Fig. I-10
VARIATION OF MONTHLY RAINFALL WITH ALTITUDE (2)

JULY ~ DECEMBER

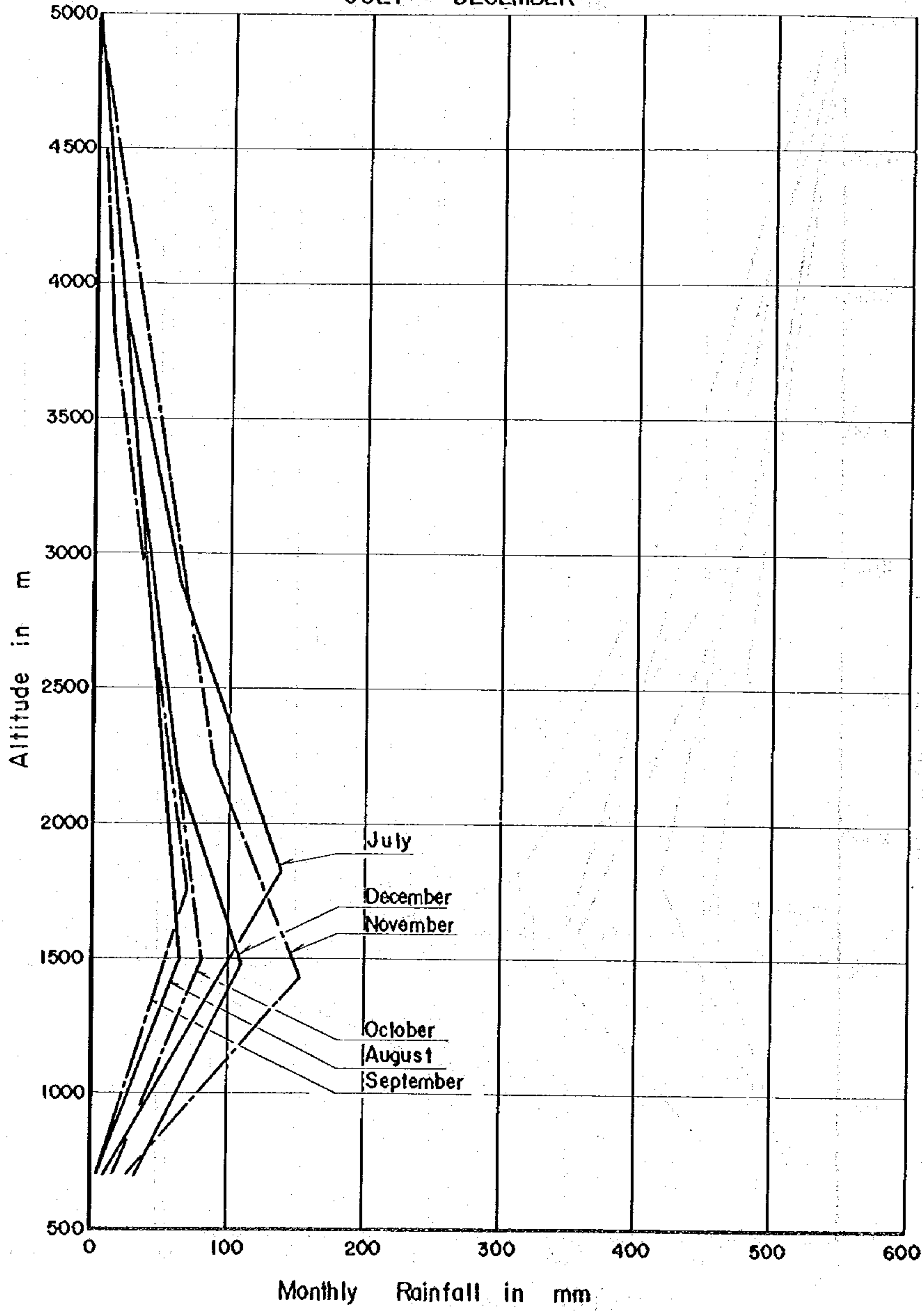


Fig. I-11 VARIATION OF DAILY MAX. RAINFALL WITH ALTITUDE (1)

