No abnormal physical or chemical properties were recognized in any of the samples analyzed. The analysis results, which are provided in App. II are summarized and shown in Table 5.6.1

5.6.2 Suspended Load

Records of suspended load in the water of the Kikuletwa River and its tributaries are given in App. II. The relationships between suspended loads and discharges of the Kikuletwa, Weru-weru, and Pangani rivers, as based on these data, are shown in Fig. 5.6.1. These relationships are in the ranges given below.

River	Gauging St. location	River discharge (cu.m/sec)	Suspended load (ppm)
Kikuletwa (3,840 sq.km)	No. 1DD-1 Below Weru-weru River confluence	14.8 - 90.1	9 - 194
Weru-weru (146 sq.km)	No. 1DD-5A Old Arusha-Moshi Rd.	6.2 - 60.6	19 - 698
Pangani (9,037 sq.km)	No. 1D-8 Nyumba ya Mungu	16.8 - 96.9	21 - 133

Using the discharge-suspended load relationship for the Weru-weru River (shown by the straight line in Fig. 5.6.1), for which the suspended load is comparatively high, the following suspended load and discharge are found for 1970, the year of average runoff condition at gauging station No. 1DD-54 on the Kikuletwa River.

River	Gauging St. location	Suspended load (ppm)	River discharge (cu.m/sec)
Kikuletwa	No. 1DD-54	28	Min. 7.65
(2,220 sq.km)	TANESCO PS	300	Max. 30.97

Based only on the above data, the total suspended load is calculated to be approximately 24,505 cu.m, against a total annual discharge of approximately 41.1 million cu.m. This corresponds to 11.04 cu.m per square kilometer annually.

The Kikuletwa River, as seen from the river profile for the 72 km from Msitu Wa Mbogo near Arusha to its confluence with the Karanga River, may be considered to be a transitional area. The average river gradient at this stretch is approximately 1/300. The suspended load, instead of being deposited at this transitional area, is carried down and deposited in to the plain area, or else is carried further down, to the Nyumba ya Mungu Reservoir.

Table 5.1.1 TEMPERATURE, HUMIDITY, SUNSHINE HOUR AND EVAPORATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Moshi Meteorological Station (3°- 21'S, 37° - 20'E, 854 m)												
1. Mean max. temperature (°C)	32.7	33.1	32.0	29.3	26.7	25.7	25.4	26.4	28.7	30.6	31.5	31.7
2. Mean min. temperature (°C)	17.6	18.0	18.0	19.3	18.4	16.7	15.8	15.4	15.9	16.9	17.8	17.7
3. Mean relative humidity (%)	41	40	45	57	63	58	54	50	44	40	42	45
4. Mean sunshine hours/day (Hr/day)	9.7	9.8	7.7	6.4	6.4	4.8	4.4	5.5	7.1	7.1	9.1	6.9 (in 1983)
5. Pan evaporation (mm/month)	276.2	281.0	305.8	184.7	126.4	108.2	-	136.2	171.2	114.5	213.4	44.7 (in 1982)
Same Meteorological Station (4° - 05'S, 37° - 44'E, 872 m)												
1. Mean max. temperature (°C)	31.5	32.2	31.8	29.4	26.8	26.2	25.8	26.6	28.3	29.9	30.5	30.4
2. Mean min. temperature (°C)	19.3	19.4	19.6	19.3	17.8	16.0	15.3	15.2	15.8	17.2	18.8	19.4
3. Mean relative humidity (%)	45	43	46	57	61	54	51	49	46	44	46	49
4. Mean sunshine hours/day (Hr/day)	9.8	8.9	8.9	6.9	4.0	5.0	4.6	6.0	6.7	6.5	8.6	6.6 (in 1983)
5. Pan evaporation (mm/month)	282.5	330.2	309.3	193.7	154.6	156.8	136.5	179.1	182.2	229.8	208.6	244.4 (in 1984)

TABLE 5.2.1(1) LIST OF MONTHLY RAINFALL AND ANNUAL RAINFALL

Location	Resist. No.	Lot(s), Long(E) & Altitude	1950's 1 2 3 4 5 6 7 8 9	1960's 0 1 2 3 4 5 6 7 8 9	1970's 0 1 2 3 4 5 6 7 8 9	1980's 0 1 2 3 4 5 6 7 8 9
Moshi (Himo) Kilena-Chini	933-745	3°-20'-0" 37-31-0 4,000ft		Jan.		Dec.
Moshi Himo Sisal Estate	933-731	3°-23' 37-33 3,150ft		Jan.	Dec.	Jan. Dec.
Hai Lerongo Forest	933-7134	3°-08' 37-03 1,400m			Jan.	Dec.
Hai Lombo Estate	933-7135	3°-12' 37-11 1,420m			Jan.	Dec.
Moshi Lukani Ltd.	933-7119	3°-10' 37-08 5,700ft			Aug.	Dec.
Moshi Nkwasira Corp. Ltd.	933-7136	3°-15' 37-09 3,750ft			Oct.	Dec.
Moshi Kikuletwa Hydro-meteo station	933-769	3°-27' 37-12 2,500ft		Jan.	Dec.	
Moshi Kibongoto	933-778	3°-12' 37-07 4,100ft		Jan.	Dec.	
Moshi Siha	933-7118	3°-07' 37-07 5,900ft			Aug. Feb.	
Hai Siha Second School	933-7142	3°-10' 37-01 4,450ft			Dec.	Oct.
Arusha Arusha Air Port	933-633	3°-22' 36-38 4,550ft		Jan.		Dec.
Himo Rombo Mission School	933-706	3°-12' 37-36 4,700ft		Jan.		Dec.
Hai Lyamungu	933-721	3°-14' 37-15 4,100ft		Jan.		Dec.
Friesian Farm	933-747	3°-03' 37-00 4,300ft		Jan.	Oct.	
Lomwe	933-775	3°-42' 37-39 4,500ft		Jan.		Dec.
Pare Hassan Sisal Estate	943-701	4°-20' 37-51 3,000ft		Jan.		Dec.
Pare Same Meteo Station	943-703	4°-05' 37-44 2,820ft		Jan.		Dec.
Pare Gonja Estate	943-811	4°-18' 38-02 549m	Oct/'37	Jan.		Dec.

TABLE 5.2.1(2) LIST OF MONTHLY RAINFALL AND ANNUAL RAINFALL

River	Regist. No.	Lot(s), Long(E) & Altitude	1950's 1 2 3 4 5 6 7 8 9	1960's 0 1 2 3 4 5 6 7 8 9	1970's 0 1 2 3 4 5 6 7 8 9	1980's 0 1 2 3 4 5 6 7 8 9
Pare (Lusshoto) Ndung Est.	943-851	4°-22' 32-03 533m		Jan. —	—	— Dec.
Kisiwani Sisal Estate	943-7011	4°-08' 37-59 685m	1949 Annual Mean Only	Jan. —	— Dec. - -	- - -
Kwiza Mission School	943-8032	4°-08' 38-01 1,105m		Jan. —	— May	
Tia Dam	943-7010	4°-14' 37-57 1,670m		Oct. —	—	— Dec.
Kilimawe Meteo. Station	943-8040	4°-25 38-05 508m		Jan. —	—	— Dec.
Mtii Primary School	943-8050	4°-00' 38-00 1,275m		Aug. —	—	— Dec.
Ibaya	933-7104	883m		Jan. —	— Jul.	

TABLE 5.2.2 LIST OF MONTHLY MEAN DISCHARGE

River	Resist. No.	Lot(s), Long(E) & Altitude	1950's 1 2 3 4 5 6 7 8 9	1960's 0 1 2 3 4 5 6 7 8 9	1970's 0 1 2 3 4 5 6 7 8 9	1980's 0 1 2 3 4 5 6 7 8 9
Sesseni 170 km^2	1DB-2A Gulutu	4°-28'-50" 38°-03-04 550m	- - - - - - - - -	May		Mar. Water level - - - - -
Mkomazi 3,600 km^2	1DB-17	5°-01'-25" 38°-16-45 380m		Nov.	Dec.	
Mombo (Soni) 520 km^2	1DB-6A	4°-54 38°-17 410m		Jan.	Dec.	
Hingiligi 38 km^2	1DB-18 Kiruka	4°-14'-05" 37-58-25 1,540ft		Jan. - - - - Jan.	Dec. - - - - - - - - - -	Apr. (Suspended) - - - -
Ruvu 3,370 km^2	1DC-2A	3°-31'-30" 37-28-0 690m	Nov. Dec.		Dec.	
Rau 270 km^2	1DC-3A	3°-30'-39" 37-28-15 700m	Dec. Nov.	Closed in Sept. 1960 Nov.	Dec.	
Mue 280 km^2	1DC-6	3°-28'-10" 37-28-39 700m	Jan.	Oct. Closed in May 1963	Nov. Dec.	
Himo 264 km^2	1DB-11A Moshi-Tanga Rd. Bridge	3°-29'-00" 37-33 760m	Nov. Oct.	Closed in Sept. 1959	Nov. Dec. - - - - - - - - - -	- - - - - - May
Kikuletwa 3,880 km^2	1DD-1	3°-31'-00" 37-17-00 700m	Nov.		Dec.	
Weru-weru 68 km^2	1DD-6A	3°-9 37-16 450m			Jan. Dec.	- -
Kikuletwa 2,220 km^2	1DD-54 TANESCO P/Station	3°-27'-30" 37-12-30 1,370m		Feb. - - - - - - - - - -	Dec. - - - - - - - - - -	- - Water level - - - - - -
Kikafu (50 sq.mile)	1DD-8	3°-20 37-14 3,500ft	Nov. Oct.	Closed in May 1963		
Kware West Fork (35 s.mile)	1DD-9	3°-18' 37-13 3,000ft	Nov. Oct.	ditto		
Kware West Fork (16 s.mile)	1DD-10	3°-17' 37-09 3,300ft	Nov. Oct.	ditto		
Sanya Juu (44 s.mile)	1DD-13	3°-11' 37-04 4,200ft	Nov. Oct.	ditto		
Ndungu	1DB-3 Main Rd.		- - - - - - - - -			
Gonja South	1DB-4 Main Rd.		- - - - - - - - -			
Gonja North	1DB-5 Main Rd.		- - - - - - - - -			
Yongoma	(1DB-3) Main Rd			Closed in May 1963		JICA 10/Dec & 1DB-23 up to date - - - - Water level & Discharge

Table 5.3.1 RAINFALL INTENSITY

	Daily max. rainfall (mm/day)	Hourly intensity (mm/hour)	Date
Moshi			
1972	92.6	35.5 (in 50 min.)	Apr. 1
1973	104.5	52.0	Apr. 2
1974	88.8	34.0	Apr. 25
1975	95.8	44.0	Apr. 21
1976	76.0	41.5	Apr. 11
1977	104.6	27.6	Apr. 22
1978	53.1	21.1 (in 45 min.)	Mar. 25
1979	138.3	27.0	Apr. 4
1980	149.7	48.0	Apr. 20
1981	-	-	-
1982	49.2	37.2	Mar. 15
1983	-	-	-
1984	-	-	-
1985	81.1	23.5	Apr. 19
1986	166.4	82.0	Apr. 9
Same			
1978	104.8	33.0 (in 44 min.)	Apr. 5
1979	37.4	23.0	Apr. 3

Table 5.4.1 MONTHLY MEAN DISCHARGE AND SPECIFIC RUN-OFF PER 100 SQ KM

(Unit: cu.m/sec)

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Remark
1. Kikuletwa	11.78	11.79	12.14	18.51	18.35	13.94	11.89	11.33	11.26	11.28	11.84	12.11	13.02	Feb/67-Dec/75
(No. 1 DD-54, 2220 sq.km)														
Run-off/100sq.km	0.53	0.53	0.55	0.83	0.83	0.63	0.54	0.51	0.51	0.51	0.55	0.55	0.57	
2. Himo	0.85	0.99	1.36	5.34	5.99	3.11	2.21	1.33	0.78	0.75	1.24	0.75	2.06	Jan/69-Dec/76
(No. 1 DC-11A. 264 sq.km)														
Run-off/100 sq.km	0.32	0.38	0.52	2.02	2.27	1.18	0.84	0.50	0.30	0.28	0.47	0.28	0.78	
3. Hingilili	0.85	0.60	0.84	0.93	0.72	0.50	0.39	0.33	0.29	0.28	0.64	1.21	0.63	Jan/63-Dec/75
(No. 1 DB-18, 38 sq.km)														
Run-off/100 sq.km	2.24	1.58	2.21	2.45	1.89	1.32	1.03	0.87	0.76	0.74	1.68	3.18	1.66	
4. Yongoma	2.24	4.01	1.24	2.89	1.33	-	-	-	-	-	1.67	5.23	-	Nov/83-Apr/87
(No. 1 DB-023, 77.5 sq.km)														
Run-off/100 sq.km	2.89	5.17	1.60	3.73	1.72	-	-	-	-	-	2.15	6.75	-	
5. Sesseni	3.36	2.68	3.69	3.44	1.98	1.19	0.80	0.55	0.46	0.43	1.48	5.47	2.13	May/63-Apr/82
(No. 1 DB-2A, 170 sq.km)														
Run-off/100 sq.km	1.98	1.58	2.16	2.02	1.16	0.70	0.47	0.32	0.27	0.25	0.87	3.22	1.25	For 170 sq.km
	(1.75)	(1.40)	(1.92)	(1.79)	(1.03)	(0.62)	(0.42)	(0.29)	(0.24)	(0.22)	(0.77)	(2.85)	(1.11)	For 192 sq.km

Table 5.5.1 MAXIMUM DAILY DISCHARGE

(Unit: cu.m/sec)

Year	R. Kikuletwa		R. Himo		R. Sesseni	
	Discharge	Date	Discharge	Date	Discharge	Date
1963	-	-	-	-	1935.98	25 Dec.
1964	-	-	-	-	175.24	5 Mar.
1965	-	-	-	-	4.62	1 Jan.
1966	-	-	-	-	5.77	28 Mar.
1967	16.50	17 May	-	-	17.16	23 Nov.
1968	55.88	3 June	34.38	6 Dec.	35.64	11 Dec.
1969	24.44	10 May	20.92	26 Feb.	13.27	13 Jan.
1970	32.28	6 May	33.35	11 Apr.	35.34	21 Feb.
1971	74.94	24 Apr.	29.93	22 Apr.	4.90	19 Jan.
1972	55.41	20 Apr.	17.55	14 Nov.	8.70	10 Dec.
1973	23.96	30 Apr.	32.58	17 Feb.	20.55	14 Dec.
1974	88.66	11 Apr.	27.38	2 May	17.43	30 Dec.
1975	21.02	23 Apr.	35.91	3 Apr.	9.69	1 Dec.
1976	-	-	52.47	12 Apr.	23.47	11 Jan.
1977	-	-	-	-	159.69	10 Dec.
1978	(53)*/	Mar. (2.98m)**/	-	-	185.46	13 Dec.
1979	(148)	May (3.58m)	-	-	21.07	12 Feb.
1980	(46)	May (1.84m)	-	-	23.34	6 Dec.
1981	(83)	Apr.(2.54m)	-	-	15.81	30 Dec.
1982	(80)	Apr.(2.52m)				
1983	-	-				
1984	-	-				
1985	(68)	Mar.(2.30m)				
1986	-	-				
1987	(28)	Apr.(1.44m)				

Note: Dischart (*/) in the parenthesis are estimated based on the water levels (**/) provided by Maji-Office and the rating curve assumed by JICA-team

Table 5.6.1 PHYSICAL AND CHEMICAL WATER ANALYSIS

Item	R. Kikuletwa TANESCO Power Station	R. Himo Moshi-Teveta Road Bridge	R. Yongoma Same-Kihurio Road Bridge	R. Sesseni Maji Gauging Station	R. Hingilill Vuje Village
1. Ref. No. at Laboratory	DP/CPL, E/MHP/II	DP/CPL, E/MHO/II	DP/CPL, E/MHP/III	DP/CPL, E/MHP/II	DP/CPL, E/MHP/I
2. Date of Test	March 3, 1988	March 3, 1988	March 3, 1988		
3. Physical Examination					
Turbidity (N.T.U.)	20	14	50	40	25
Settleable matter (ml/lit)	less than 0.1	less than 0.1	less than 0.1	-	-
Colour (mg pt/lit)	15	20	40	50	20
pH	8.4	7.0	8.2	-	-
Conductivity at 25°C (uS/cm)	100	99	97	155	39
4. Chemical Examination (mg/lit)					
Alkality (as $CaCO_3$)					
Phenophthalein	20	Nil			
Total	570	60			
Hardness (as $CaCO_3$)					
Carbonate		52			
Non-carbonate		Nil			
Total		52			
Calcium		10.8			
Magnesium		6.1			
Iron	0.08	Nil	0.02	0.009	Nil
Ammonical Nitrogen	Nil	Nil	Nil	Nil	
Nitrate Nitrogen	0.9	0.04	0.3	0.02	0.12
Nitrite Nitrogen	less than 0.001	less than 0.001	less than 0.001		
Chloride	3.5	3.6	8.5	14.2	7.1
Permanaate Value (as $KMnO_4$)	1.2	1.8	4.6	3.0	3.0
5. Judgement	Alkaline Water	Moderate Soft Water	Alkaine & Slightly Turbid		

