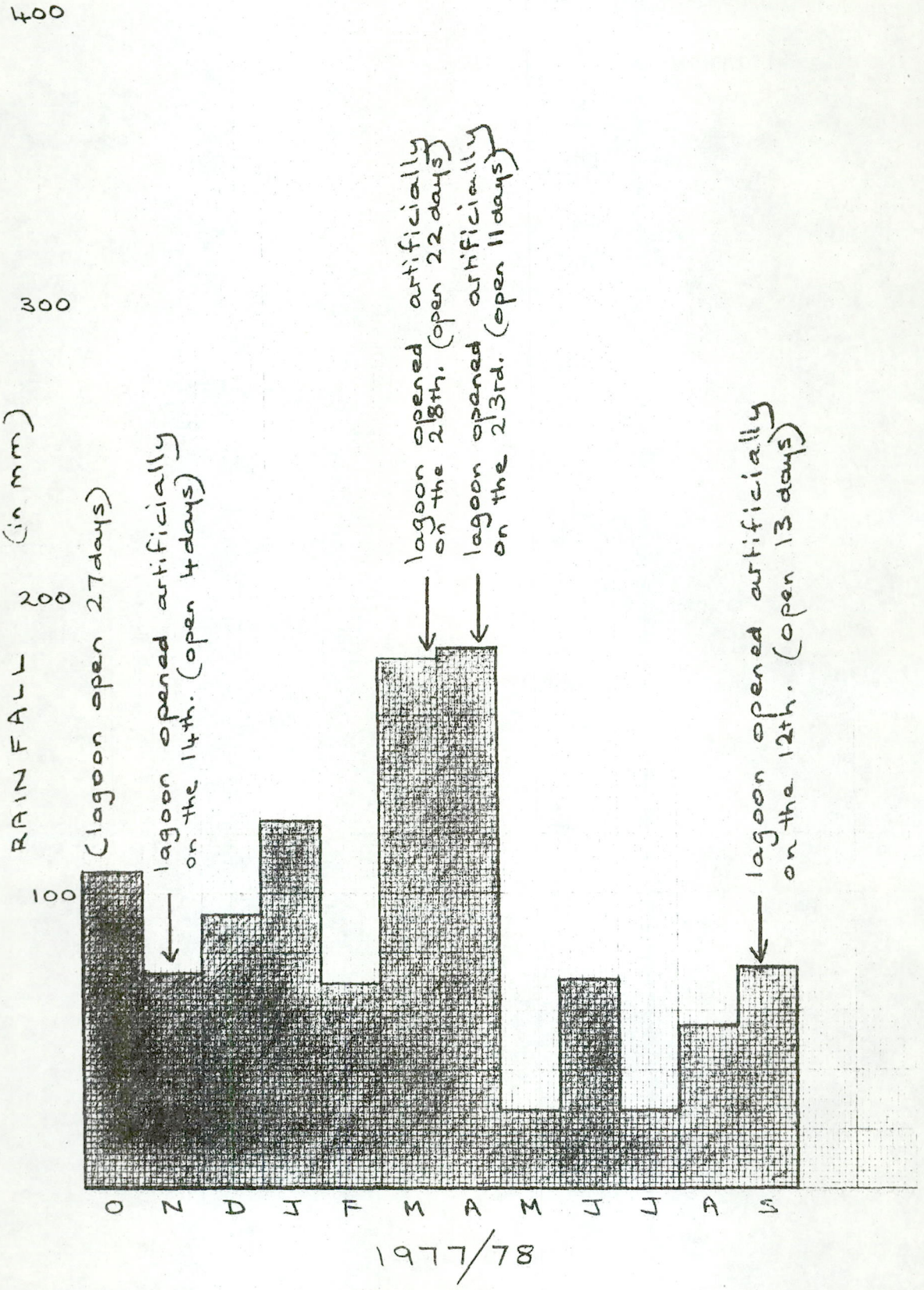

TRACED CHECKED: DATE: REF MEMO 8/15	ZINKWASI MONTHLY RAINFALL 1977/78	FIGURE 8

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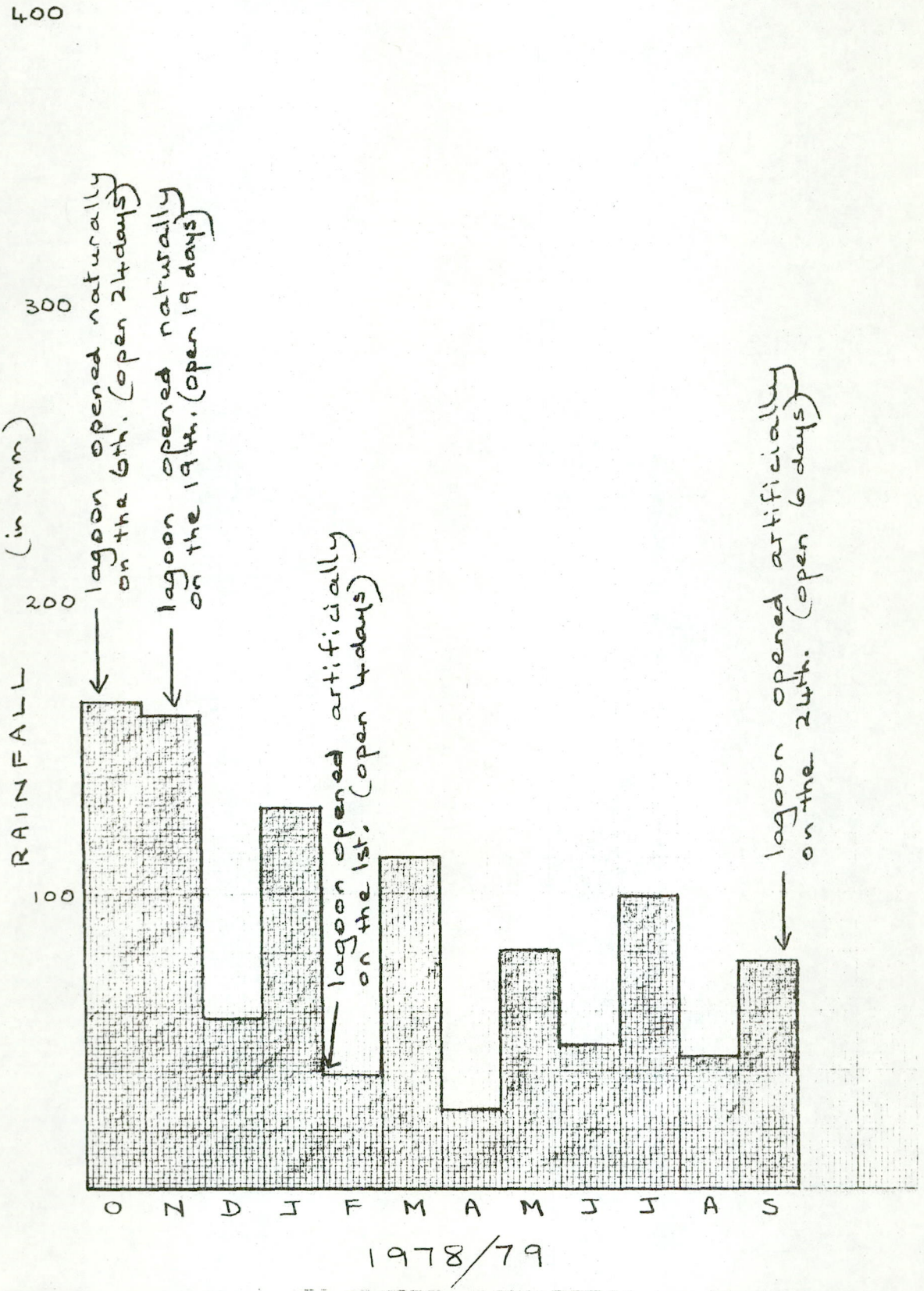