— for Catchment Areas —

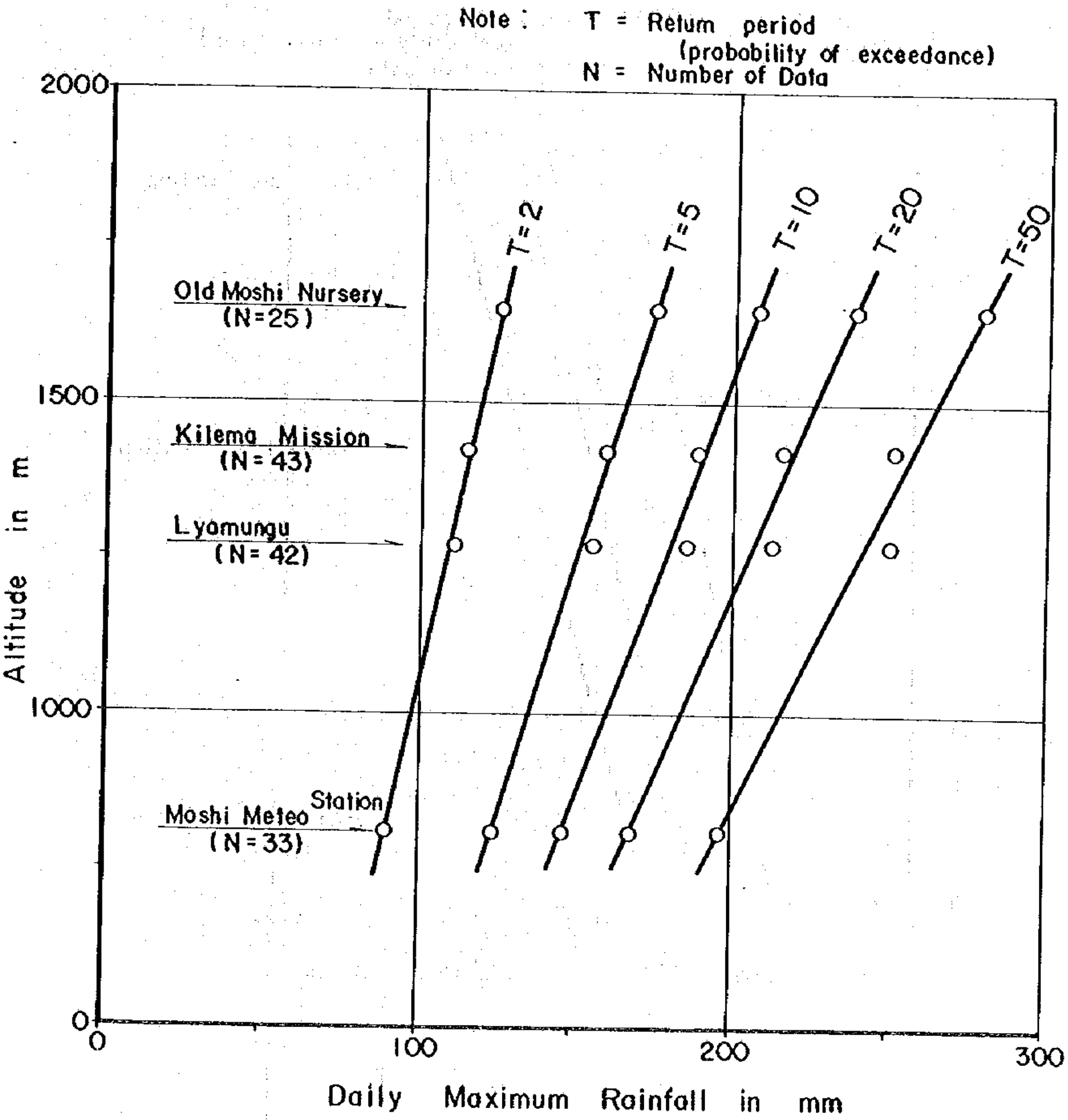


Fig. I-12 VARIATION OF DAILY MAX. RAINFALL WITH ALTITUDE (2)