Fig.5.3.1(1) MONTHLY RAINFALL

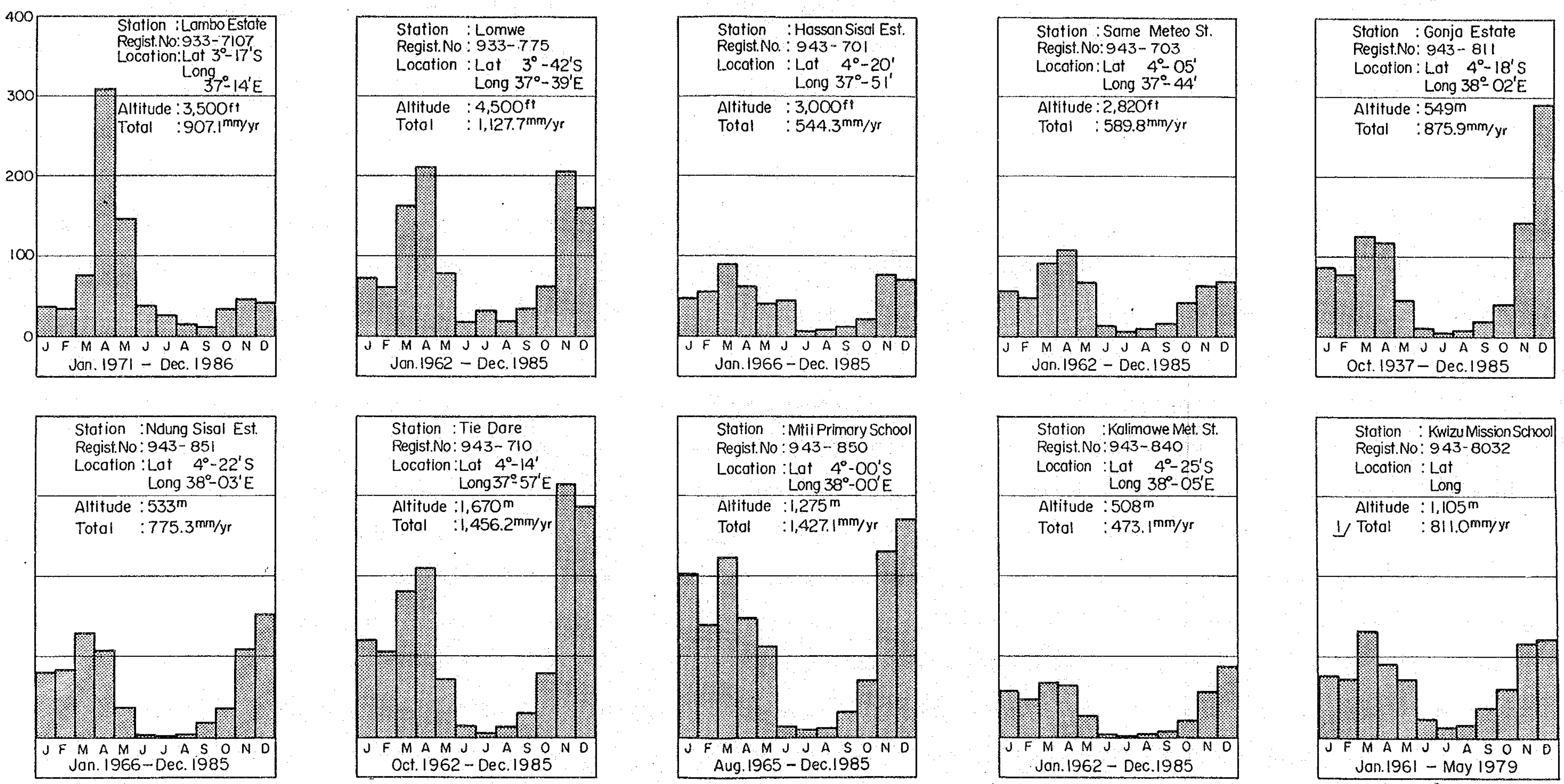


Fig. 5.3.1 (2) MONTHLY RAINFALL

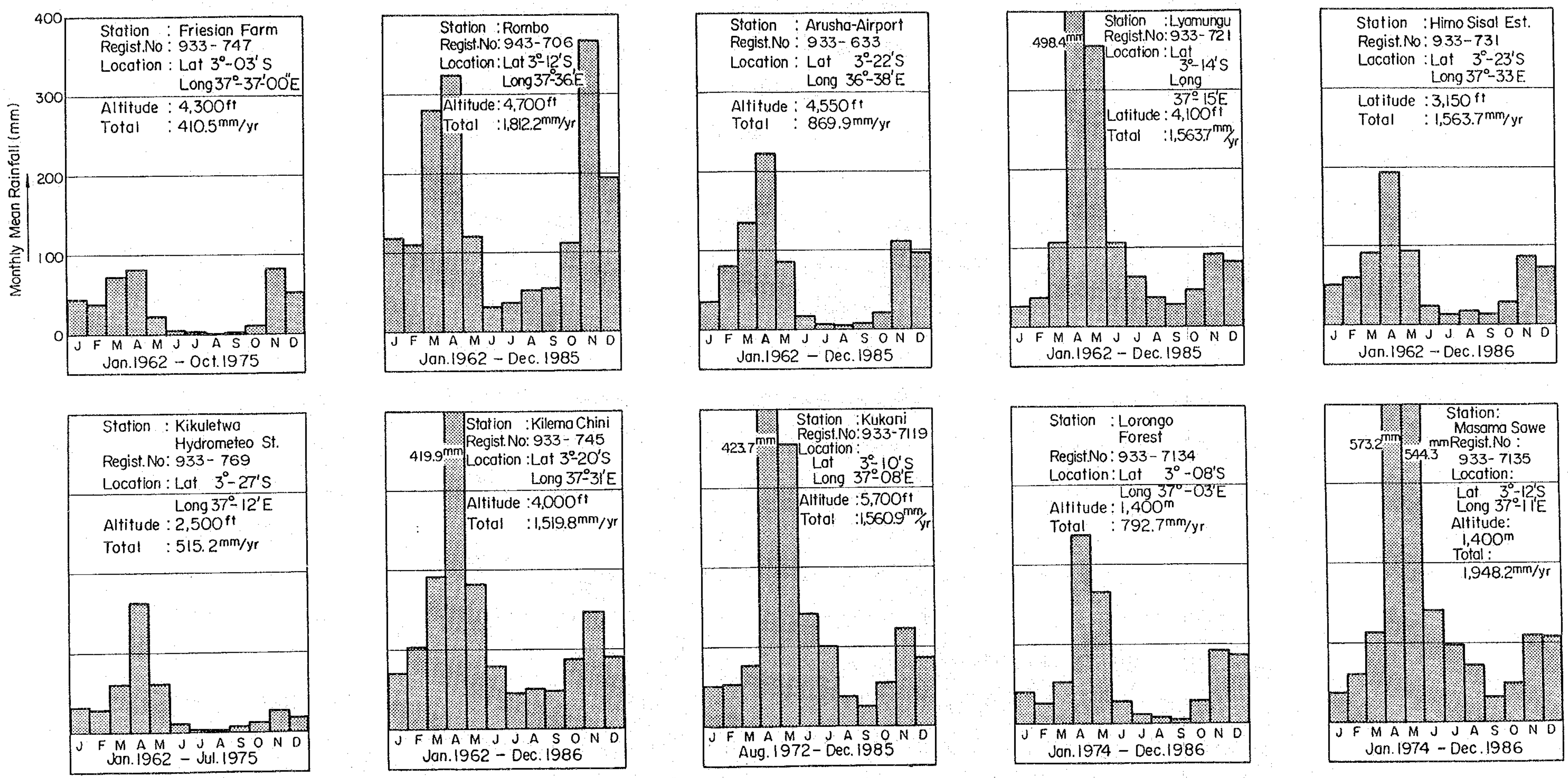
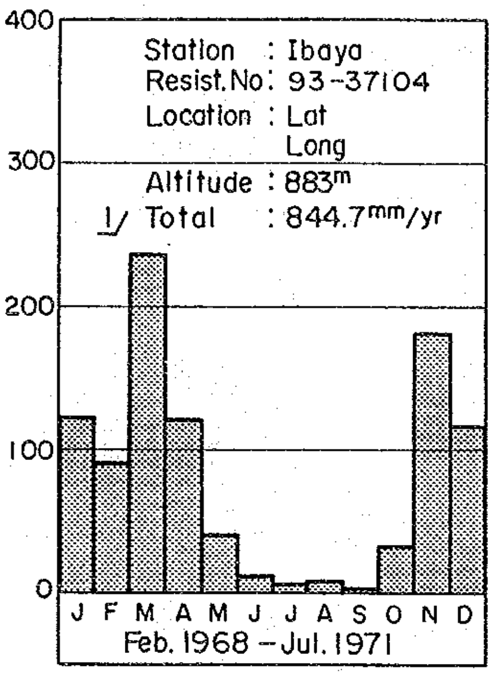
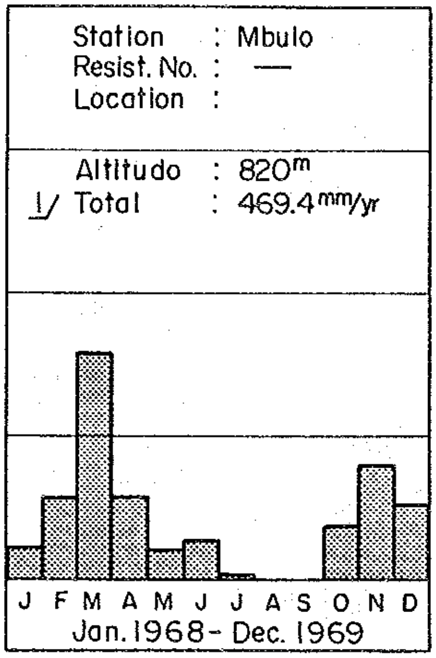


Fig. 5.3.1 (3) MONTHLY RAINFALL





1/ According to the data in F/S report for Mkomazi Valley Irr. Development Project.

Fig. 5.3.2(1) ISOHYETAL MAP IN KILIMANJARO REGION

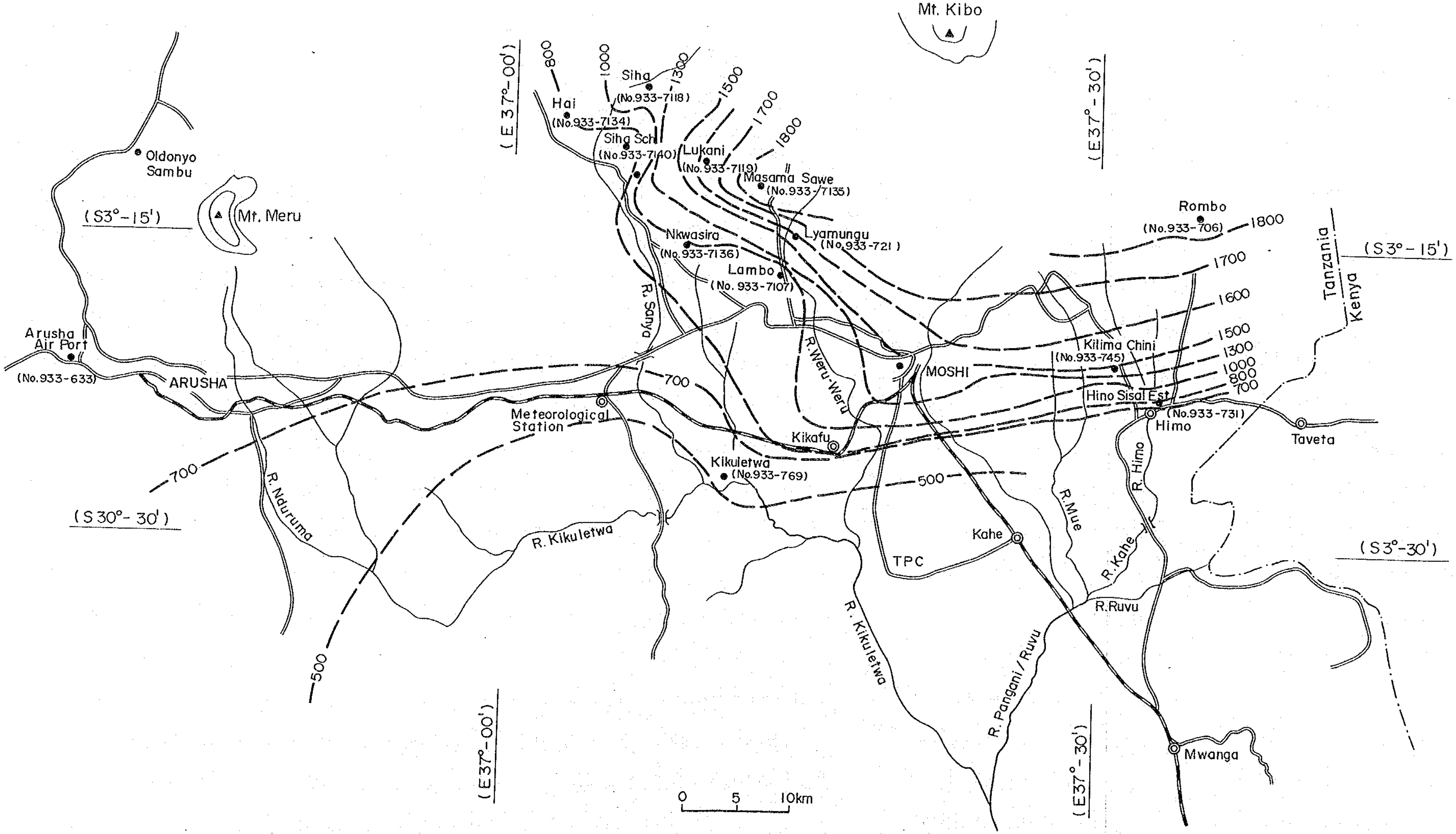
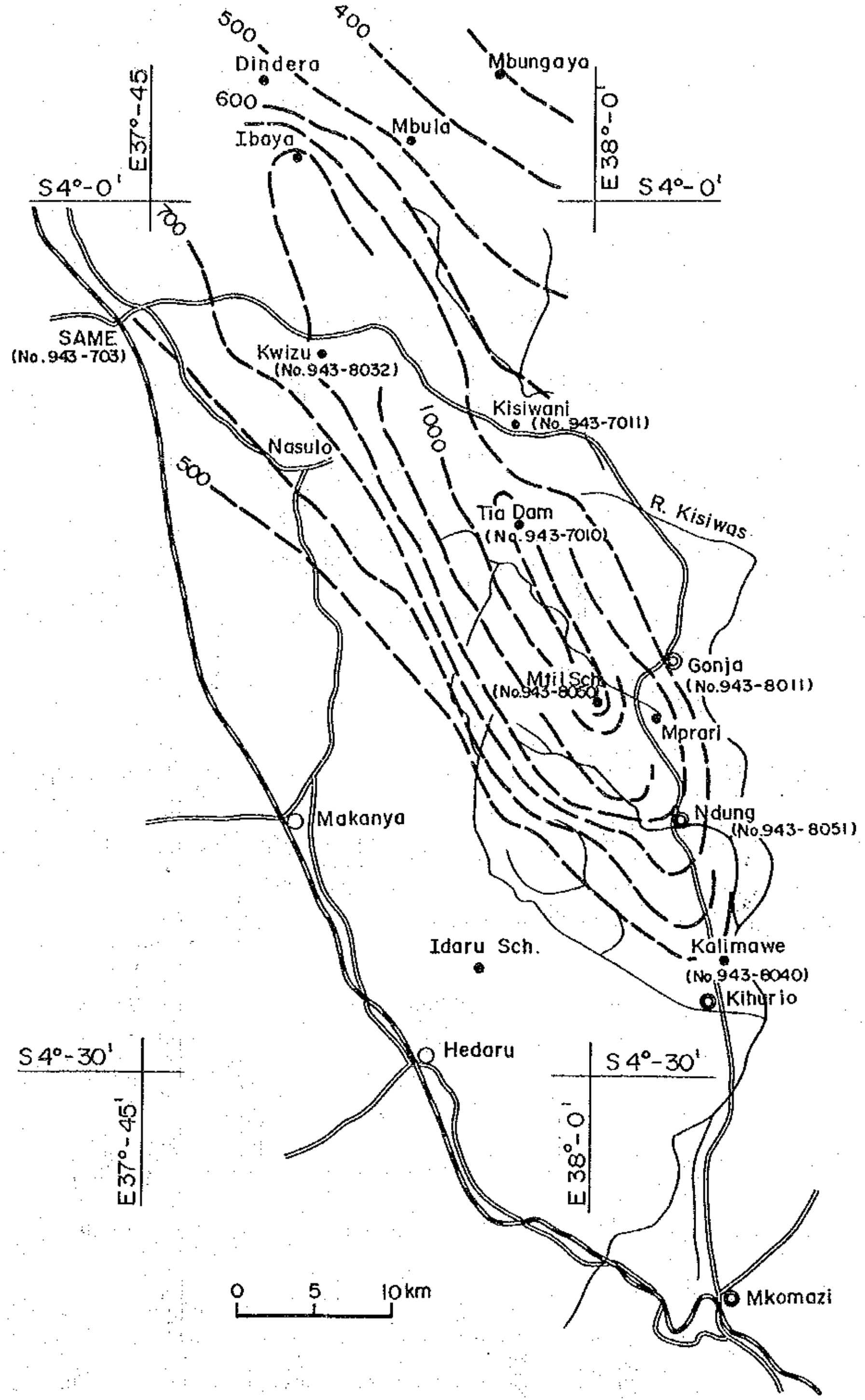