TRACED CHECKED DATE REF MEMO 8115	ZINKWASI MONTHLY RAINFALL 1978/79	FIGURE 9

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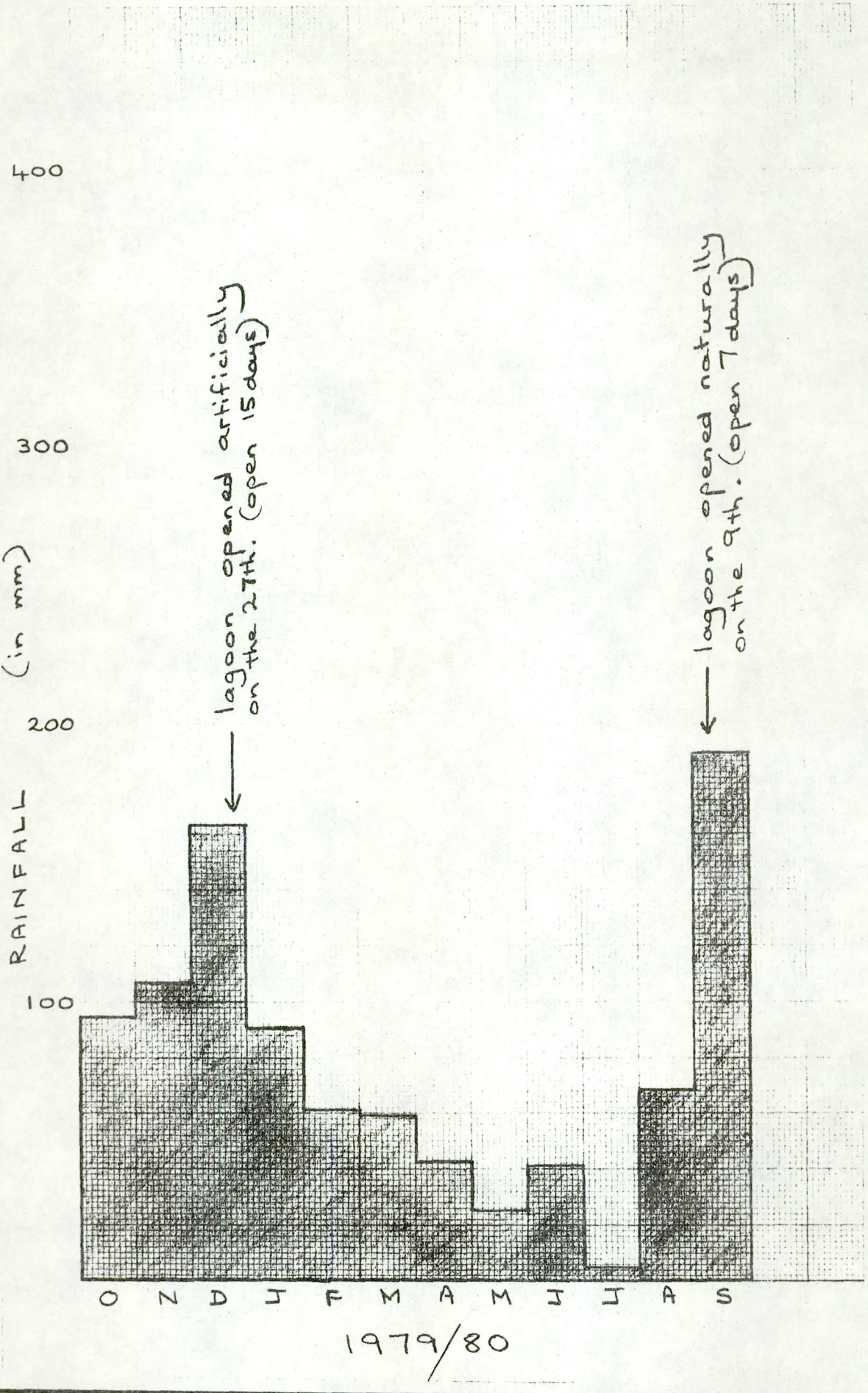