— for the Lower-Moshi Area —

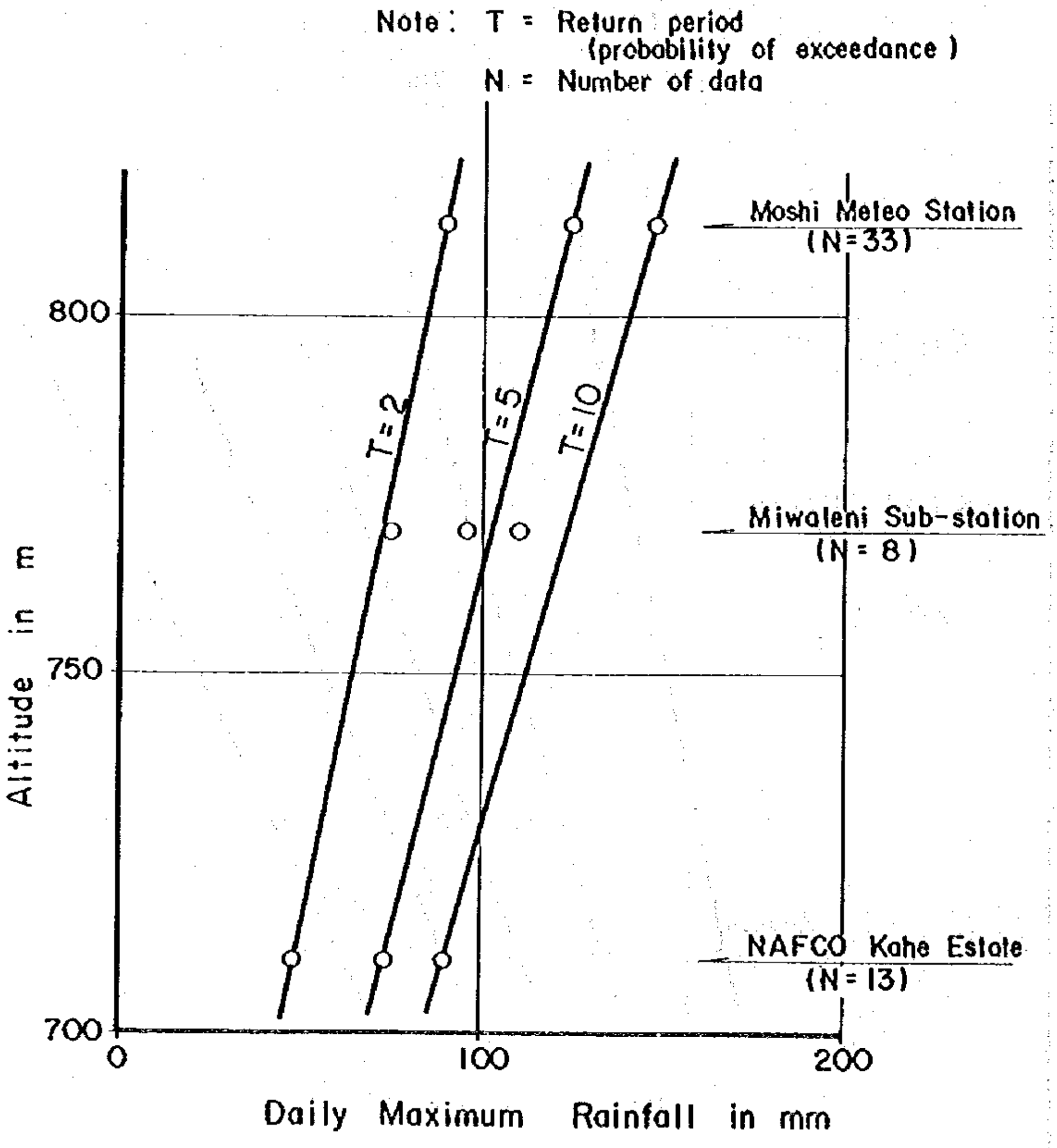


Fig.I - 13

DISTRIBUTION PATTERN OF DAILY RAINFALL

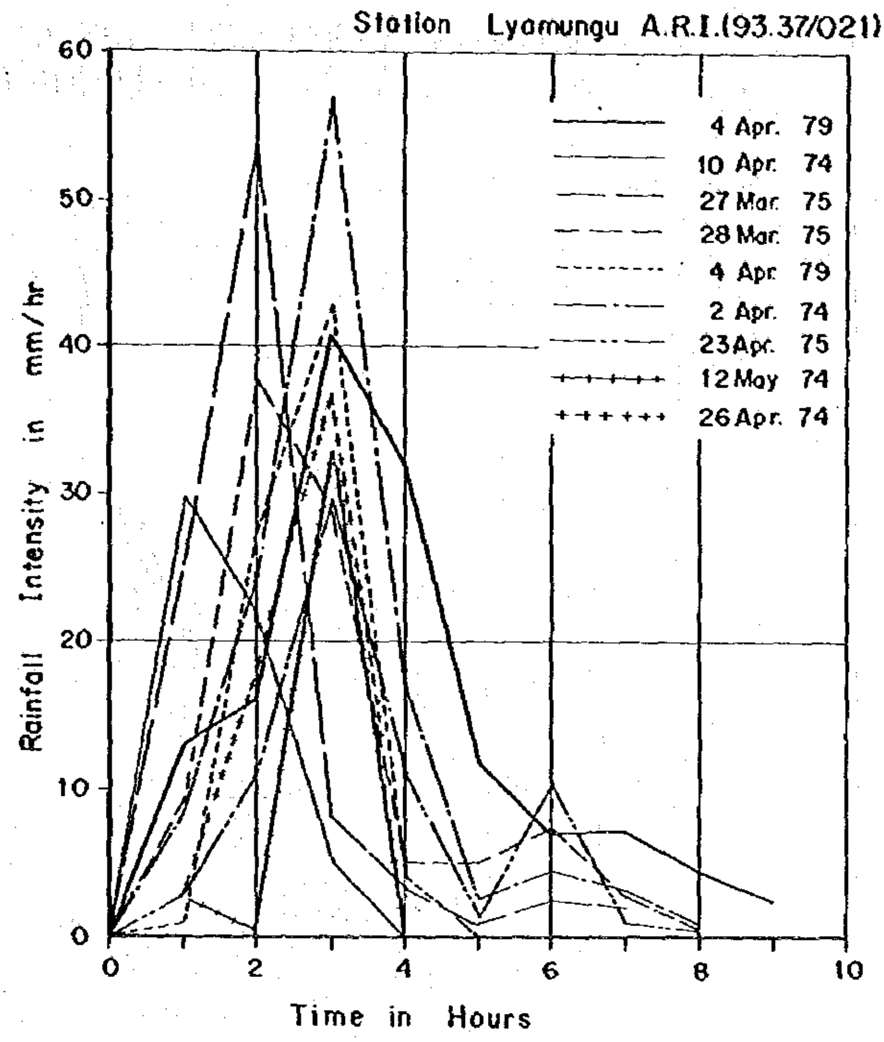


Fig. I - 14

COEFFICIENT FOR RAINFALL INTENSITY CALCULATION