Fig.5.3.2(2) ISOHYETAL MAP IN MT. SOUTH PARE



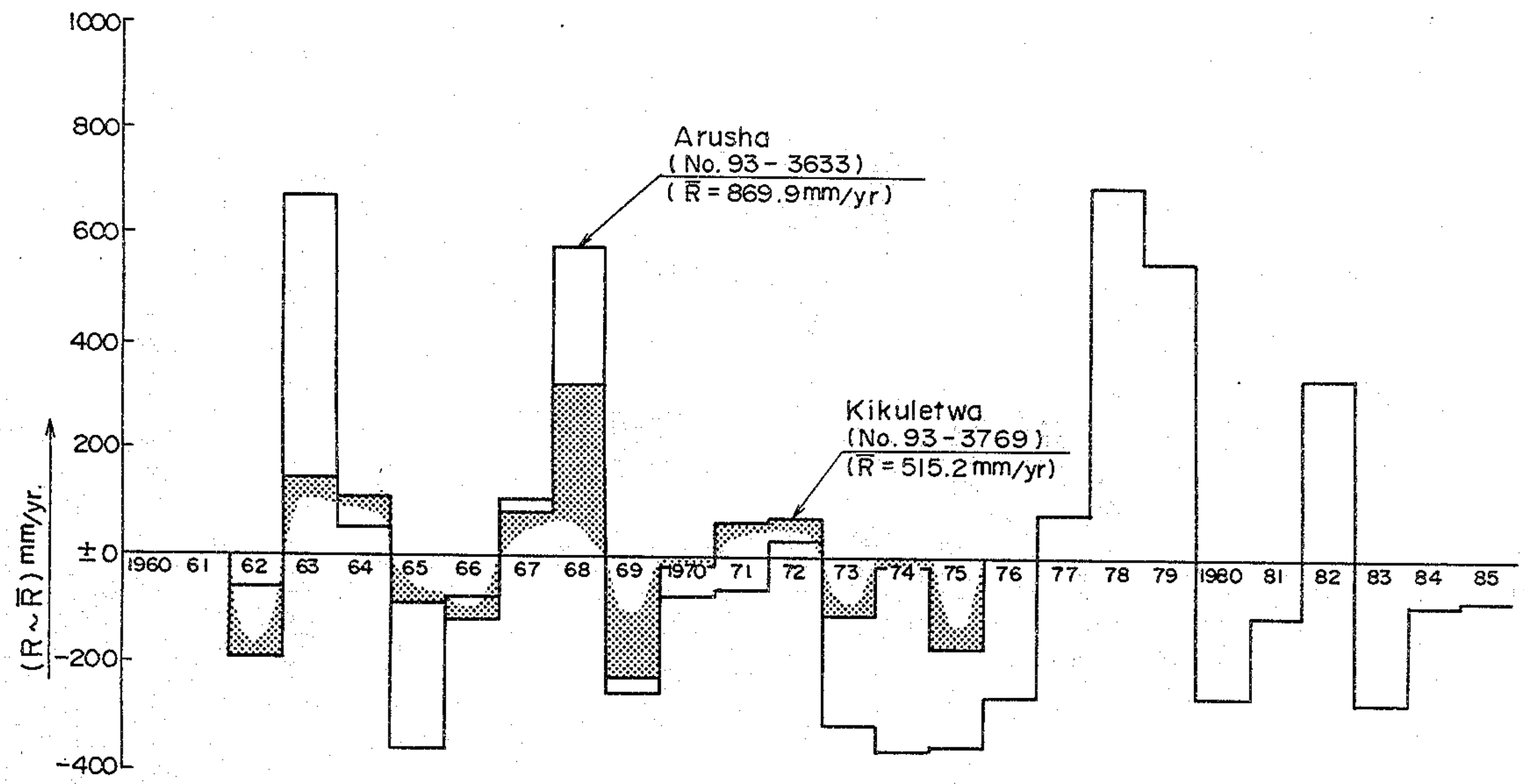


Fig. 5.3.3 ANNUAL HYROLOGY-RAINFALL AT ARUSHA AND KIKULETWA

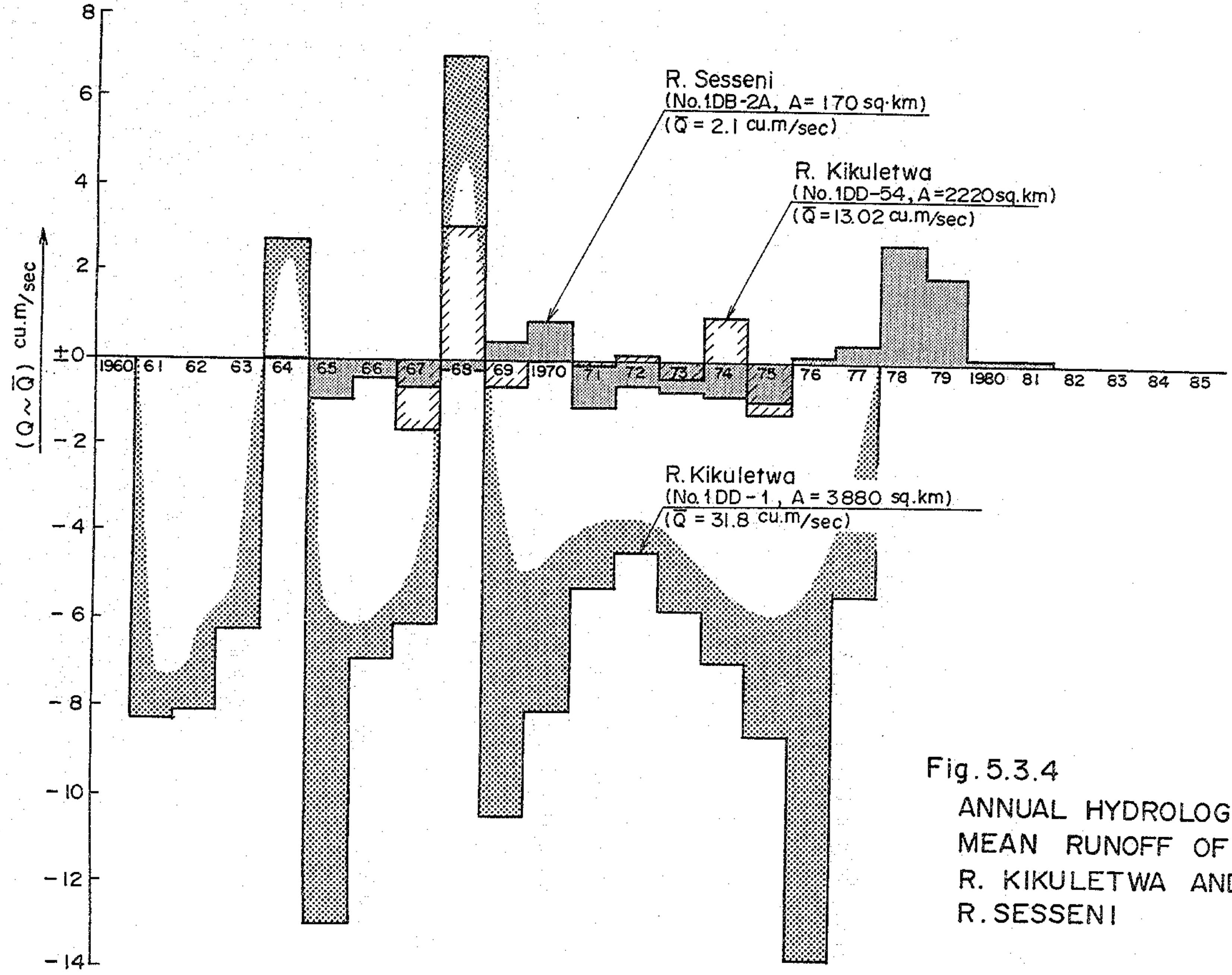


Fig. 5.3.4
ANNUAL HYDROLOGY-
MEAN RUNOFF OF
R. KIKULETWA AND
R. SESSENI

Fig. 5.4.1 MONTHLY MEAN DISCHARGE OF THE KIKULETWA RIVER AT TANESCO POWER STATION (No. IDD - 54)

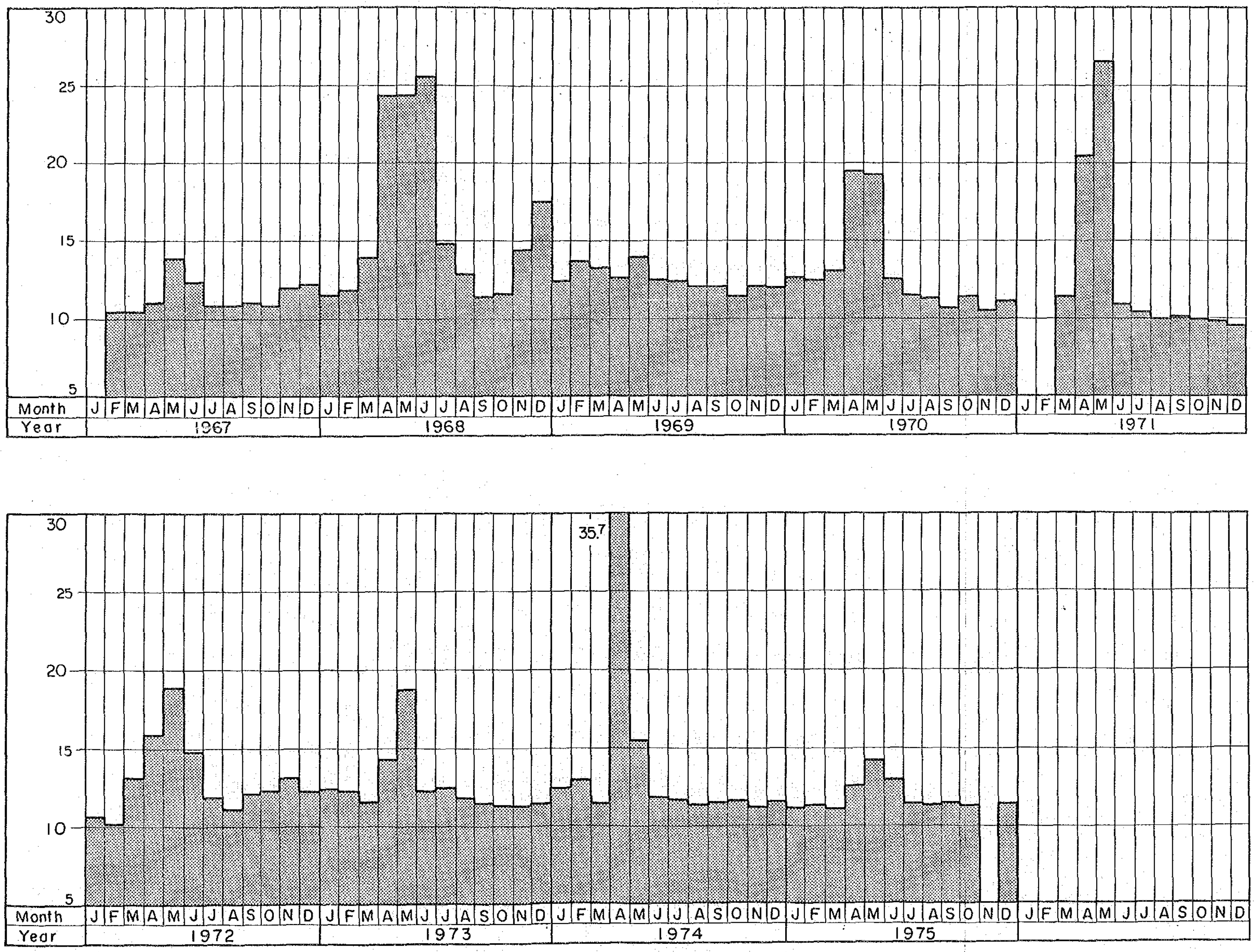
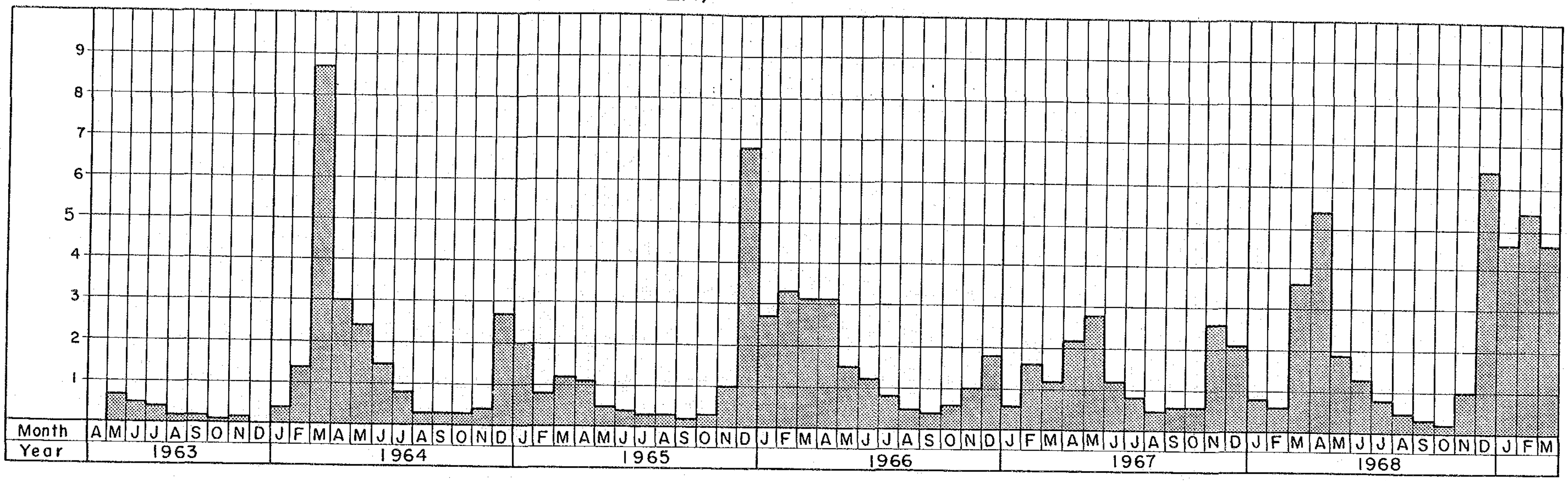


Fig.5.4.2(1) MONTHLY MEAN DISCHARGE OF THE SESSENI RIVER AT GULUTU GAUGING STATION (No. IDB-2A)



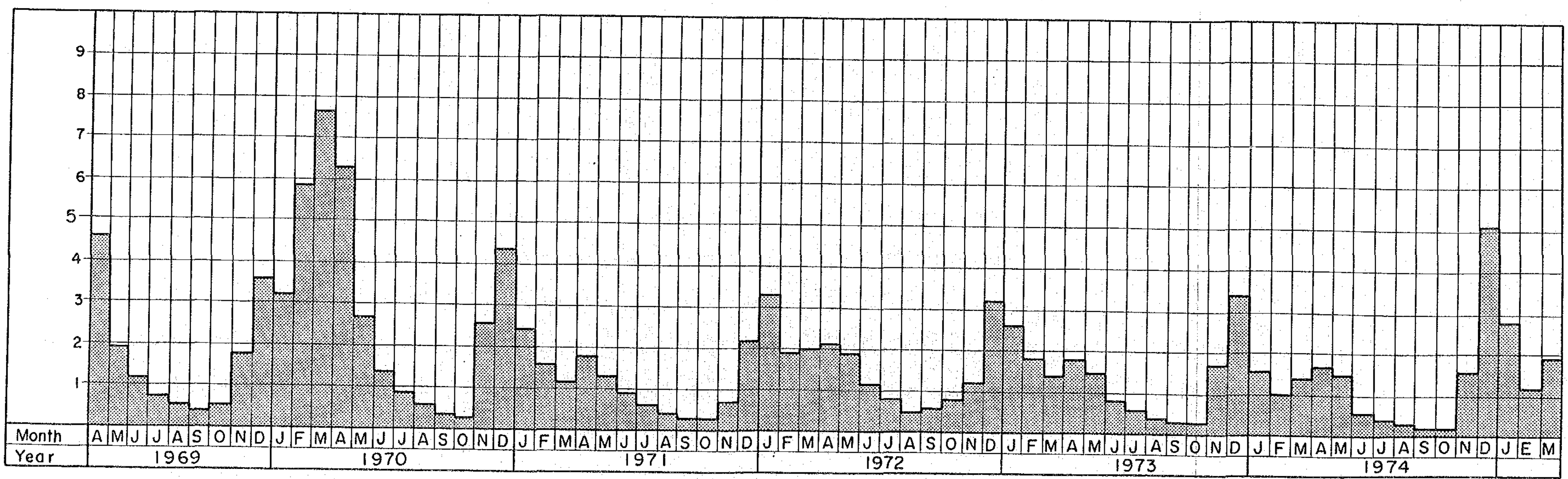
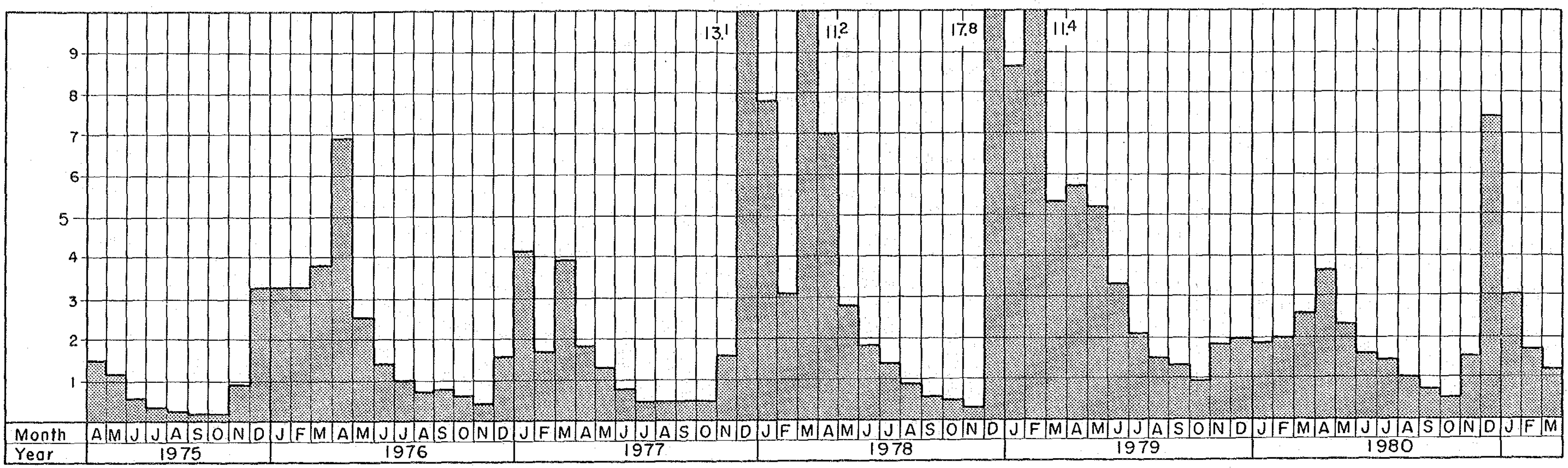