TRACED CHECKED : DATE : REF. MEMO 8115	ZINKWASI MONTHLY RAINFALL 1979/80	FIGURE 10

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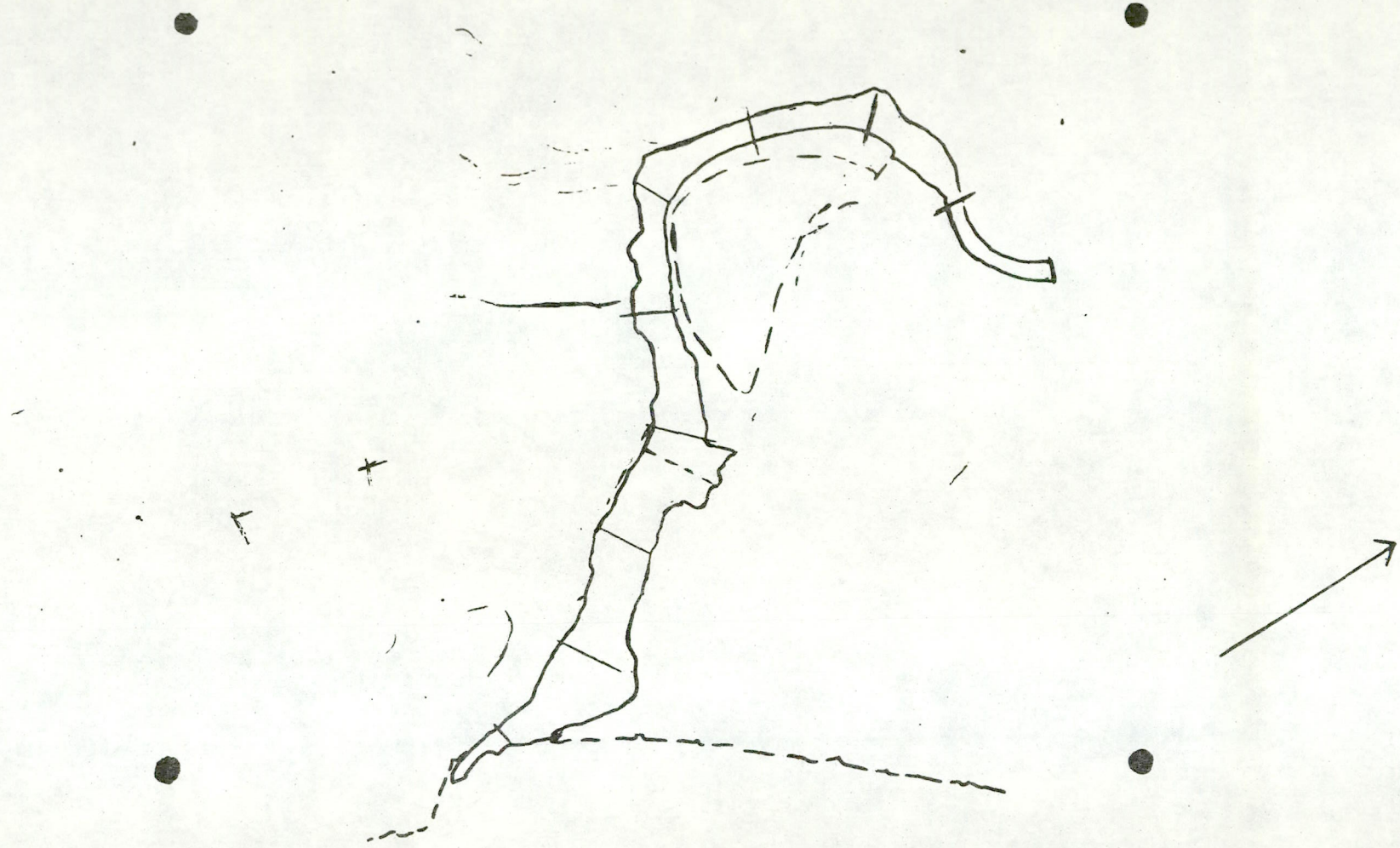
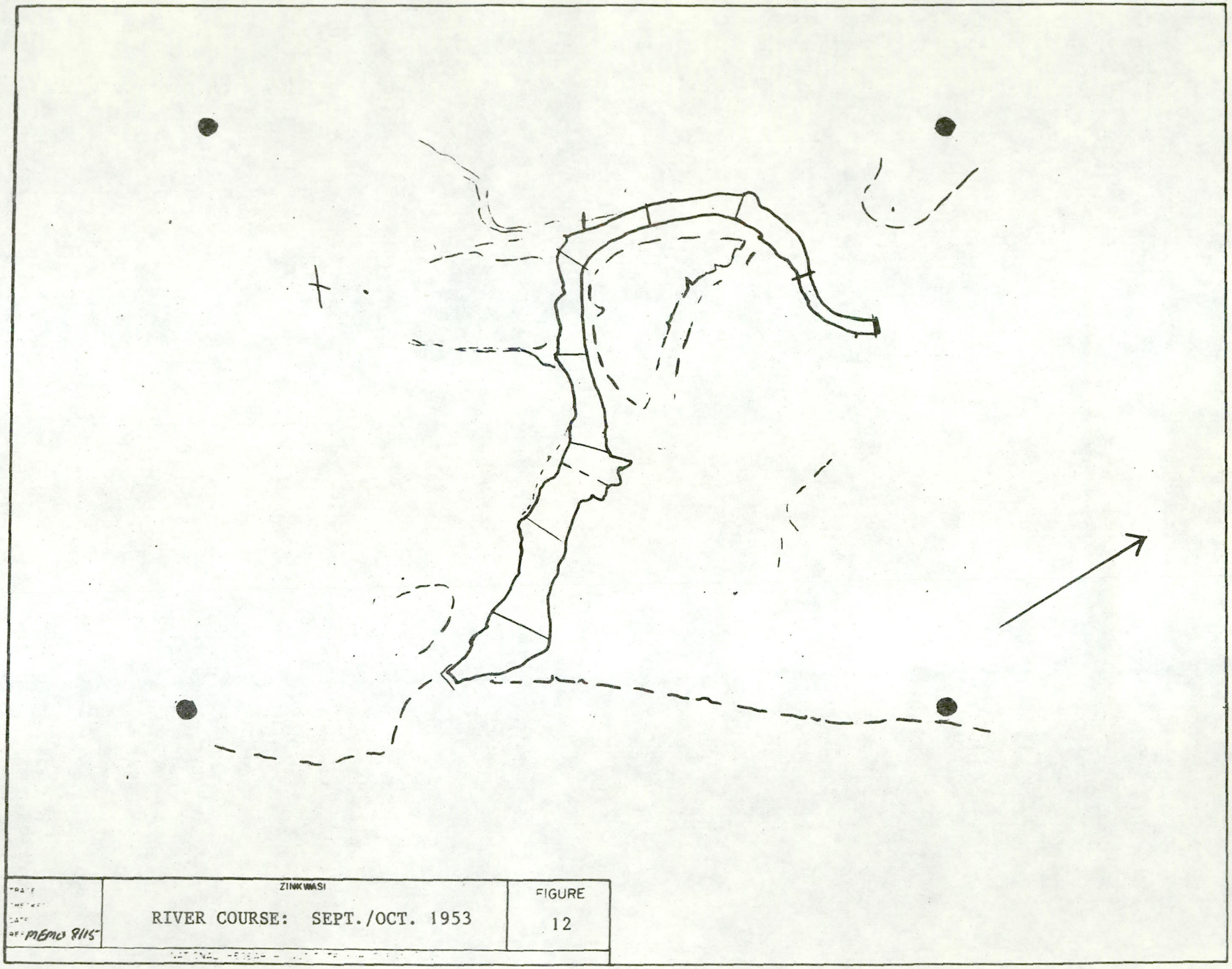
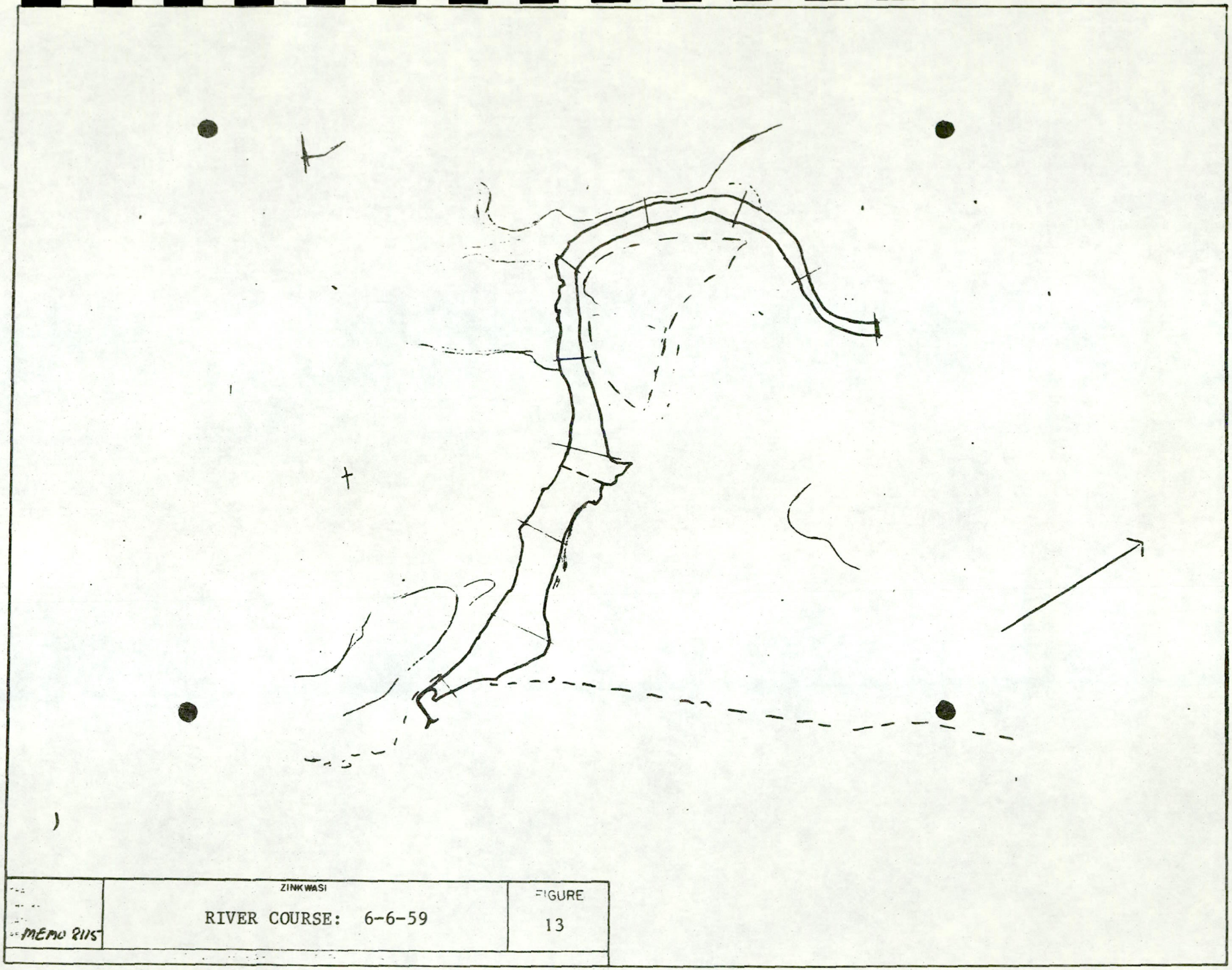