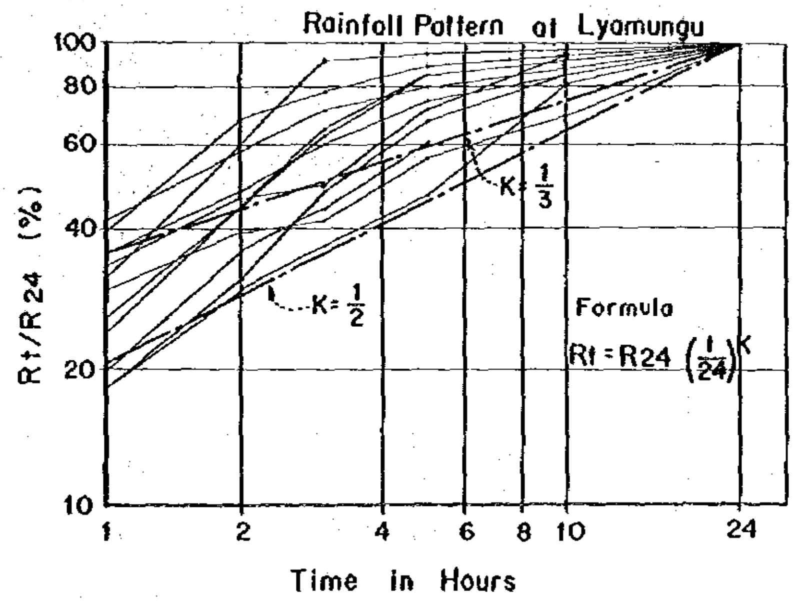


Fig.I-15 VARIATION OF CATCHMENT AREA WITH ALTITUDE (I)

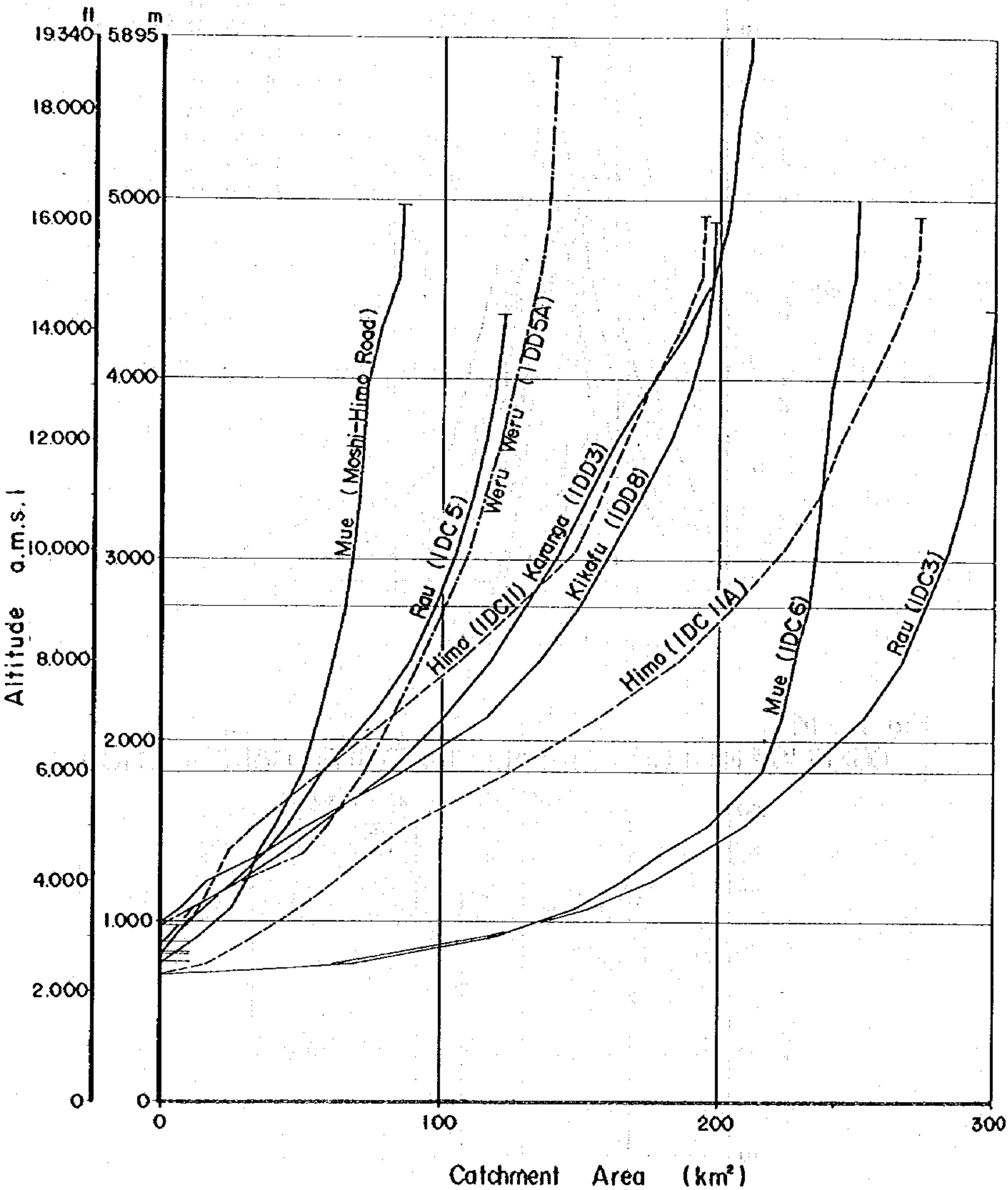


Fig. I-16 VARIATION OF CATCHMENT AREA WITH ALTITUDE (2)

Seasonal Rivers (Rau ~ Mue)