Fig.5.4.2(2) MONTHLY MEAN DISCHARGE OF THE SESSENI RIVER AT GULUTU GAUGING STATION
(No. IDB-2A)



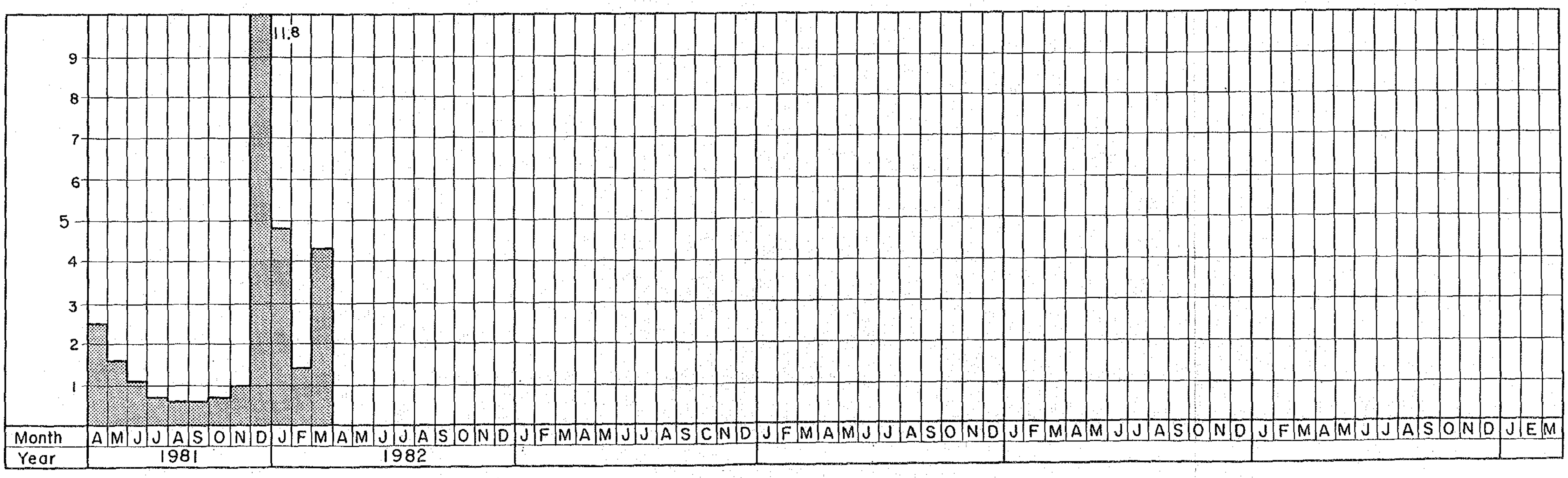
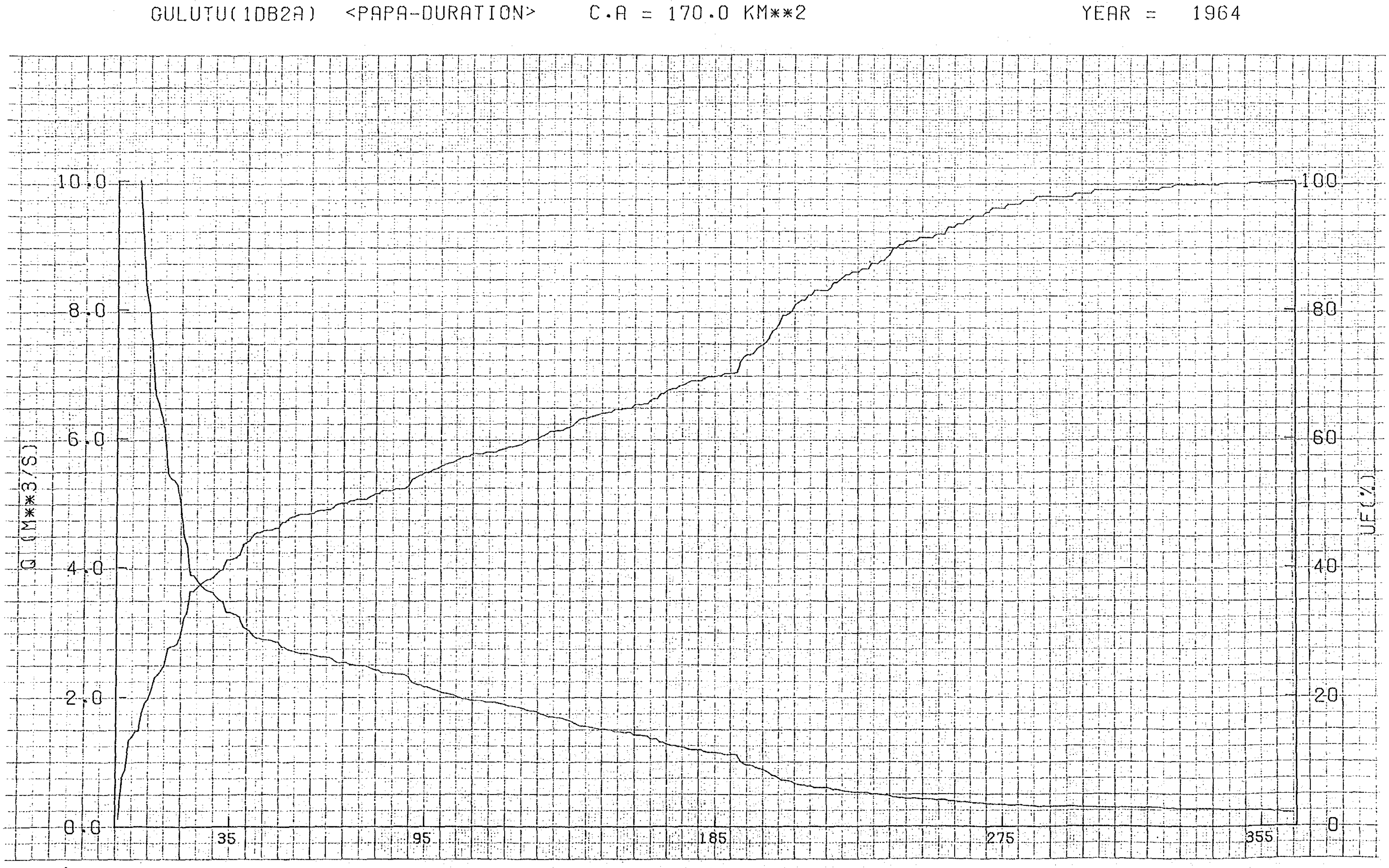


Fig. 5.4.3 (1) DURATION CURVE (Sesseni River in 1964)



2

Fig. 5.4.3 (2) DURATION CURVE (Kikuletwa River in 1970)

TANESCO(1DD54) <PAPA-DURATION> C.A = 2220.0 KM**2 YEAR = 1970

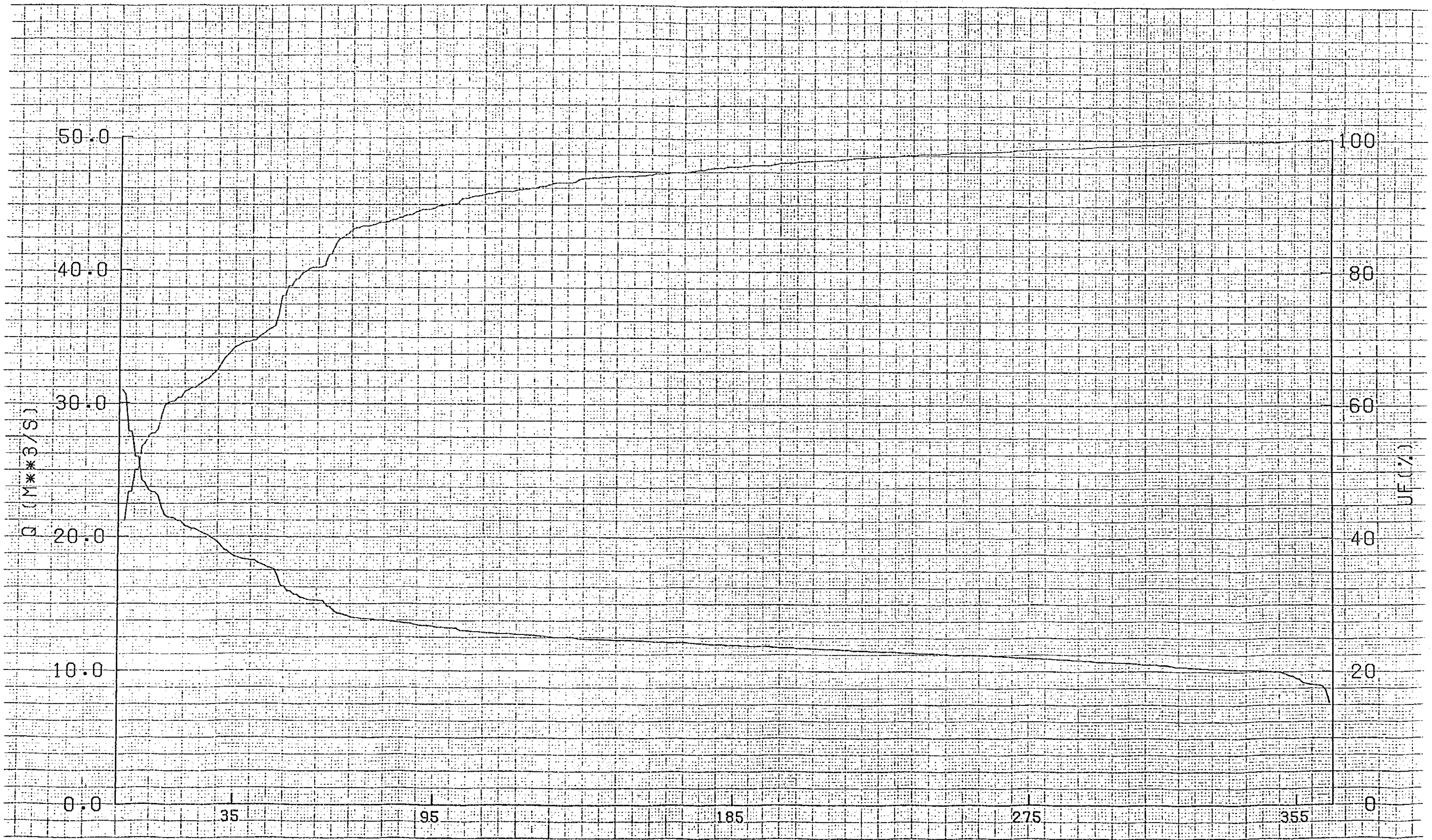


Fig. 5.4.3 (3) DURATION CURVE (Himo River in 1970)