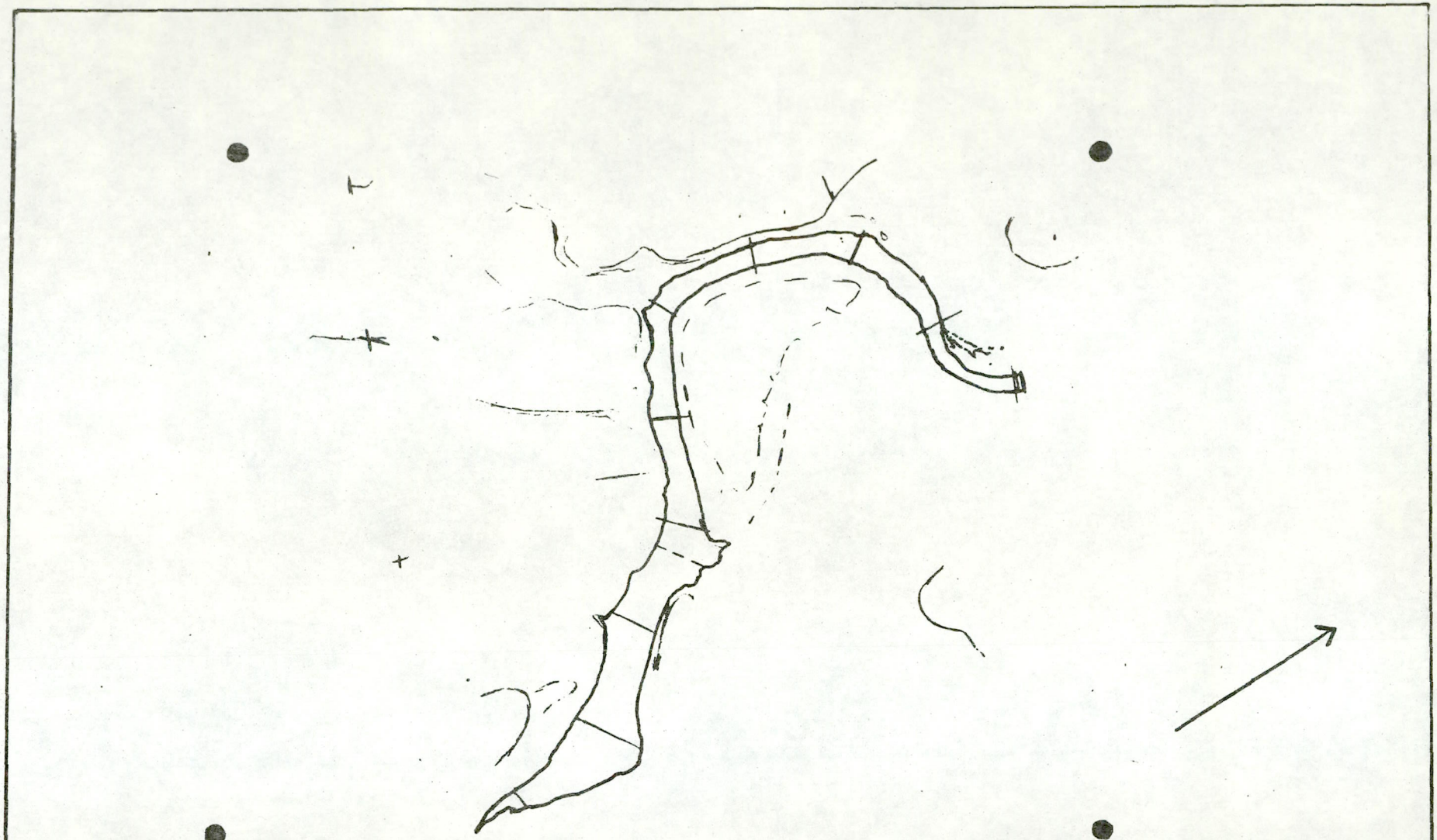
MEMO 8/15	ZINKWASI RIVER COURSE: 5-5-37	FIGURE 11