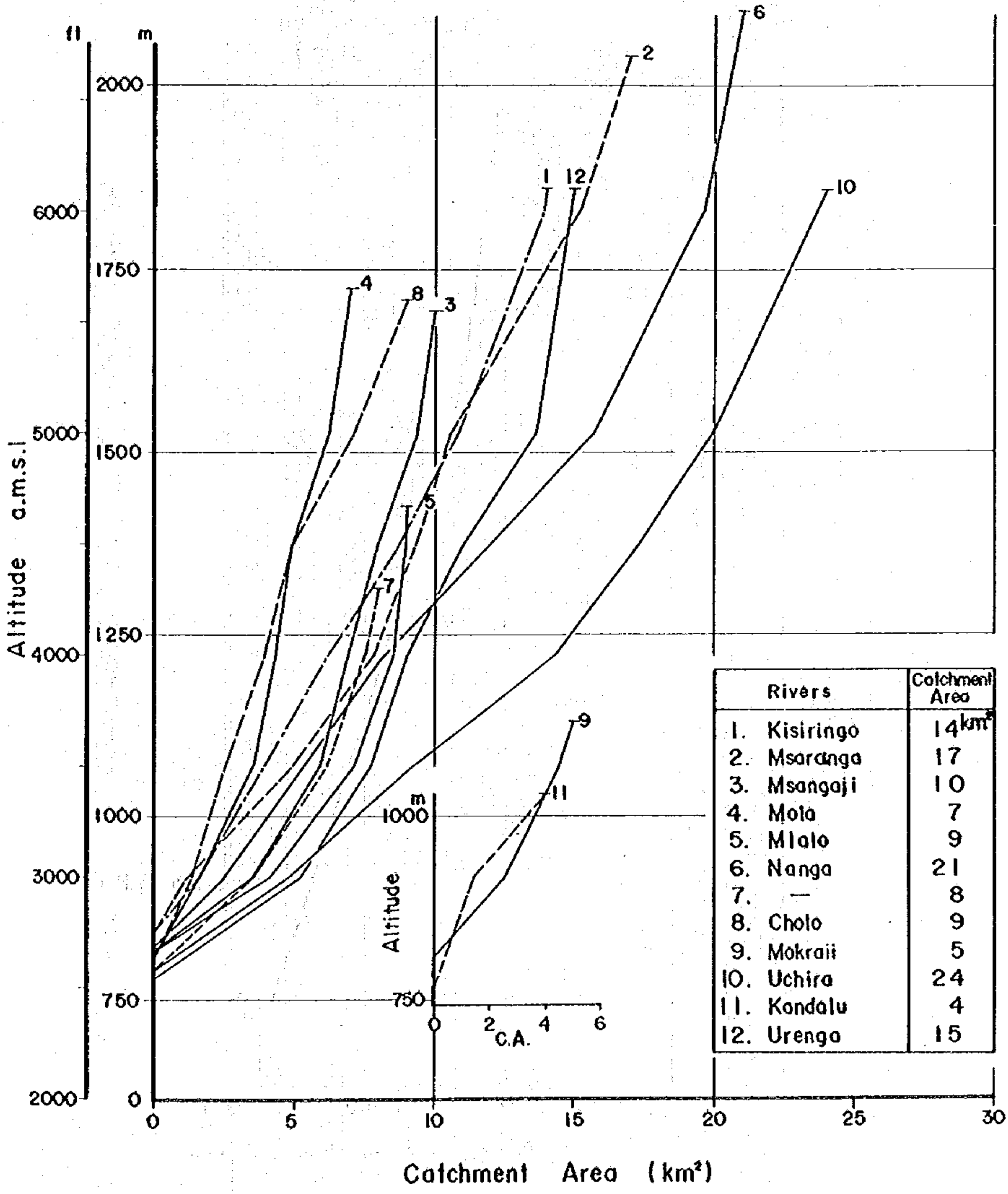


Fig. I-17 VARIATION OF LAND COVER AND EVAPOTRANSPIRATION WITH ALTITUDE

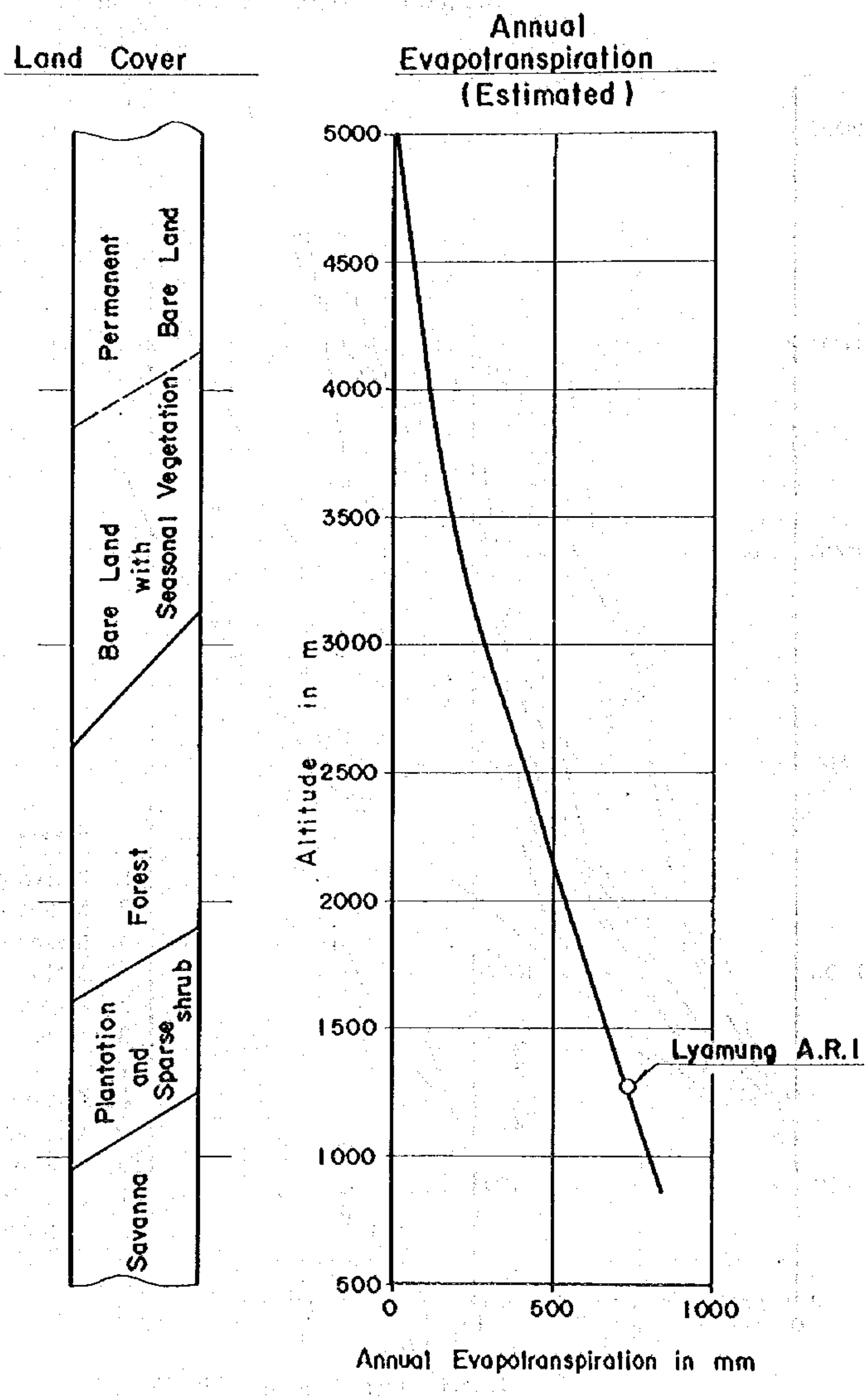


Fig. I - 18 AVAILABILITY OF DISCHARGE RECORD

No.	RIVER SYSTEM	RIVER	STATION No.	CATCH. AREA
1	Rau	Rau	IDC 3	300
2	"	"	IDC 3A	300
3	"	"	IDC 5	122
4	"	Njoro	IDC 35	24
5	Mue	Mue	IDC 6	250
6	"	Cholo	IDC 9	9
7	"	Uchira	IDC 10	24
8	"	Soko	IDC 30	26
9	"	"	IDC 30A	26
10	"	Miwaleni	IDC 33	81
11	Himo	Himo	IDC 11	194
12	"	"	IDC 11A	272
13	Ruvu	Ruvu	IDC 1	2 590
14	"	"	IDC 2	1 810
15	"	"	IDC 2A	1 810
16	"	"	IDC 32	1 800
17	Kikuletwa	Kikuletwa	IDD 1	3 840
18	"	Karanga	IDD 3	211
19	"	Weru Weru	IDD 5A	141
20	"	Kikafu	IDD 8	198
21	"	"	IDD 8A	198