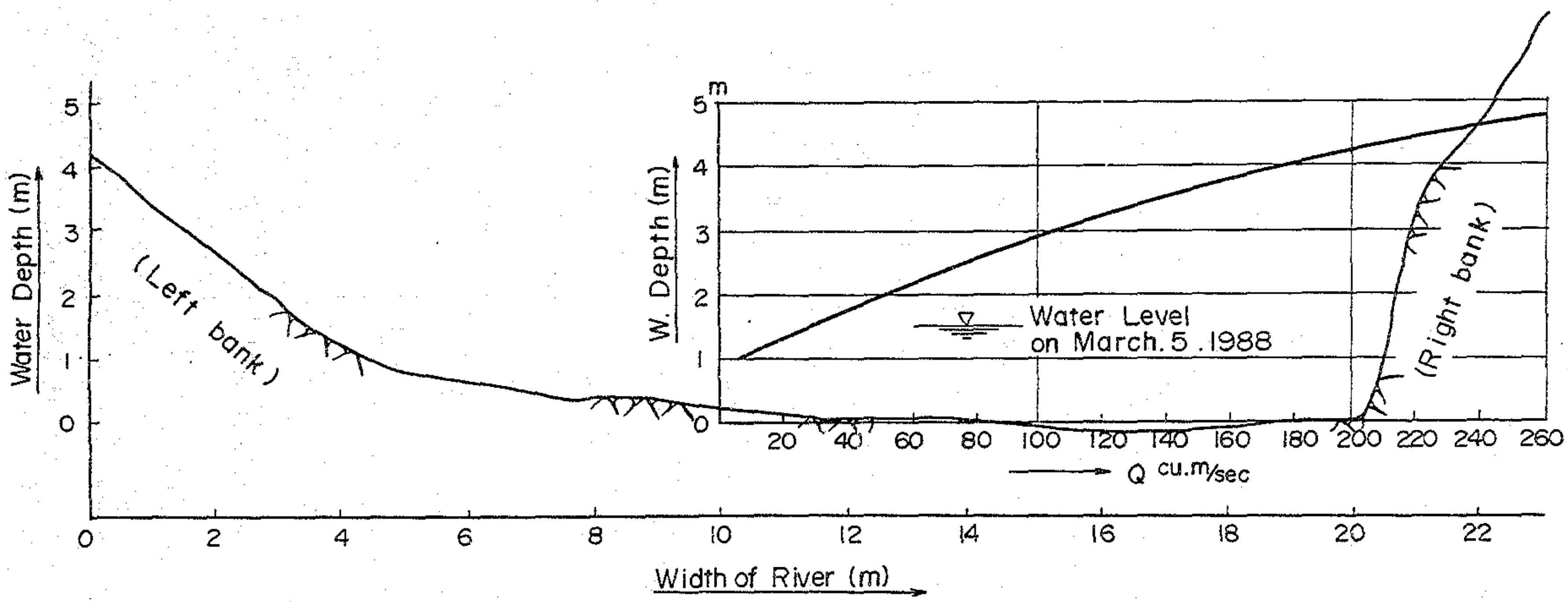


Fig. 5.5.1 CROSS SECTION AND RATING CURVE AT 1DD-54 OF R. KIKULETWA

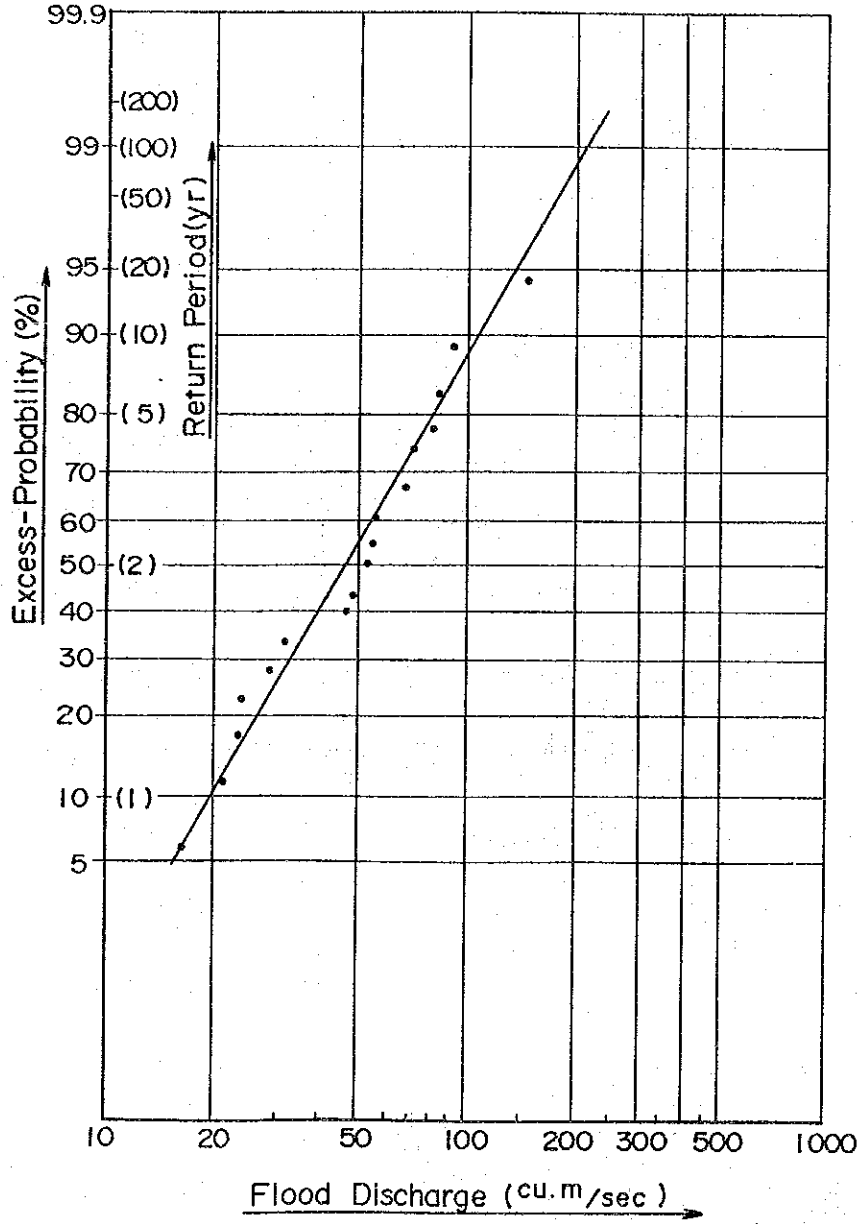


Fig. 5.5.2 PROBABLE FLOOD OF R. KIKULETWA AT GAUGING STATION NO. 1DD-54

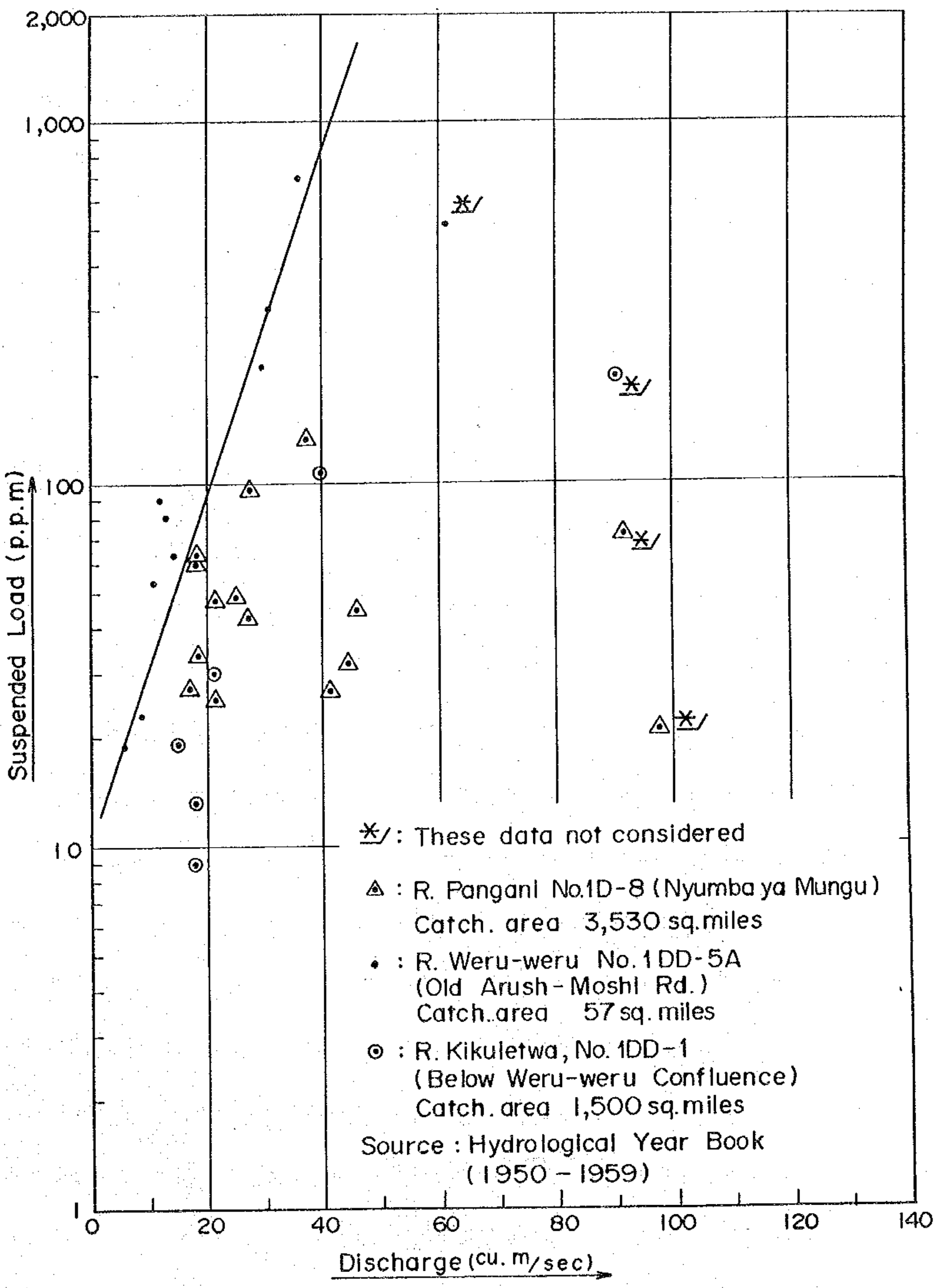


Fig. 5.6.1 SEDIMENTATION - DISCHARGE CURVE

CHAPTER 6
DEVELOPMENT SCHEME

CHAPTER 6 DEVELOPMENT SCHEME

6.1 OUTLINE OF THE KIKULETWA RIVER BASIN

The Kikuletwa River, which flows southeast, drains numerous tributaries rising from the south slopes of Mt. Meru and Mt. Kilimanjaro, merges with the Pangani River, and empties into the Indian Ocean south of Tanga.

Kikuletwa Hydropower Station (1,160 kW), Nyumba ya Mungu Hydropower Station (8,000 kW), Hale Hydropower Station (21,000 kW), and Pangani Falls Hydropower Station (17,500 kW) have been developed over this distance to form one of the main electric power source areas of Tanzania.

A feature of the Kikuletwa River is that infiltration water and snowmelt from Mt. Meru and Mt. Kilimanjaro contribute to the river discharge in the dry season, so that a stable runoff is maintained throughout the year. This stable discharge for the above-mentioned power stations is sustained by the base-flow discharge.

The Kikuletwa No. 1 and No. 2 Hydropower Projects are located in the vicinity of the confluence of the Kikuletwa and Kware rivers, approximately 20 km southwest of Moshi. The project area is located on the southern slope of Mt. Kilimanjaro, on a broad, gently undulating plateau of 700-800 m elevation.

The Kikuletwa River forms a steep V-shaped valley cutting through the flat plateau from approximately 2 km downstream of the existing TANESCO Power Station, with a river gradient of about 1/50 from that point. The top soil of the plateau is thin and the basement rock is tuff breccia. The V-shaped valley has been formed by river erosion.

6.2 POWER GENERATION SCHEME

6.2.1 Kikuletwa No. 1 Hydropower Development Project (Rehabilitation Plan)

The existing TANESCO Power Station, completed in 1935-1936, is a run-of-river power station with an installed capacity of 1,160 kW.

The electric power produced here is supplied mainly to Moshi. Because of a lack of replacement parts, adequate maintenance of the power station has not been carried out. The civil structures and electromechanical equipment have seriously deteriorated, and the station is being operated at only about 40 percent of its installed capacity. Repair or rehabilitation is urgently needed.

Repair and reinforcement of deteriorated parts can keep civil structures, such as intake dams and headrace canals, in service for prolonged time periods. Electromechanical equipment, such as turbines and generators, however, cannot be completely rejuvenated by merely exchanging parts. Moreover, repair costs would be roughly the same as that required for installing new equipment.

The Kikuletwa No. 1 Hydropower Development Project (Rehabilitation Plan), therefore, calls for the reinforcement, insofar as possible, of the existing civil structures, such as intake dams and headrace canals, and for the construction of a new 1,500 kW power station at the site of the existing power station. Further, the plan would utilize the available head between the intake of the existing Kikuletwa Power Station and the high water level of the intake dam for the planned Kikuletwa No. 2 Hydropower Development Project approximately 2 km downstream. With this scheme, a maximum available discharge of 15.4 cu.m/sec and an effective head of 12.7 m will be made available to generate a maximum of 1,500 kW.

The annual energy production of this power station is estimated at 10.5×10^6 kWh. The generated power is to be transmitted to Moshi along an existing 33 kV transmission line.

The outline of the Kikuletwa No. 1 Hydropower Development Project (Rehabilitation Plan) is as follows:

(a) Intake Facilities on Kikuletwa and Kware Rivers

The sediment deposited, by landslides from both abutments, on the upstream side of the intake dams is to be removed, and the gates will be repaired. Concrete damaged with the deterioration of intake facilities is to be replaced with fresh concrete.

(b) Headrace Canals from the Kikuletwa and Kware Rivers

Both open canals are presently unlined, and sliding of the canal slopes has resulted in a considerable deposition of debris at the canal bottoms. These deposits will be removed, and the canal floor will then be trimmed and lined with concrete. As the canal walls are unlined, many parts are damaged, and there are leaks in many places. Because there is also the risk of slope sliding, the slopes are to be stabilized with shotcrete after having been trimmed.

(c) Head Tank

The Kikuletwa No. 1 Hydropower Development Project calls for the existing head tank to be enlarged and used in the Rehabilitation Plan. The deteriorated concrete at certain parts of the head tank wall will be repaired.

(d) Penstock and Powerhouse

The relative positions of the penstock route and powerhouse were investigated, and it was determined that the powerhouse will be designed as a semi-underground structure, and that the penstock will be installed underground.

(e) Generating Equipment

A propeller type turbine is considered suitable for this power station. The S-type tubular turbine and the Kaplan turbine were studied. Because the difference between dry-season discharge and average discharge is small (as described in Chapter 5), there would be very little variation in turbine efficiency. It was determined that a horizontal-shaft S-type tubular turbine, which will require less excavation for the powerhouse foundation, was adopted.

The generator is to be 3-phase, AC, and synchronous. Because the output of the project will be small in comparison with the total system capacity in the area, and because any outages here will have little effect on the system, one unit is considered sufficient and appropriate. This is also favorable from the viewpoint of ease of operation.

(f) Transmission and Transformation Scheme

The substation is to be located adjacent to the switchyard, which is approximately 100 m downstream of the existing power station. The present transformer, cables, and terminal box, which are leaking oil, are to be replaced with new units. The existing 33 kV transmission line is to be used without modification.

(g) Timing of Development

Given the present situation of a supply capability shortage in the Kilimanjaro Region, which is resulting in an excessive bus voltage drop in the region, the Project should be implemented as soon as possible. Rapid implementation will allow the station to be commissioned in 1991, which will help to alleviate the voltage drop.

(h) Construction Cost and Construction Period

The construction cost of the Kikuletwa No. 1 Hydropower Development Project was estimated on the assumption that the present engineering levels would be adopted for the preliminary design, construction methods, and construction materials, and taking into consideration the topography, geology, regional conditions, construction environment, and other characteristics of the project area. The cost estimate was made on the basis of March 1988 prices. The construction cost is estimated at US$7.198 million, as described in Chapter 11. The construction period is estimated to be 15 months.

(i) Economic Evaluation

An economic evaluation of the Project by the internal rate of return method yields an EIRR of 13.30 percent. Applying a discount rate of 10 percent, the benefit-cost ratio will be 1.27.

(j) Project Features

A detailed study of the optimum development scale is described in Chapter 7.

6.2.2 Kikuletwa No. 2 Hydropower Development Project

According to the results of study conducted during the Identification Stage, this project site is the second most economically favorable, following the Kikuletwa No. 1 Project. With this project, a development scale that can strengthen the power system in the Kilimanjaro Region can be realized. The Kikuletwa River, from the proposed intake dam site for this Project to the existing power station tailrace upstream, has a comparatively gentle gradient of about 1/500.

On the other hand, the river gradient downstream of the proposed intake dam site is steep, at approximately 1/50. Using the head of 78.2 m by a headrace of 3,300 m, a maximum output of 11,000 kW can be produced, with a maximum power discharge of 17.9 cu.m/sec. The annual energy production at this power station is estimated as 67×10^6 kWh. This electric energy will be supplied mainly to Arusha and Moshi, in the northern part of the Kilimanjaro Region.

The outline of the power generation scheme is as follows:

(a) Intake Dam and Daily Regulation Capacity

The intake dam site was selected in consideration of topographical and geological conditions. Geological investigations, including field investigation, indicate that there are no problems with the bearing capacity and permeability of the foundation rock.

Judging from the topographical conditions of the selected dam site, and with a permissible dam height of 13 m, the effective storage volume of the regulating pond will be 118,000 m^3. It will be possible to use this storage volume to supplement the discharge during the dry season. As described in Chapter 7, 4.4 hours of peak generation can be achieved by 17.9 m^3/sec discharge even in the low-water season.

One sand flush gate will be provided to handle the sediment deposited at the upstream face of the intake dam. Flood flows will be discharged from a non-gated-overflow section provided at the center of the dam.

(b) Headrace, Head Tank and Penstock

A 3,300-km non-pressure headrace, consisting of culvert and open canal, is planned for the head tank connection. In consideration of economy and ease of construction, the headrace route will be through comparatively flat plateau on the left bank.

The head tank will have an overflow section at the left side wall, and overflow water will be discharged into a stream on the left bank. On the basis of technical and economic comparisons of powerhouse and penstock locations, it was decided that the penstock shall be installed on the ground surface.

(c) Powerhouse

On the basis of various studies, including those concerning the penstock route, it was decided that the powerhouse will be constructed above ground on the left bank of the Kikuletwa River.

(d) Generating Equipment

The Francis turbine is suitable for the basic conditions of the Kikuletwa No. 2 Hydropower Development Project. A vertical-shaft Francis turbine is best suited to the topographical conditions of the powerhouse site. Considering the system operation and the output called for by the development scheme, a plural number of main equipment units is desirable. Considering the equipment scale merit, it is proposed that the power station utilize two units.

(e) Transmission Line and Substation Scheme

A 33 kV double-circuited transmission line is to be constructed between the Kikuletwa No. 2 Power Station and the Kiyungi Substation. An outdoor switchyard is to be provided at a flat area near the head tank. A 33 kV overhead line is to be used to connect the equipment between the outdoor switchyard and the powerhouse. 33 kV double-circuited switchgears are to be added at the Kiyungi Substation.

(f) Timing of Development

The Kikuletwa No. 2 Hydropower Development Project is not considered in TANESCO's master plan (reviewed in 1987) of the power sector. On the basis of the power demand and supply balance in the Arusha-Kilimanjaro region, however, it is felt that the Project should be commissioned by about 1994. From the standpoint of power system planning, and to help cope with the increasing power demand in the region, to help mitigate the voltage drop, and to supplement the shortage of reactive power, it is desirable that the project be implemented as soon as possible.

(g) Construction Cost and Construction Period

The construction cost of the Kikuletwa No. 2 Power Development Project was estimated with due consideration to the topographical, geological, and regional conditions of the site. The estimated construction cost, as described in Chapter 11, is US$49.400 million.

On the basis of the various conditions which apply, the construction period is estimated at 48 months.

(h) Economic Evaluation

The EIRR of this Project is 12.03 percent. At a discount rate of 10 percent, the benefit-cost ratio will be 1.17.

(i) Project Features

A detailed study of the optimum development scale is described in Chapter 7.

CHAPTER 7
OPTIMUM DEVELOPMENT SCALE

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7.1 STUDY ON PROJECT FEATURES

The output of a hydropower station is determined by the available head and the runoff. The head is mainly governed by the topographical features of the intake and tailrace sites.

As mentioned in Chapter 6, it was decided that the best option for the Kikuletwa No. 1 Hydropower Development Project is to utilize the existing intake facilities, while the best option for the Kikuletwa No. 2 Project is to locate the intake dam 2.2 km downstream of the existing TANESCO Power Station. Given the topographical and geological conditions, the basic layouts for these two plans would not change even if the development scale were to change. Consequently, the development scale depends on the effective head and maximum power discharge.

At both project sites, the effective heads are determined by the intake water levels of the regulating ponds, the hydraulic losses of the headraces, and the water levels at the tailraces. Since the effective heads would not greatly change in response to change in the development scale, comparison studies of several development scales were made for cases when the maximum power discharges were as follows.

Kikuletwa No. 1 : 16.4 cu.m/sec, 15.4 cu.m/sec, 13.3 cu.m/sec, 12.0 cu.m/sec and 11.0 cu.m/sec

Kikuletwa No. 2 : 20.6 cu.m/sec, 17.9 cu.m/sec, 15.1 cu.m/sec and 13.8 cu.m/sec

7.2 EVALUATION ON OPTIMUM DEVELOPMENT SCALE

7.2.1 General

The evaluation, which utilizes an equalizing discount rate, is based on the "economic internal rate of return" (EIRR). The evaluation compares the present value of the total costs incurred from start of construction through to a specified time after operation startup, to the present value of the total costs which would be incurred over the same period by an alternative thermal power station.

7.2.2 Classification of Electric Power and Electric Energy in Supply Pattern

(1) Firm Output: P_{Fr}

Since Kikuletwa No. 1 Power Station is a run-of-river station, firm output is determined by the daily river discharge. That is, the firm output at the time of firm discharge is expressed by the following equation:

$$P_{Fr} = 9.8 \cdot \eta \cdot H_e \cdot Q_{LL}$$

where, $P_{Fr} \leqq Pmax$

η : total generating efficiency (0.85)

H_e : effective head (m)

Q_{LL}: firm discharge (cu.m/sec)

Firm discharge (Q_{LL}) is the discharge available throughout the year. Using the discharge (Qd) estimated at the damsite, as described in Chapter 5, the firm discharge was taken to be the average value (10.54 cu.m/sec) of the 90-percent discharge of the runoff duration for the 9 years from 1968 through 1975.

(2) Firm Peak Output (P_F)

Since Kikuletwa No. 2 Power Station will have daily regulating capability, the firm output will be determined by the pattern of the daily load of power demand and the daily river discharge. That is, the firm peak output at the time of firm discharge is expressed by the following equation:

$$P_F = 9.8 \cdot \eta \cdot H_e \cdot Q_{LL} \cdot 24/T_p$$

where, $P_F \leqq P_{max}$

η : total generating efficiency (0.85)

H_e : effective head (m)

Q_{LL}: firm discharge (cu.m/sec)

Tp : peak duration time (hr)

(3) Annual Energy Production (E_r)

The annual energy production was taken to be the average value of the annual total energy production at the generator end calculated using the daily discharge at the dam site during the 9-year period from 1967 through 1975.

7.2.3 Calculation of Energy Production

The electric power and electric energy production defined in 7.2.2 are calculated by the method shown in Fig. 7.2.1 using the runoff data. The results are shown in Tables 7.2.1 and 7.2.2. The daily available discharge for power generation at the damsite for the 9-year period from January 1, 1967 to December 31, 1976 is shown in Tables 7.2.3 and 7.2.4.

7.2.4 Benefits

Only the direct benefits accruing from the electric power to be produced at Kikuletwa No. 1 and No. 2 Power Stations were considered.

Construction costs, operation and maintenance costs, and equipment replacement costs for alternative equivalent thermal power stations were estimated. These costs were considered to be the benefits of the proposed hydropower projects.

7.2.5 Costs

The costs for the individual cases used in evaluating the power generation projects consist of construction costs and operation and maintenance costs (O&M).