TRACE CHECKED DATE REF: MEMO 8/15	ZINKWASI RIVER COURSE: SEPT./OCT. 1953	FIGURE 12

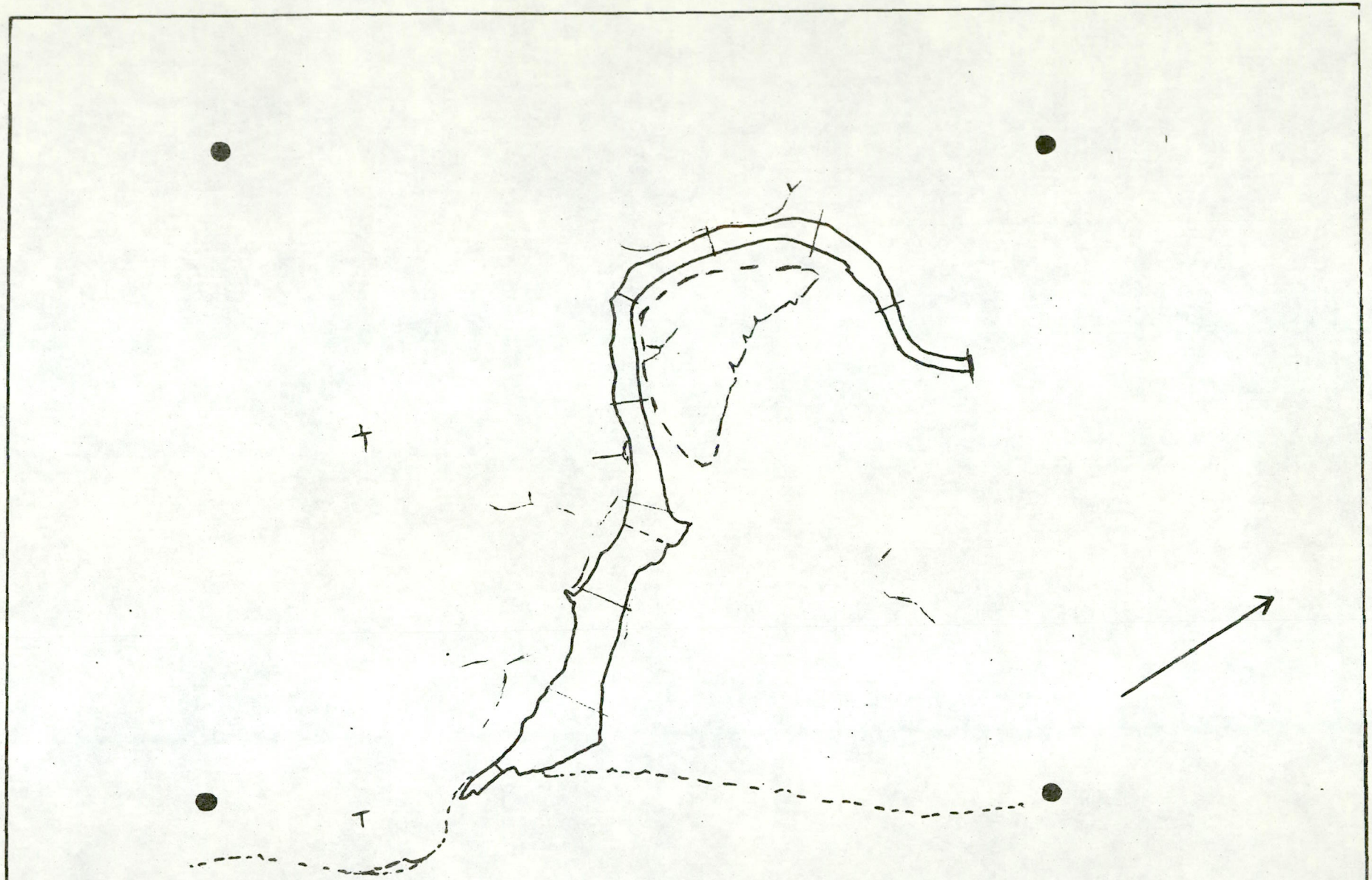


	ZINKWASI	FIGURE
MEMO 2115	RIVER COURSE: 6-6-59	13

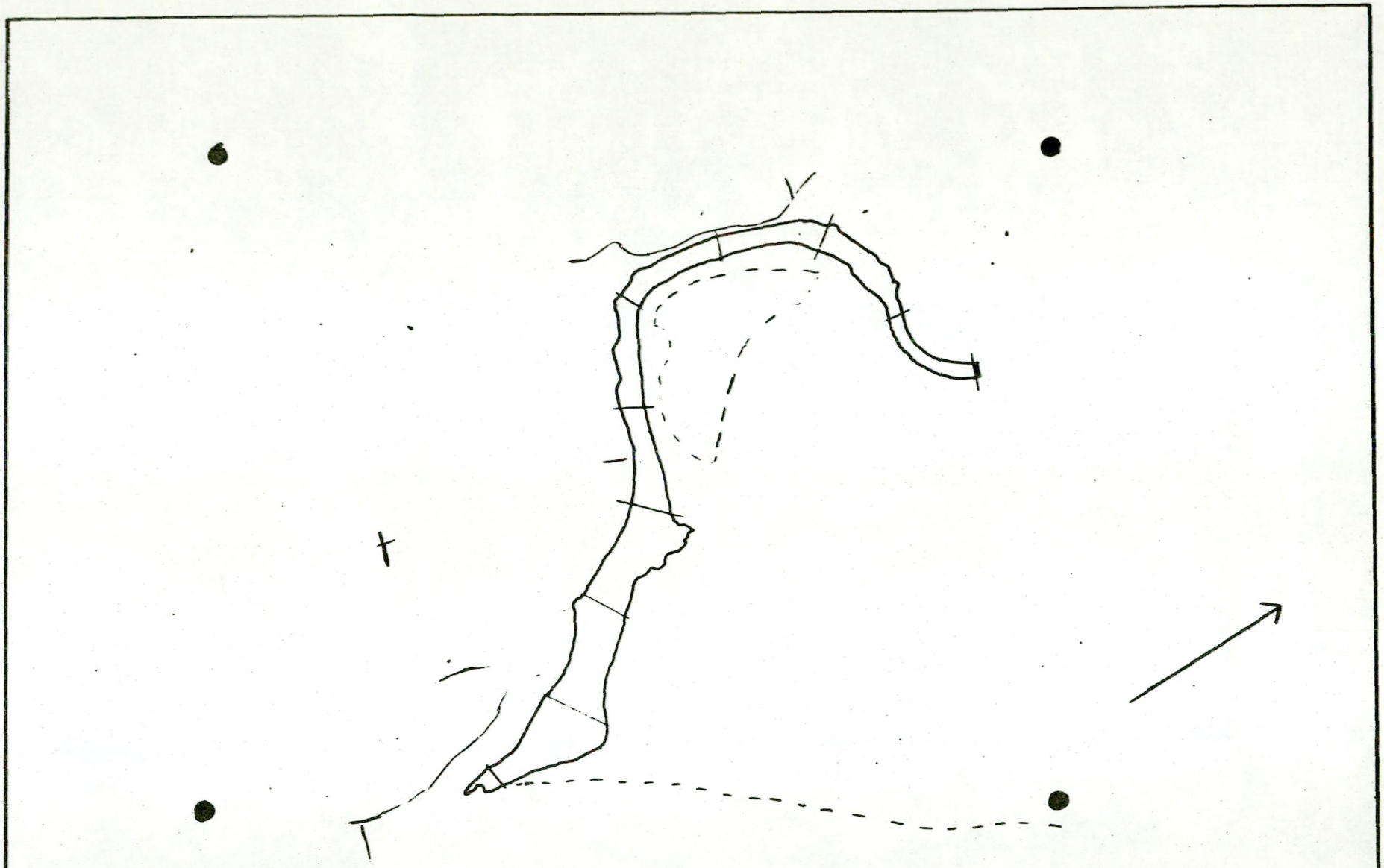


MEMO 8/15	ZINKWASI RIVER COURSE: 3-5-64	FIGURE 14

MEMO 8/15	ZUNKWASI RIVER COURSE: 21-8-67	FIGURE 15



TRACED CHECKED DATE SEE MEMO 8/15	ZINKWASI RIVER COURSE: 3-6-73	FIGURE 16

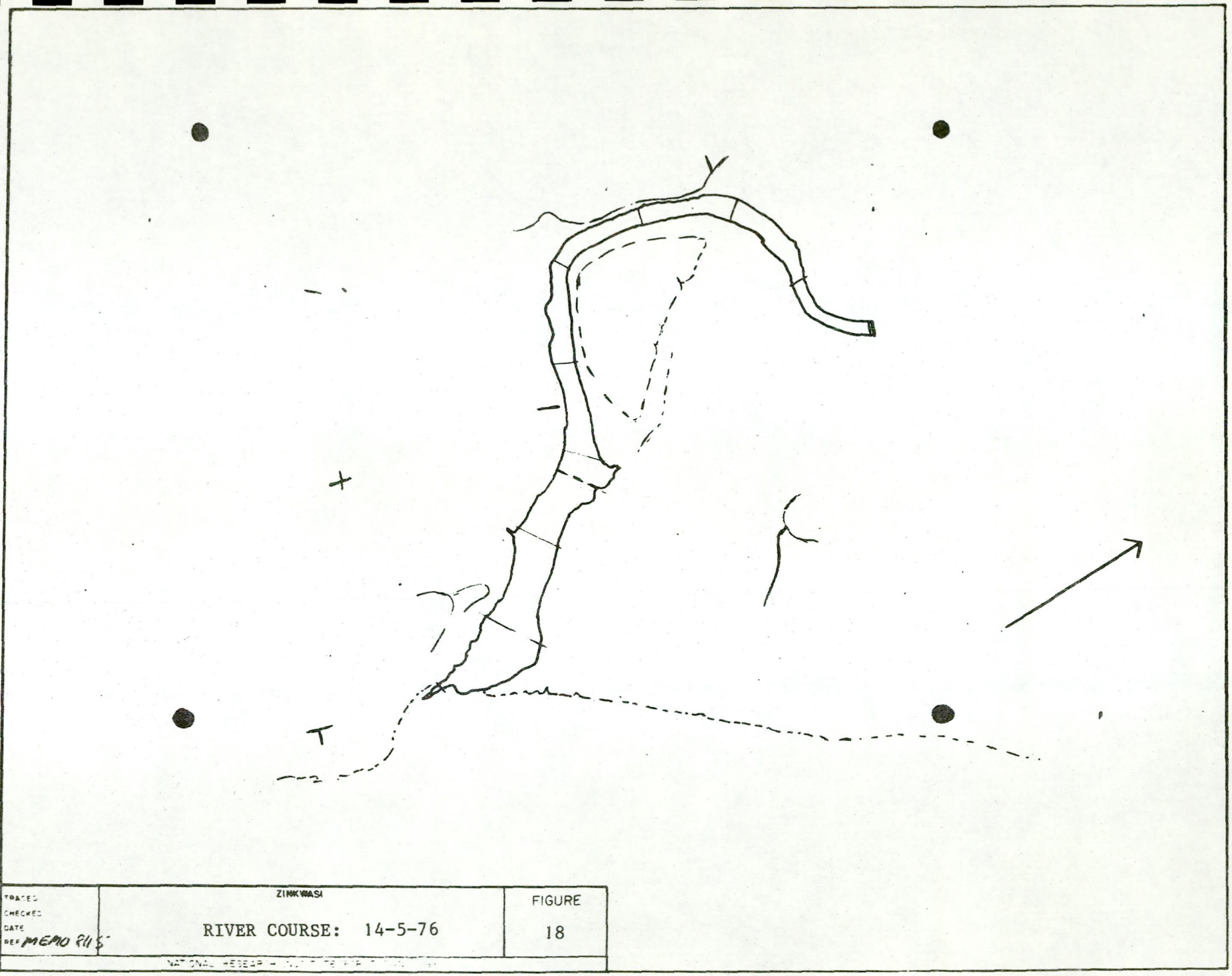


ZINKWASI

RIVER COURSE: 11-3-74