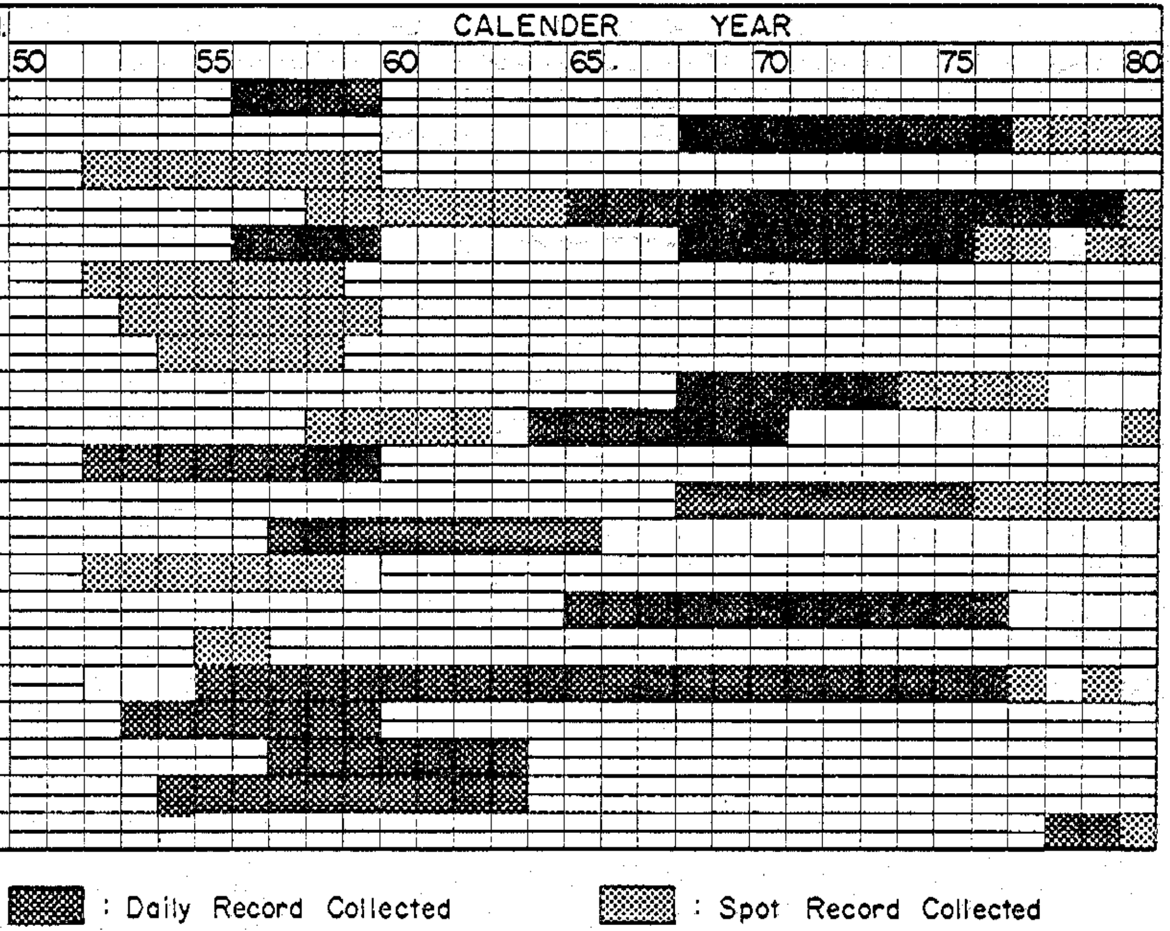
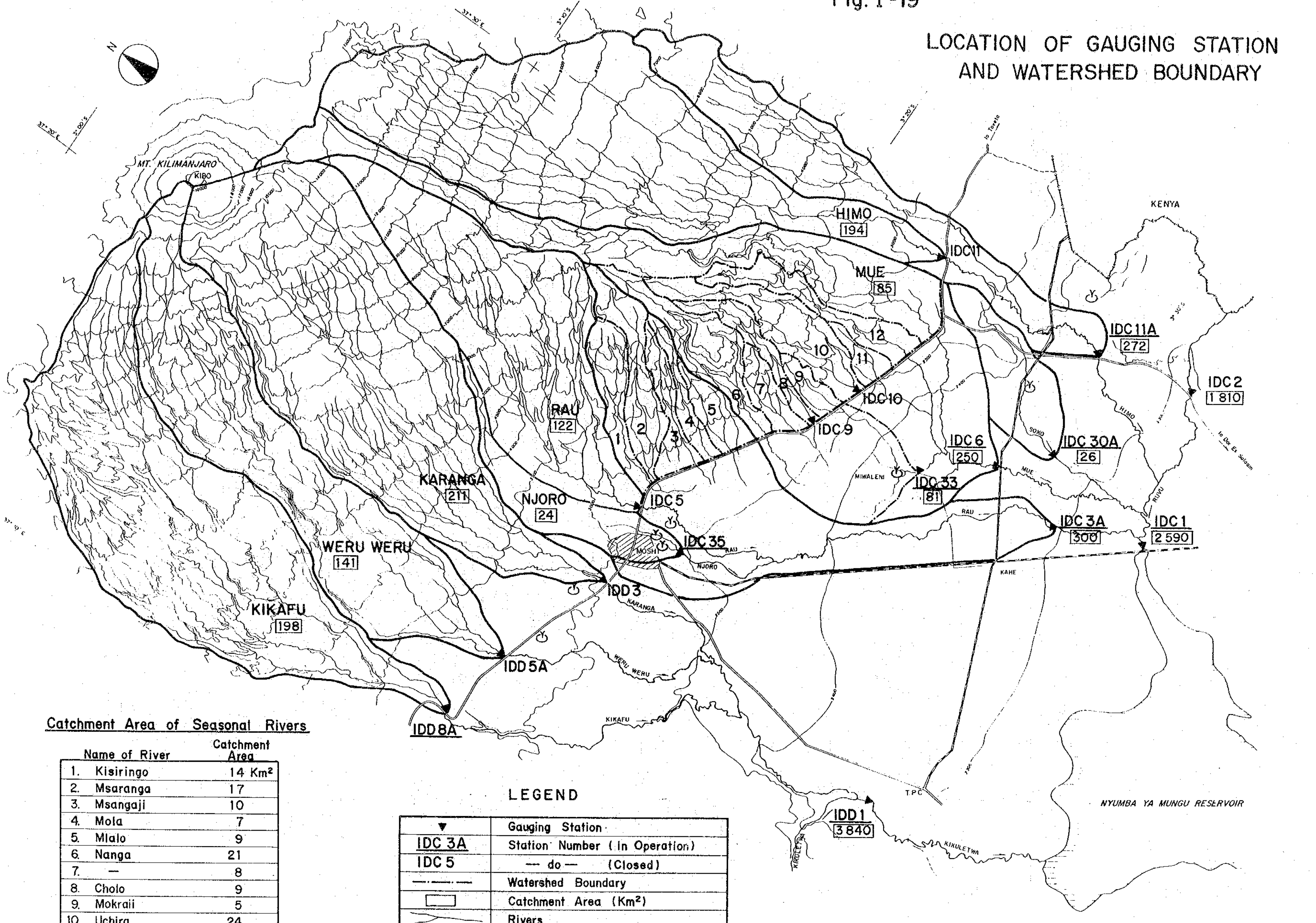