(1) Construction Cost

The construction cost comprises the cost for civil facilities, including access roads and preparatory work, hydraulic equipment; electro-mechanical equipment; and transmission and transformation facilities. Engineering and administrative costs, and a contingency amount, were also added in arriving at a total construction cost.

The construction cost was estimated at March 1988 prices.

(2) Operation and Maintenance Cost

The operation and maintenance cost was calculated based on the calculated construction cost, to which were applied the following ratios.

Civil facilities:	1%
Hydraulic equipment:	2%
Electro-mechanical equipment:	2%
Transmission and transformation facilities:	1.5%

(3) Costs

Cost breakdowns for the individual cases studied are shown in Tables 7.3.2 and 7.3.5.

7.3 OPTIMUM DEVELOPMENT SCALES

7.3.1 Kikuletwa No. 1 Hydropower Development Project (Rehabilitation Plan)

(1) Maximum Power Discharge

Comparison studies were made of the five cases given in Table 7.3.1 by applying maximum power discharges of between 11.0 and 16.4 cu.m/sec.

The relationships between benefits and costs of these cases are shown in Fig. 7.3.1 and Table 7.3.3. For all the cases, the water level of the head tank was taken to be 830.30 m. The maximum power discharge of 15.4 cu.m/sec, achieved in Case 2, was found to be the optimum scale; the output for this would be 1,500 kW.

The factors for determining the maximum power discharge in the rehabilitation plan are, first, the runoff at the intake dam site, and second, the equipment cost for electro-mechanical equipment, etc.

As indicated by Fig. 7.3.1, the benefit curve shows a section of gradual increase between 11 and around 15.4 cu.m/sec, and a section of more sudden increase. Benefit increases as the maximum power discharge increases, and the curve shape becomes similar to the runoff duration curve.

In determining cost, the electro-mechanical equipment cost and the headrace construction cost are the principal variables. The headrace construction cost is roughly constant up to 15.4 cu.m/sec, so that the gradient of the cost curve as equipment capacity changes will be roughly constant. For power discharge greater than 15.4 cu.m/sec, however, the electro-mechanical equipment cost increases greatly, and the curve gradient becomes steeper.

The benefit-cost curve relationship, therefore, indicates that the optimum scale is 15.4 cu.m/sec.

(2) Rated Head

The normal water level of the head tank is EL. 830.30 m. This is the level which will permit the continued use of the present facility as described in Chapter 9. From the viewpoint of topography, too, it would be difficult to draw water at a higher intake level.

The tailrace water level is set at EL. 817.40 m, in consideration of the influence of back-water on the intake level at Kikuletwa No. 2, which will be constructed 2.2 km downstream.

(3) Costs

The costs for the Kikuletwa No. 1 Project are shown in Table 7.3.2.

7.3.2 Kikuletwa No. 2 Hydropower Development Project

(1) Maximum Power Discharge

The results of comparison studies of four cases of maximum power discharge between 13.8 and 20.6 cu.m/sec are shown in Table 7.3.4. The relationships of maximum power discharge, benefit, and cost are shown in Fig. 7.3.2. and Table 7.3.6. The water level of the head tank is EL. 812.3 m. Based on this figure, the optimum maximum power discharge is around 17.9 cu.m/sec (Case 2), producing an output of 11,000 kW.

There are three principal factors for determining the maximum power discharge of this hydropower plan. The first is the runoff duration at the intake dam site, the second is the headrace construction cost, and the third is the electro-mechanical equipment cost.

As Fig. 7.3.2 shows, the benefit curve shows a comparatively gradual increase as maximum power discharge increases. The kWh-value and the kW-value of the electricity contribute to this tendency.

For determining cost, the principal variable factors in this case are the electro-mechanical equipment cost and the headrace construction cost. The cost per kilowatt of electro-mechanical equipment will vary more or less linearly. The headrace construction cost curve shows a split at the point for Case 2; the variation in construction cost per kilowatt is large from Case 4 to Case 2, and is small from Case 2 to Case 1 is small.

Based on the benefit and cost curves, the optimum maximum power discharge is about 17.9 cu.m/sec.

(2) Regulating Pond Capacity of Kikuletwa No. 2 Hydropower Station

The power discharge of the Kikuletwa No. 2 Hydropower Development Project will be governed by the inflow at the intake site. The monthly average available discharge at the intake site of Kikuletwa No. 2 Power Station, in the case of a maximum power discharge of 17.9 cu.m/sec, will be 12.38 cu.m/sec (9-year average from 1967 to 1975), with a maximum monthly average available discharge of 15.68 cu.m/sec in May, and a minimum monthly average available discharge of 11.26 cu.m/sec in September.

The 90-percent firm discharge for the 9-year period from 1967 to 1975 is 10.54 cu.m/sec. If a regulating pond is not provided at the Kikuletwa No. 2 intake site, it will not be possible to regulate the discharge to correspond to variations in power demand. In such a case, the power station output would fluctuate corresponding to variation in available power discharge, and the value of the power station would suffer. A regulating pond is, therefore, required. The considerations described below indicate that the regulating pond capacity of the Project is 117,800 cu.m.

(i) Required regulating Capacity from Representative Daily Load Curve of Power Demand

Assuming that Kikuletwa No. 2 Power Station supplies electric power for peak demand of the daily load curve in the dry season, the following regulating capacities will be necessary at 90-percent firm discharge (10.54 cu.m/sec).

Peak Duration	Regulating Capacity Required
5 hr :	132,000 cu.m; (17.9-10.54) cu.m/sec x 5 hr x 3,600 sec
4 hr :	106,000 cu.m; (17.9-10.54) cu.m/sec x 4 hr x 3,600 sec
3 hr :	79,000 cu.m; (17.9-10.54) cu.m/sec x 3 hr x 3,600 sec

Based on the actual daily load curve of the Arusha and Moshi areas as recorded on September 24, 1987, the peak duration time is estimated to be 4 to 5 hours. (See Figs. 7.3.4 & 7.3.5)

As the Kikuletwa No. 2 Hydropower Station is to supply power to meet peak demand, a storage capacity for about 4.4-hour peak (18% peak) operation is considered necessary.

The regulating capacity necessary for 4.4-hour peak operation will be 116,600 cu.m, as calculated below.

(17.9-10.54) cu.m/sec x 4.4 hr x 3,600 sec
= 116,600 cu.m

(ii) Storage Capacity of Regulating Pond

The water level and storage capacity curve for the intake site are shown in Fig. 7.3.3. The total storage capacity will be 208,800 cu.m at the regulating pond's normal high water level of EL. 818.00 m. At the low water level of EL. 816.00 m, the storage capacity will be 91,000 cu.m. Consequently, the regulating pond capacity will be 117,800 cu.m. (208,800 m^3 - 91,000 m^3).

(iii) Variation in Power Discharge

The power discharge of Kikuletwa No. 2 Power Station will vary according to the inflow at the intake site.

In case of peak duration time of 4.4 hours,

(1) Off-peak power discharge at 90-percent firm discharge of 10.54 cu.m/sec.................... ... 8.89 cu.m/sec

(2) Off-peak power discharge at minimum monthly average intake of 11.26 cu.m/sec .... 9.77 cu.m/sec

(3) Off-peak power discharge at monthly average intake of 12.38 cu.m/sec .... 11.14 cu.m/sec

The relationships of the above are shown in Fig. 7.3.6.

It is thought that actual daily load will vary considerably, so that the power discharge at off-peak hours will vary according to the peak duration and the inflow.

(3) Costs

The costs of the Kikuletwa No. 2 Project are shown in Table 7.3.5.

Table 7.2.1 ANNUAL ENERGY PRODUCTION AT KIKULETWA No.1 HYDROPOWER STATION

(Unit: 10^3kWh)

Month / Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1967	769.230	695.194	771.090	785.606	1,016.344	872.872	787.704	787.465	772.782	787.441	854.518	912.965	9,813.211
68	845.317	813.185	1,023.352	1,095.696	1,137.958	1,101.250	1,090.762	932.034	804.770	844.840	900.069	1,094.075	11,683.308
69	898.520	896.112	976.132	899.163	998.800	885.243	907.840	880.595	852.205	837.403	874.802	895.302	10,802.117
70	930.032	835.424	916.302	1,098.247	1,120.081	905.528	852.658	834.805	758.385	845.817	755.739	828.202	10,681.220
71	900.570	839.644	920.259	933.011	1,132.333	781.006	768.110	735.549	731.402	735.716	708.399	692.524	9,878.523
72	783.723	706.063	969.338	1,006.428	1,114.003	1,013.031	880.118	822.767	870.393	919.591	939.185	906.291	10,930.931
73	913.346	826.152	860.572	942.188	839.143	872.609	915.563	871.990	825.365	839.667	811.349	846.270	10,364.214
74	874.111	829.012	845.865	1,087.353	1,004.664	843.243	859.785	831.325	818.524	854.375	796.690	841.527	10,486.474
75	824.436	751.162	816.689	869.940	990.958	902.262	845.293	833.661	818.477	837.713	795.903	840.120	10,126.614
Total	7,739.285	7,191.948	8,099.599	8,717.632	9,354.284	8,177.044	7,907.833	7,530.191	7,252.303	7,502.563	7,436.654	7,857.276	94,766.612
Average	859.921	799.105	899.955	968.626	1,039.365	908.560	878.648	836.688	805.811	833.618	826.295	873.031	10,529.624

Table 7.2.2 ANNUAL ENERGY PRODUCTION AT KIKULETWA No.2 HYDROPOWER STATION

(Unit: 10^6kWh)

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1967	4.793	4.332	4.804	4.895	6.352	5.439	4.908	4.907	4.815	4.906	5.324	5.688	61.163
68	5.267	5.067	6.376	7.740	8.231	7.875	6.826	5.807	5.014	5.264	5.825	7.302	76.594
69	5.598	5.583	6.082	5.602	6.320	5.516	5.657	5.487	5.310	5.218	5.451	5.578	67.402
70	5.795	5.205	5.784	7.664	7.911	5.642	5.313	5.201	4.725	5.270	4.709	5.160	68.379
71	5.611	5.266	5.871	6.229	8.039	4.866	4.786	4.583	4.518	4.584	4.414	4.315	63.082
72	4.883	4.399	6.077	6.607	7.660	6.534	5.484	5.126	5.423	5.730	5.866	5.647	69.436
73	5.714	5.148	5.362	6.171	7.477	5.437	5.705	5.433	5.143	5.232	5.055	5.273	67.150
74	5.595	5.396	5.270	7.815	6.520	5.254	5.357	5.180	5.100	5.323	4.964	5.243	67.017
75	5.137	4.680	5.089	5.478	6.479	5.751	5.267	5.194	5.100	5.220	4.959	5.235	63.589
Total	48.393	45.076	50.715	58.201	64.989	52.314	49.303	46.918	45.148	46.747	46.567	49.441	603.812
Average	5.377	5.008	5.635	6.467	7.221	5.813	5.478	5.213	5.016	5.194	5.174	5.493	67.090

Table 7.2.3 AVAILABLE DISCHARGE FOR KIKULETWA No.1 HYDROPOWER STATION

(Unit: cu.m/sec-day)

Month / Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1967	322.71	291.65	323.49	329.58	426.38	366.19	330.46	330.36	324.20	330.35	358.49	383.01	4,116.87
68	354.63	341.15	429.32	459.67	477.40	462.00	457.60	391.01	337.62	354.43	377.60	458.99	4,901.42
69	376.95	375.94	409.51	377.22	419.02	371.38	380.86	369.43	357.52	351.31	367.00	375.60	4,531.74
70	390.17	350.48	384.41	460.74	469.90	379.89	357.71	350.22	318.16	354.84	317.05	347.45	4,481.02
71	377.81	352.25	386.07	391.42	475.04	327.65	322.24	308.58	301.84	308.65	297.19	290.53	4,139.27
72	328.79	296.21	406.66	422.22	467.35	424.99	369.23	345.17	365.15	385.79	394.01	380.21	4,585.78
73	383.17	346.59	361.03	395.27	352.04	366.08	384.10	365.82	346.26	352.26	340.38	355.03	4,348.03
74	366.71	347.79	354.86	456.17	421.48	353.76	360.70	348.76	343.39	358.43	334.23	353.04	4,399.32
75	345.87	315.13	342.62	364.96	415.73	378.52	354.62	349.74	343.37	351.44	333.90	352.45	4,248.35
Total	3,246.81	3,017.19	3,397.97	3,657.25	3,924.34	3,430.46	3,317.52	3,159.09	3,037.51	3,147.50	3,119.85	3,296.31	39,751.80
Average	360.76	335.24	377.55	406.36	436.04	381.16	368.61	351.01	337.50	349.72	346.65	366.26	4,416.87

Table 7.2 4 AVAILABLE DISCHARGE FOR KIKULETWA No.2 HYDROPOWER STATION

(Unit: cu.m/sec-day)

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1967	322.71	291.65	323.49	329.58	427.68	366.19	330.46	330.36	324.20	330.35	358.49	383.01	4,118.17
68	354.63	341.15	429.32	521.16	554.20	530.25	459.63	391.01	337.62	354.43	392.17	491.65	5,157.22
69	376.95	375.94	409.51	377.22	425.52	371.38	380.86	369.43	357.52	351.31	367.00	375.60	4,538.24
70	390.17	350.48	389.41	516.04	532.62	379.89	357.71	350.22	318.16	354.84	317.05	347.45	4,604.04
71	377.81	354.57	395.29	419.43	541.24	327.65	322.24	308.58	304.18	308.65	297.19	290.53	4,247.36
72	328.79	296.21	409.16	444.84	515.73	439.96	369.23	345.17	365.15	385.79	394.97	380.21	4,675.21
73	384.74	346.59	361.03	415.49	503.44	366.08	384.10	365.82	346.26	352.26	340.38	355.03	4,521.22
74	376.71	363.29	354.86	526.17	438.97	353.76	360.70	348.76	343.39	358.43	334.23	353.04	4,512.31
75	345.87	315.13	342.62	368.87	436.22	387.22	354.62	349.74	343.37	351.44	333.90	352.45	4,281.45
Total	3,258.38	3,035.01	3,414.69	3,918.80	4,375.62	3,522.38	3,319.55	3,159.09	3,039.85	3,147.50	3,135.38	3,328.97	40,655.22
Average	362.04	337.22	379.41	435.42	486.18	391.38	368.84	351.01	337.76	349.72	348.38	369.89	4,517.25

Table 7.3.1 STUDY OF DEVELOPMENT SCALE (Maxmimum Discharge)
KIKULETWA NO. 1 HYDROPOWER PROJECT

(Unit: 10^3 US$)

Case	Case 1	Case 2	Case 3	Case 4	Case 5
Catchment Area (km^2)	2,200	2,200	2,200	2,200	2,200
Intake Water level (m)	830.47	830.47	830.47	830.47	830.47
Maximum Discharge (m^3/s)	16.4	15.4	13.3	12.0	11.0
Power Facilities					
Dam Height	Existing	Existing	Existing	Existing	Existing
Canal B x L (m, km)					
Penstock D x L (m, m)	2.6 x 20	2.5 x 20	2.4 x 20	2.4 x 20	2.2. x 20
Turbine Unit No.	1	1	1	1	1
Power Generating Plan					
Head Tank Water Level (m)	830.30	830.30	830.30	830.30	830.30
Tail Water Level (m)	817.40	817.40	817.40	817.40	817.40
Effective Head (m)	12.70	12.70	12.70	12.70	12.70
Max. Discharge (m^3/s)	16.40	15.40	13.30	12.00	11.00
Installed Capacity (MW)	1.74	1.50	1.32	1.19	1.09
Annual Energy (GWh)	11.54	10.53	10.25	9.91	9.36
Firm Energy (GWh)	9.19	9.19	9.19	9.19	9.19
Construction Cost (10^6US$)	8.425	7.198	7.090	6.888	6.766
Economic Evaluation					
Present Value of Benefit ($10^6$$)	8.321	7.756	7.599	7.409	7.101
Present Value of Cost (10^6US$)	7.168	6.124	6.032	5.86	5.756
B-C	1.153	1.632	1.567	1.549	1.345
B/C	1.160	1.267	1.260	1.264	1.233
EIRR	12.03	13.30	13.28	13.29	13.00

Table 7.3.2 CONSTRUCTION COST OF KIKULETWA NO. 1 HYDROPOWER PROJECT

(Unit 10^3US$)

Case	Case 1	Case 2	Case 3	Case 4	Case 5
Installed Capacity (MW)	1.74	1.50	1.32	1.19	1.09
1. Civil Works	2,556	2,446	2,422	2,403	2,344
1-1 Prepatory Works	81	81	81	81	81
1-2 Headrace	1,230	1,230	1,230	1,230	1,230
1-3 Head Tank	296	296	296	296	196
1-4 Penstock & Powerhouse	932	822	798	779	720
1-5 Miscellaneous Works	17	17	17	17	17
2. Hydraulic Equipment	238	210	187	182	168
3. Electromechanical Facilities	4,045	3,168	3,126	2,983	2,955
4. Transmission Line & Substation	125	125	125	125	125
5. Total Cost (1+2+3+4)	6,964	5,949	5,860	5,693	5,592
6. Engineering & Administration (5 x 10%)	696	595	586	569	559
7. Physical Contingency (5+6) x 10%	765	654	644	626	615
Grand Total (5+6+7)	8,425	7,198	7,090	6,888	6,766

Table 7.3.3 CALCULATION OF BENEFIT/COST RATIO
KIKULETWA NO. 1 HYDROPOWER PROJECT (REHABILITATION)