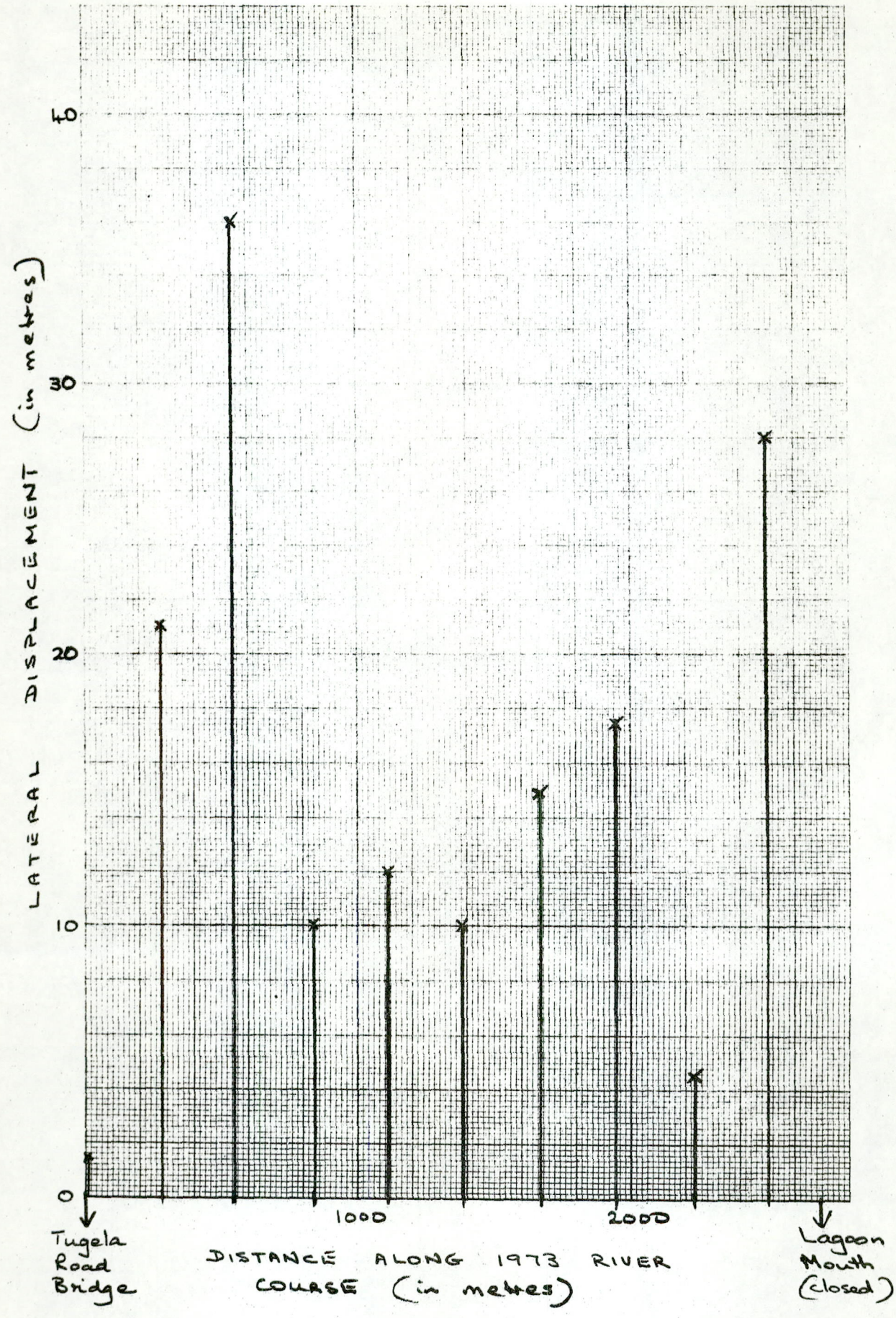
FIGURE 17

MEMPHIS



TRACED	ZINKWASI	FIGURE
CHECKED	RIVER COURSE: 14-5-76	18
DATE		
REF MEMO 8115		

NATIONAL HERBAR



TRACED CHECKED DATE REF MEMO 8/15	ZINKWASI THALWEG DISPLACEMENT 1937-76	FIGURE 19

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SCALE 1 10 000 approx

TRACED JMO CHECKED DATE 81-03-31 REF MEMO 8115	NATAL ESTUARIES ZINKWASI : 5-5-37	PHOTOGRAPH 1

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SCALE 1 10 000 approx

TRACED JMO CHECKED DATE 81-03-31 REF MEMO 8115	NATAL ESTUARIES ZINKWASI : 6-6-59	PHOTOGRAPH 2

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY

SCALE : 1: 10 000 approx

TRACED JMO CHECKED DATE 81-03-31 REF MEMO 8115	NATAL ESTUARIES ZINKWASI : 14-5-76	PHOTOGRAPH 3

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SCALE 1 10 000 approx

TRACED JMO CHECKED DATE 81-03-31 REF MEMO 8115	NATAL ESTUARIES ZINKWASI : 3-6-73	PHOTOGRAPH 4

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