Item	Case 1 ($Q_{max}=16.4m^3/s$)	Case 2 ($Q_{max}=15.4m^3/s$)	Case 3 ($Q_{max}=13.3m^3/s$)	Case 4 ($Q_{max}=12.0m^3/s$)	Case 5 ($Q_{max}=11.0m^3/s$)
Firm capacity (MW)	1.055	1.055	1.055	1.055	1.055
Energy generation (GWh)	11.540	10.53	10.25	9.91	9.360
Investment cost:					
Power station (10^3US$)	8.300	7.073	6.965	6.763	6.641
Transmission line (10^3US$)	0.125	0.125	0.125	0.125	0.125
Cost of alternative diesel power plant (US$/kw)	1,200	1,200	1,200	1,200	1,200
Diesel oil price (US$/barrel)	42.94	42.94	42.94	42.94	42.94
Lubrication price (US$/kg)	2.433	2.433	2.433	2.433	2.433
Cost of alternative diesel (10^3US$)					
- Investment cost	1.357	1.357	1.357	1.357	1.357
- O and M cost	0.506	0.506	0.506	0.506	0.506
- Fuel cost	6.459	5.893	5.736	5.546	5.238
Total (B)	8.321	7.756	7.599	7.409	7.101
Cost of the project (10^3US$)					
- Investment cost	6.109	5.218	5.140	4.993	4.905
- O and M cost	1.059	0.906	0.892	0.867	0.851
Total (C)	7.168	6.124	6.032	5.860	5.756
Benefit/Cost Ratio:(B)/(C)	1.153	1.267	1.260	1.264	1.233
EIRR (%)	12.03	13.30	13.28	13.29	13.00

Table 7.3.4 STUDY OF DEVELOPMENT SCALE (Maxmimum Discharge)
KIKULETWA NO. 2 HYDROPOWER PROJECT

(Unit: 10^3US$)

Case	Case 1	Case 2	Case 3	Case 4
Catchment Area (km^2)	2,280	2,280	2,280	2,280
Intake Water level (m)	818	818	818	818
Maximum Discharge (m^3/s)	20.6	17.9	15.1	13.8
Pondage				
High Water level (m)	818	818	818	818
Low Water Level (m)	816	816	816	816
Total Storage Capacity (10^3m^3)	208.9	208.9	208.9	208.9
Effective Storage Capacity (10^3m^3)	117.9	117.9	117.9	117.9
	(Concrete Gravity)			
Dam (H x L)	13 x 103.5	13 x 103.5	13 x 103.5	13 x 103.5
Head Race (B x H x L)	3x2.8x3.250	3x2.8x3.250	3x2.8x3.250	3x2.8x3.250
Power Generating				
Head Tank Water Level (m)	812.30	812.30	812.30	812.30
Tail Water Level (m)	730.90	730.90	730.90	730.90
Effective Head (m)	78.2	78.3	78.2	78.2
Maximum Discharge (m^3/s)	20.6	17.9	15.1	13.8
Installed Capacity (KW)	12,700	11,000	9,300	8,500
Annual Energy Production (10^3kWh)	67,300	67,090	63,360	63,290
Construction Cost (10^6US$)	52.84	49.4	46.7	45.17
Economic Evaluation				
Present Value of Benefit ($10^6$$)	45.802	43.74	40.578	39.094
Present Value of Cost (10^6US$)	39.846	37.248	35.209	34.054
B-C	5.956	6.492	5.369	5.040
B/C	1.149	1.174	1.152	1.148
EIRR	11.79	12.03	11.75	11.68

Table 7.3.5 CONSTRUCTION COST OF KIKULETWA NO. 2 HYDROPOWER PROJECT

(Unit 10^3US$)

Case	Case 1	Case 2	Case 3	Case 4
Installed Capacity (MW)	12.7	11.0	9.3	8.5
1. Civil Works	28,292	26,791	26,091	25,606
1-1 Preparatory Works	8,450	8,450	8,450	8,450
1-2 Dam & Intake	1,472	1,472	1,472	1,472
1-3 Headrace	12,641	11,616	11,141	10,852
1-4 Head Tank	820	820	820	820
1-5 Penstock	1,752	1,617	1,563	1,509
1-6 Powerhouse	2,157	1,816	1,645	1,503
1-7 Miscellaneous Works	1,000	1,000	1,000	1,000
2. Hydraulic Equipment	2,657	2,505	2,273	2,000
3. Electromechanical Facilities	11,920	10,730	9,430	8,930
4. Transmission Line & Substation	800	800	800	800
5. Total Cost (1+2+3+4)	43,669	40,826	38,594	37,336
6. Engineering & Administration (5 x 10%)	4,367	4,083	3,860	3,728
7. Physical Contingency (5+6) x 10%	4,804	4,491	4,246	4,106
Grand Total (5+6+7)	52,840	49,400	46,700	45,170

Table 7.3.6 CALCULATION OF BENEFIT/COST RATIO
KIKULETWA NO. 2 HYDROPOWER PROJECT

Item	Case 1	Case 2	Case 3	Case 4
Firm capacity (MW)	12.7	11	9.3	8.5
Energy generation (GWh)	67.3	67.09	64.5	63.29
Investment cost:				
Power station (10^6US$)	52.04	48.6	45.9	44.37
Transmission line (10^6US$)	0.8	0.8	0.8	0.8
Cost of alternative diesel power plant (US$/kw)	950	950	950	950
Diesel oil price (US$/barrel)	42.94	42.94	42.94	42.94
Lubrication price (US$/kg)	2.433	2.433	2.433	2.433
Calculation of Benefit/Cost ratio at 10% discount rate:				
- Investment cost	10.691	9.260	7.829	7.155
- O and M cost	3.986	3.452	2.919	2.668
- Fuel cost	31.125	31.028	29.830	29.271
Total (B)	45.802	43.740	40.578	39.094
Cost of the project (10^6US$)				
- Investment cost	34.354	32.112	30.353	29.356
- O and M cost	5.492	5.136	4.856	4.698
Total (C)	39.846	37.248	35.209	34.054
	5.956	6.492	5.369	5.040
Benefit/Cost Ratio:(B)/(C)	1.149	1.174	1.152	1.148
EIRR (%)	11.79	12.03	11.75	11.68

Fig. 7.2.1. CALCULATION PROCEDURE OF SUPPLY CAPACITY AND ENERGY PRODUCTION

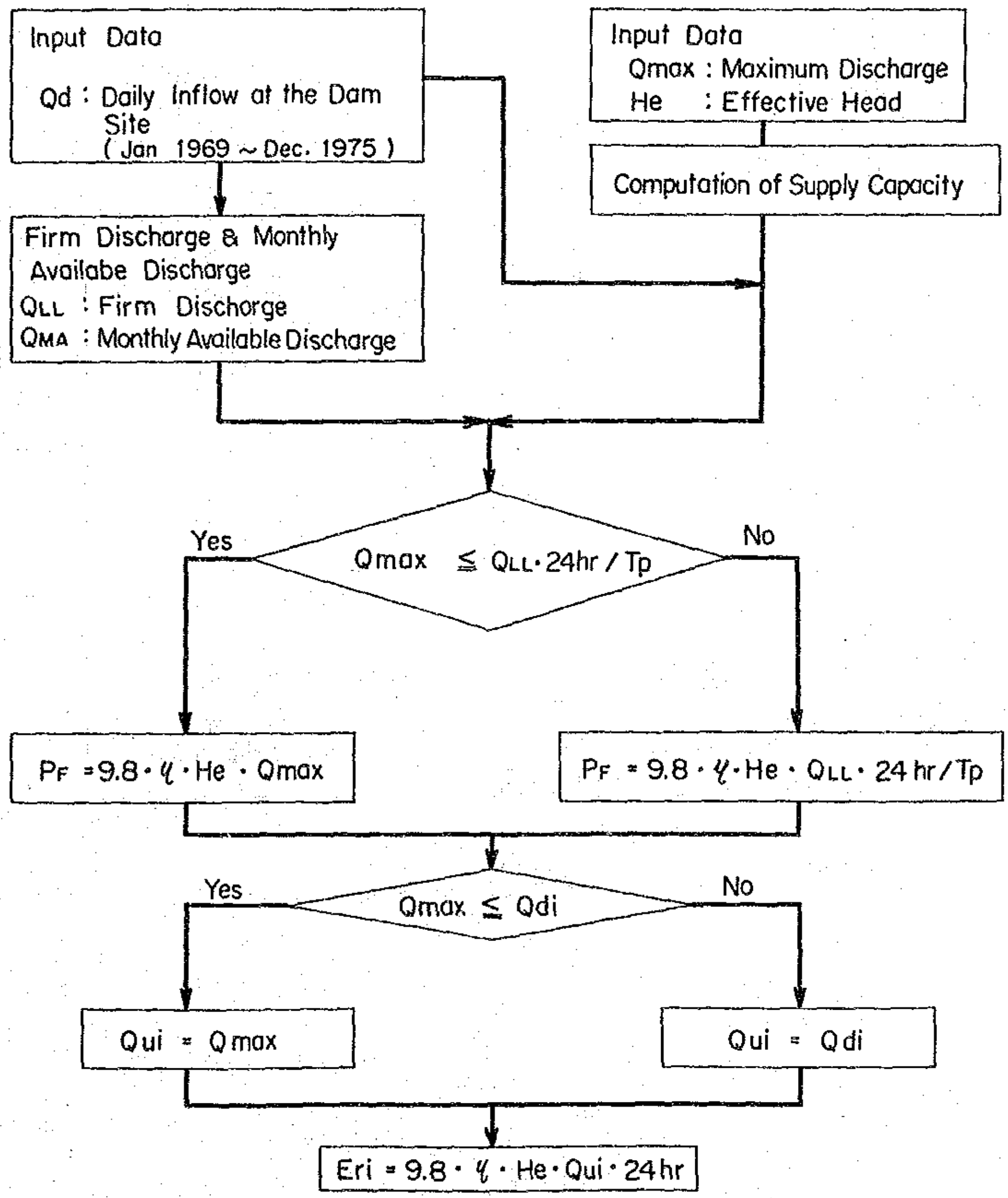


Fig. 7.3.1. STUDY FOR OPTIMUM DEVELOPMENT SCALE
KIKULETWA No.1 PROJECT
(MAXIMUM DISCHARGE)

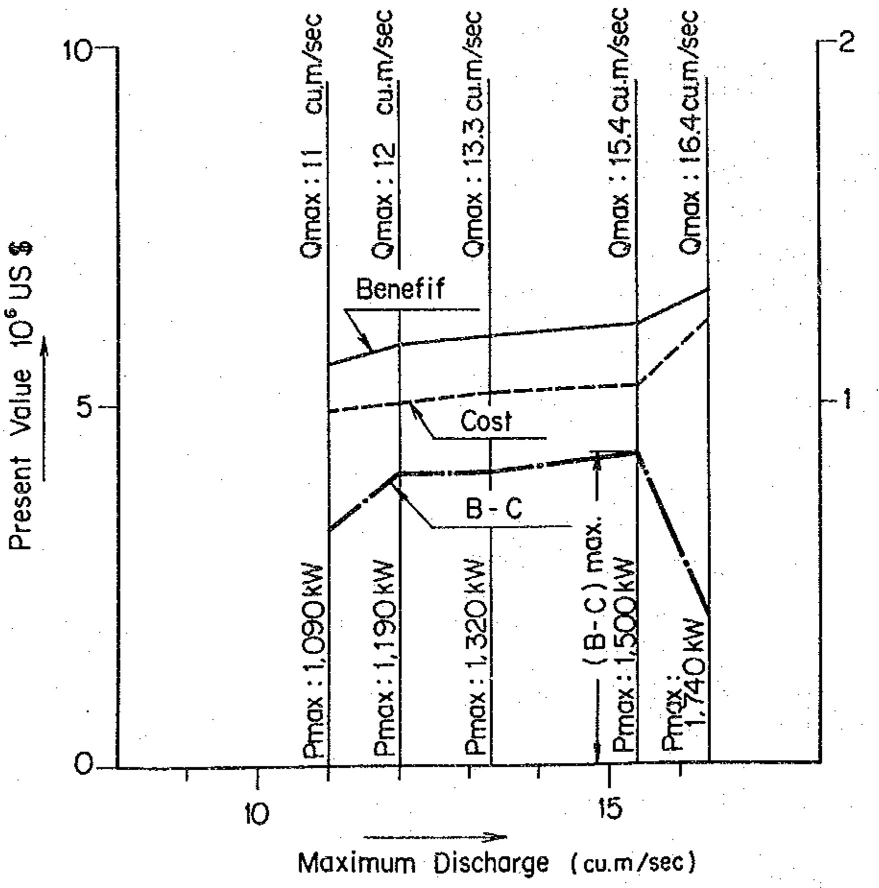


Fig. 7.3.2. STUDY FOR OPTIMUM DEVELOPMENT SCALE
KIKULETWA No. 2 PROJECT
(MAXIMUM DISCHARGE)

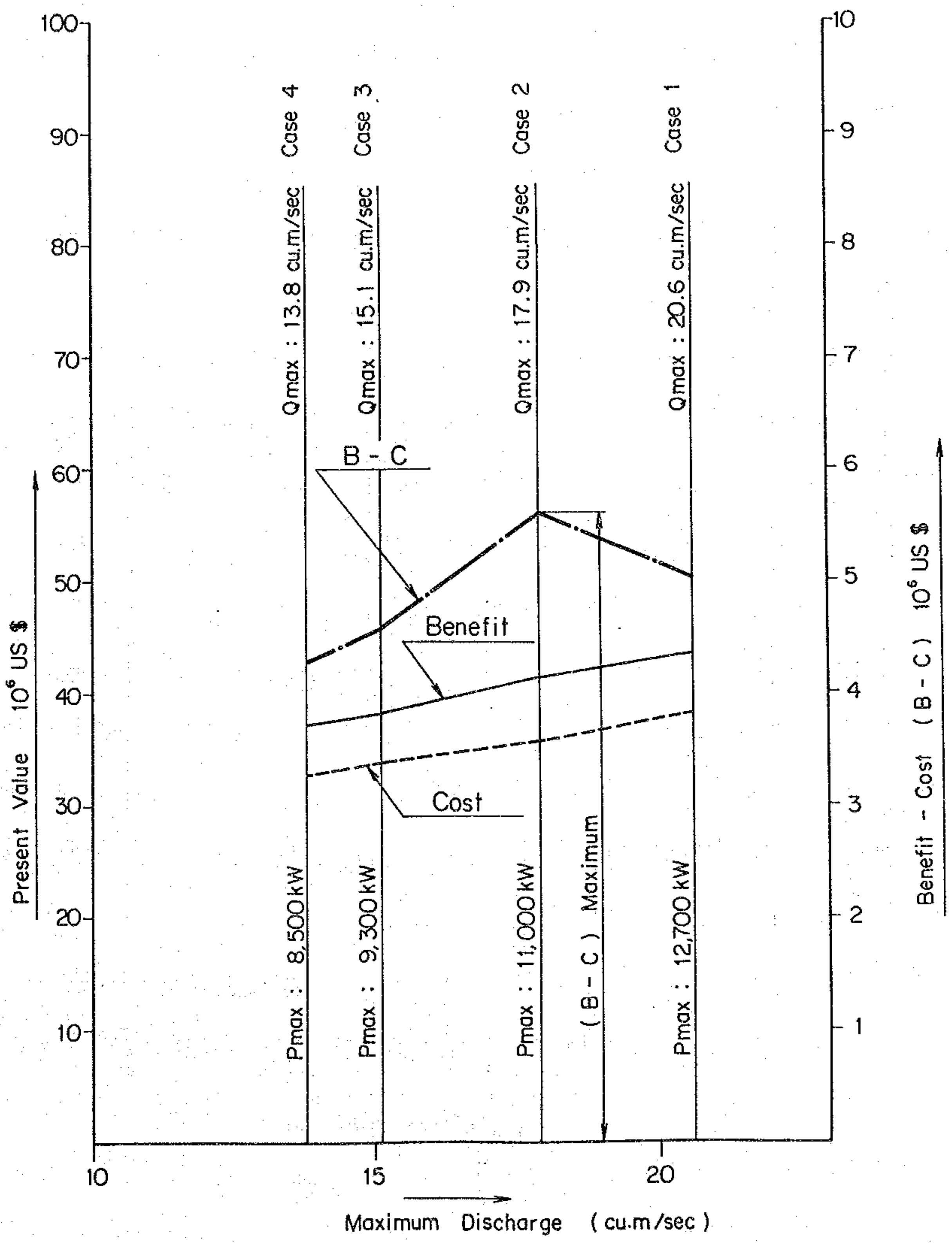
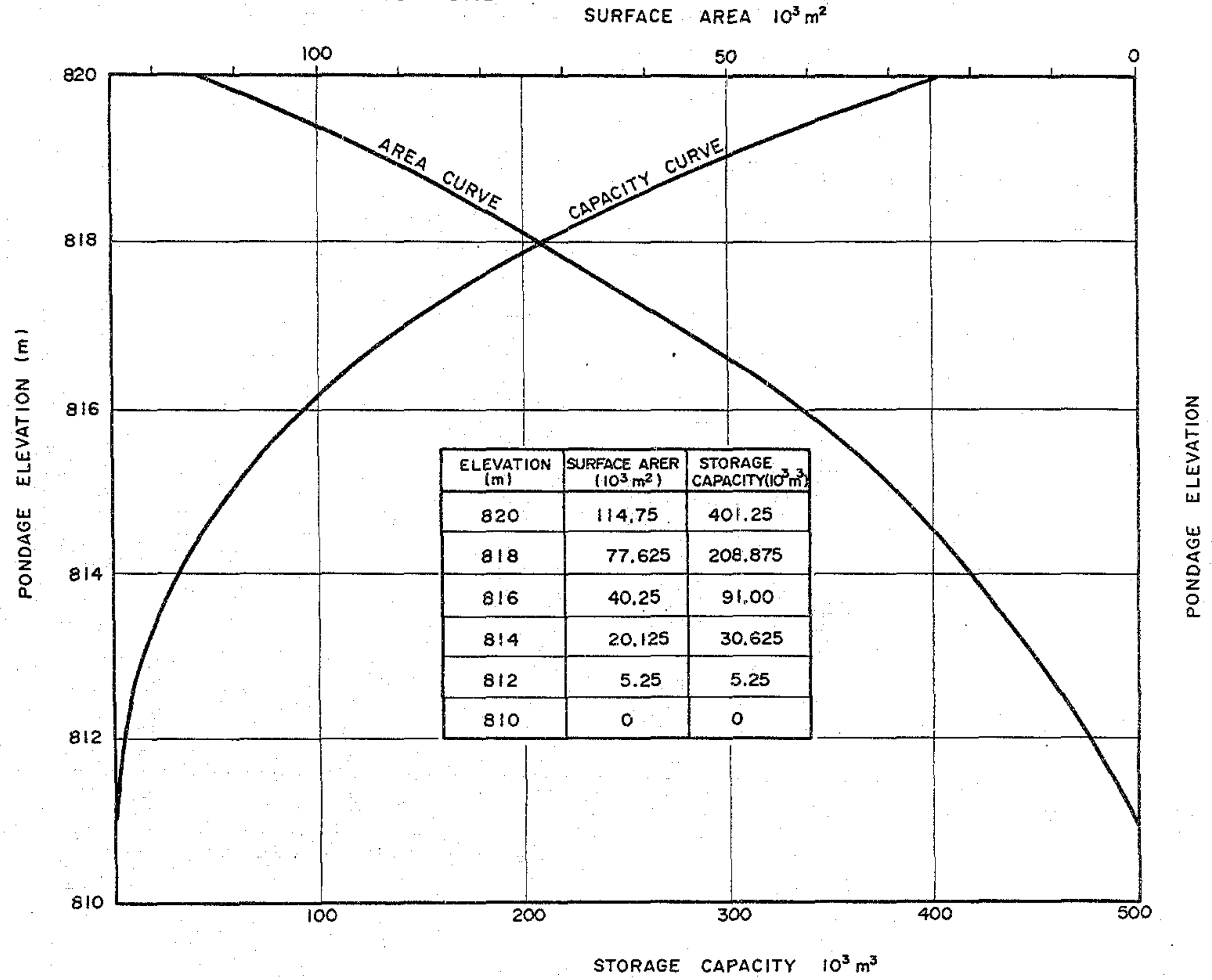


Fig. 7·3·3 STORAGE CAPACITY AND SURFACE AREA CURVE OF KIKULETWA NO. 2 REGULATING POND



ELEVATION (m)	SURFACE ARER ($10^3 m^2$)	STORAGE CAPACITY($10^3 m^3$)
820	114.75	401.25
818	77.625	208.875
816	40.25	91.00
814	20.125	30.625
812	5.25	5.25
810	0	0

Fig. 7.3.4. DAILY LOAD CURVE AT NORTHERN REGION

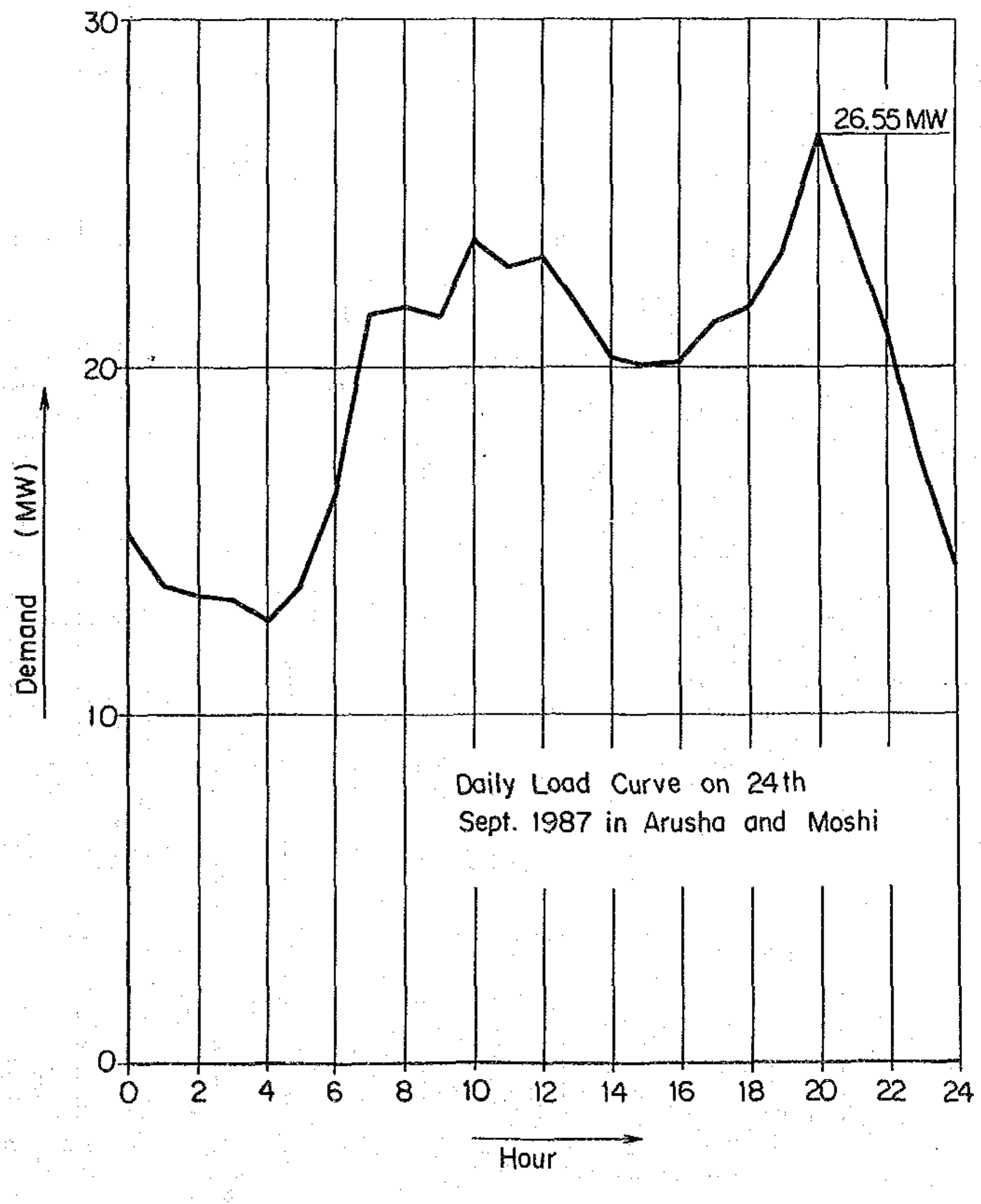
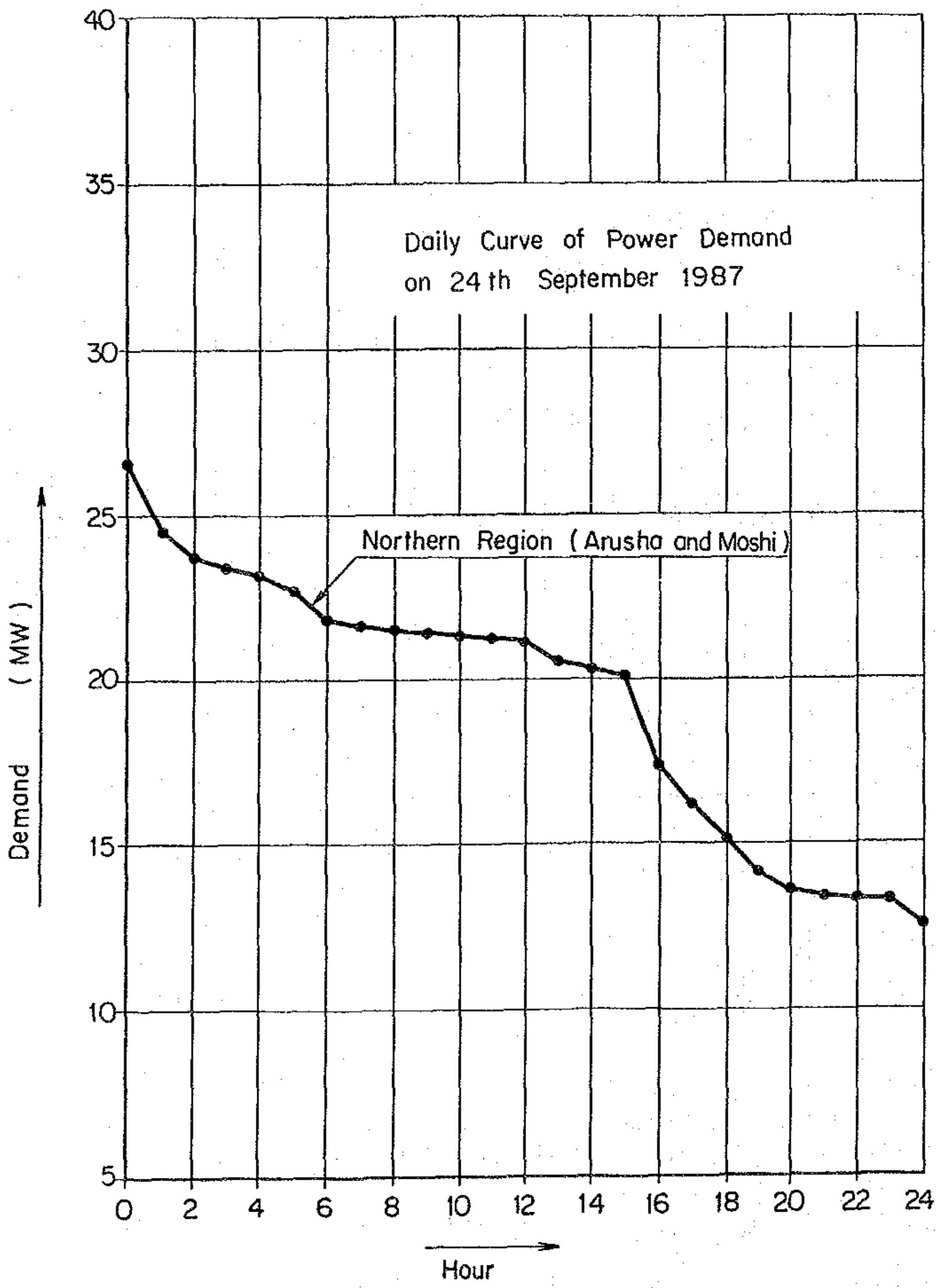


Fig. 7.3.5. TYPICAL DAILY LOAD CURVE



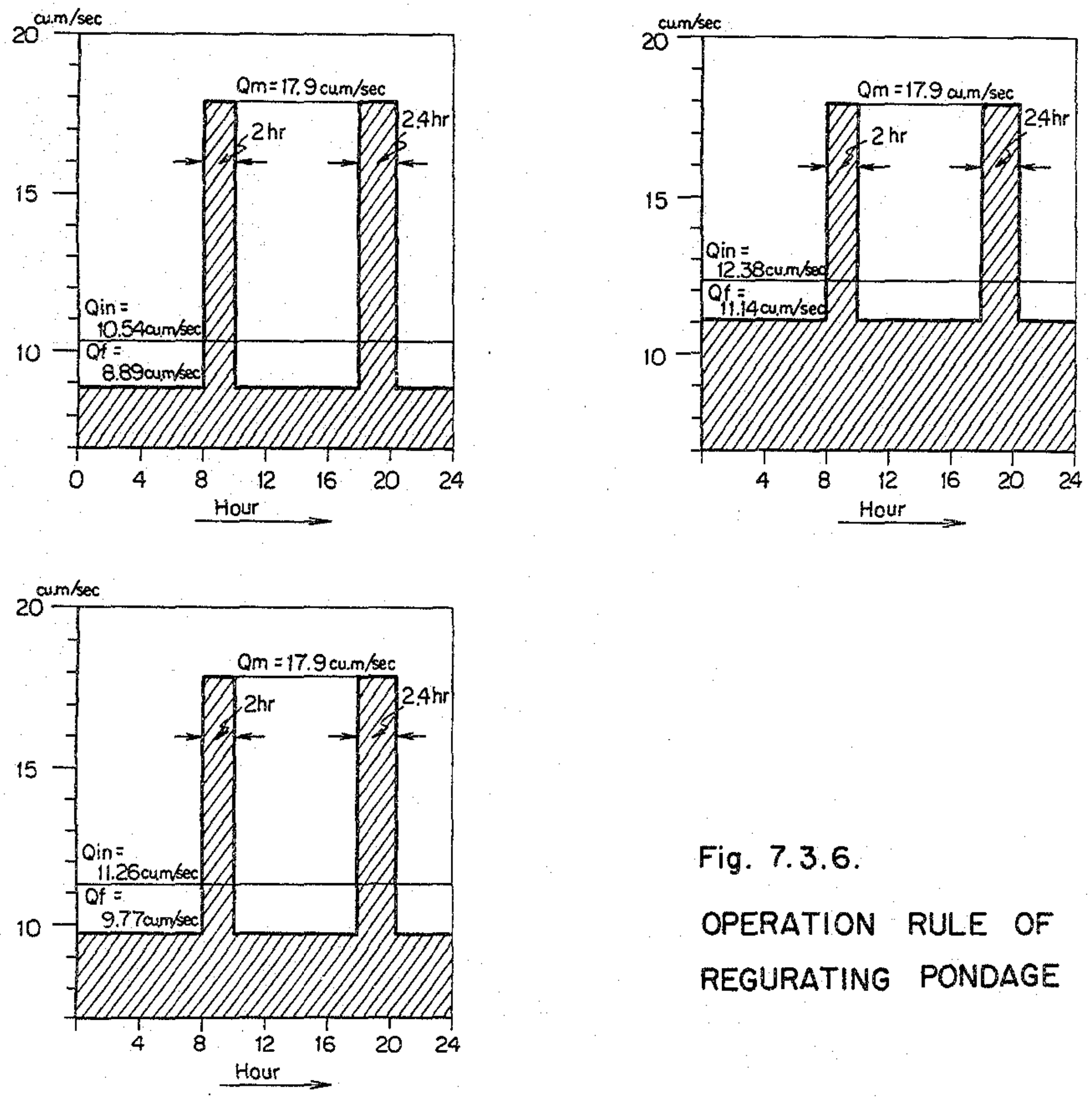


Fig. 7.3.6.

OPERATION RULE OF REGURATING PONDAGE

CHAPTER 8

POWER TRANSMISSION SCHEME AND POWER SYSTEM ANALYSIS

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CHAPTER 8 POWER TRANSMISSION SCHEME AND POWER SYSTEM ANALYSIS

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8.1 KIKULETWA NO.1 POWER STATION (REHABILITATION)

(1) Power Transmission Method

The electric power generated at the Kikuletwa No. 1 Power Station (1.5 MW), as shown in Figs. 8.1.1 and 8.1.2, is to be sent along the existing 33 kV transmission line to the Kiyungi Substation.

(2) Transmission Line Facilities

The existing transmission line may be outlined as follows:

Section	:	Kikuletwa No. 1 Power Station - Kiyungi Substation (15 km)
Voltage	:	33 kV
Conductor size	:	HDCC 0.1 sq.in (corresponding to 65 mm^2)
Number of circuits	:	1
Current carrying capacity	:	310 A (corresponding to 17 MW/CCT, ambient temperature 40°C)

In order to enhance reliability, it will be necessary to replace or reinforce some of the wooden poles supporting the line.

8.2 KIKULETWA NO.2 POWER STATION

(1) Power Transmission Method

The electric power generated at the Kikuletwa No. 2 Power Station (11 MW) is to be transmitted to the Kiyungi Substation along a newly constructed 33 kV, 2-cct transmission line (Figs. 8.1.1 and 8.1.2).

(2) Transmission Line Facilities

The transmission line to be constructed may be outlined as follows:

Section	:	Kikuletwa No. 2 Power Station - Kiyungi Substation (14 km)

Voltage	:	33 kV
Number of circuits	:	2
Conductor size	:	Wolf (corresponding to ACSR 160 mm^2)
Current carrying capacity	:	460 A (corresponding to 25 MW/cct, ambient temperature 40°C)

Although a single circuit transmission line would have sufficient capacity, double circuits are preferable for the following reasons:

- To increase reliability of power supply in the power system
- To improve voltage maintenance capability in the Arusha-Kilimanjaro Region

8.3 POWER SYSTEM ANALYSIS

(1) Analysis

Power system analyses were conducted to examine the system characteristics resulting from construction of new power sources and associated transmission line. The analysis covered the following:

- Effect of improving electric power system with rehabilitation of Kikuletwa No. 1 Power Station and construction of Kikuletwa No. 2 Power Station
- Transmission line for Kikuletwa No. 2 Power Station
- Power flow and voltage calculations for use in analyzing the above-mentioned items
- Short-circuit current calculations for determining switchgear specifications

(2) Calculation Premises

Premises for the power system analysis were as follows:

(i) Objective years and Items of Calculation

The expansion plans for power stations and the transmission lines, and the system calculation items required for these plans, are shown in Table 8.3.1.

The scope of the power system considered in the calculations covers the 132 kV, 66 kV, and 33 kV systems from Chalinze Substation to Njiro Substation, which are part of the interconnected system. The impedances are shown in Fig. 8.3.1.

(iii) Power Flow and Voltage Calculations

Power flow and voltage calculations were made based on the system operating conditions shown below.

System voltage	:	100 ± 5%
Operating voltage of generator	:	100 ± 5%
Operating power factor of generator	:	Above 0.80
Tap ratio of transformer	:	1.00 ± 0.10
Power factor of load	:	0.95
Time band of load	:	Peak hour
Bus voltage at Chalinze Substation	:	100% constant
Power demand and supply	:	See Table 2.2.12

(iv) Short-circuit Current Calculation

Short-circuit current calculations were made based on the assumed power system in 1994. The short-circuit current flowing into the 132 kV bus of the Chalinze Substation from the interconnected system was assumed at 2.2 kA (corresponding to 500 MVA). The generator reactance used in the calculations is transient reactance (Xd').