Fig. I-19

LOCATION OF GAUGING STATION AND WATERSHED BOUNDARY



Catchment Area of Seasonal Rivers

Name of River	Catchment Area
1. Kisiringo	14 Km²
2. Msaranga	17
3. Msangaji	10
4. Mola	7
5. Mlalo	9
6. Nanga	21
7. —	8
8. Cholo	9
9. Mokraii	5
10. Uchira	24
11. Kandalu	4
12. Urenga	15

LEGEND

▼	Gauging Station
IDC 3A	Station Number (In Operation)
IDC 5	— do — (Closed)
—·—·—	Watershed Boundary
▭	Catchment Area (Km²)
~~	Rivers
♉	Springs
~3000~	Contour Line in Feet

Fig.I-20 RESULTS OF DISCHARGE MEASUREMENT

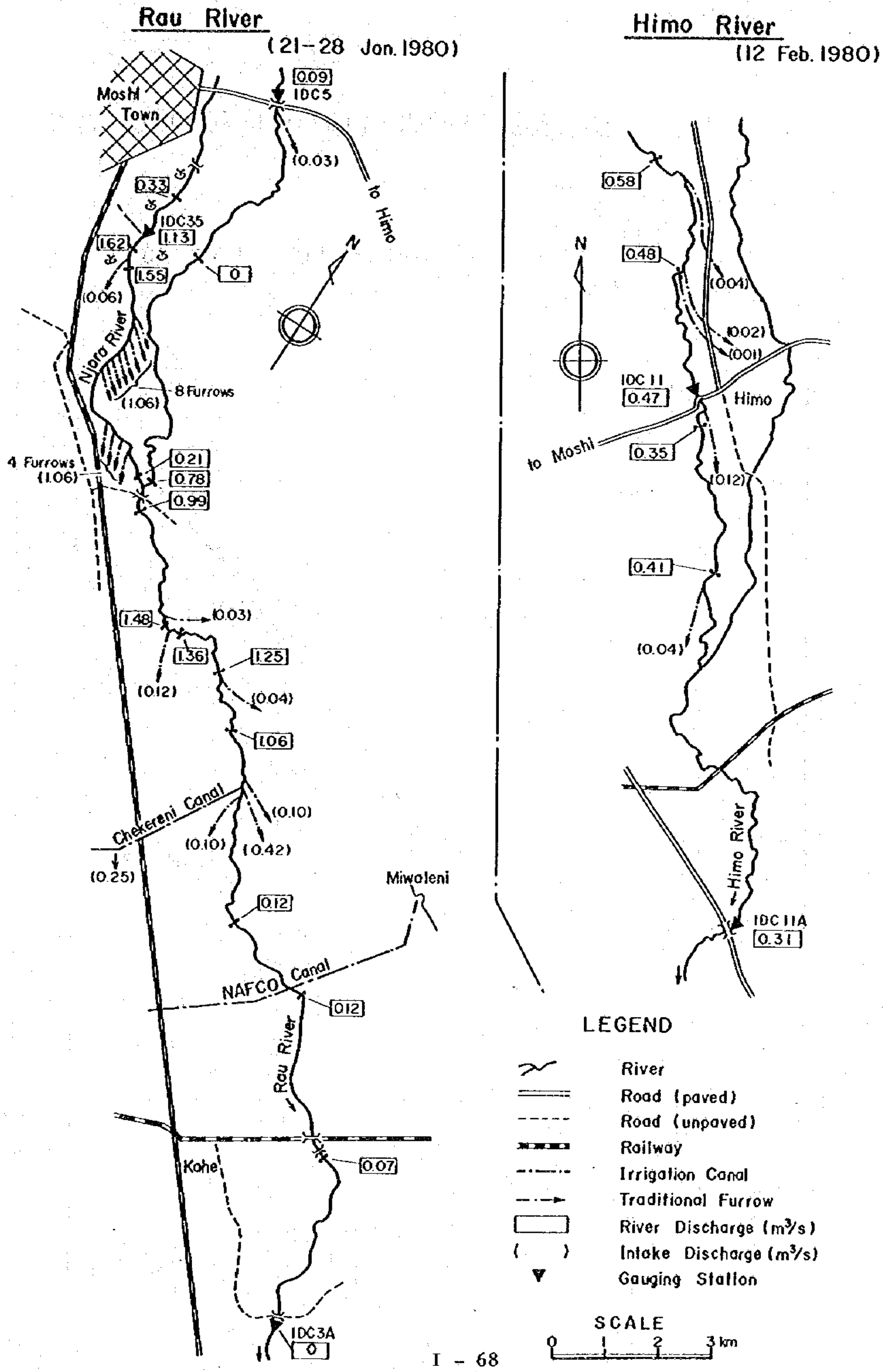


Fig. I-21 RATING CURVE FOR THE NJORO RIVER

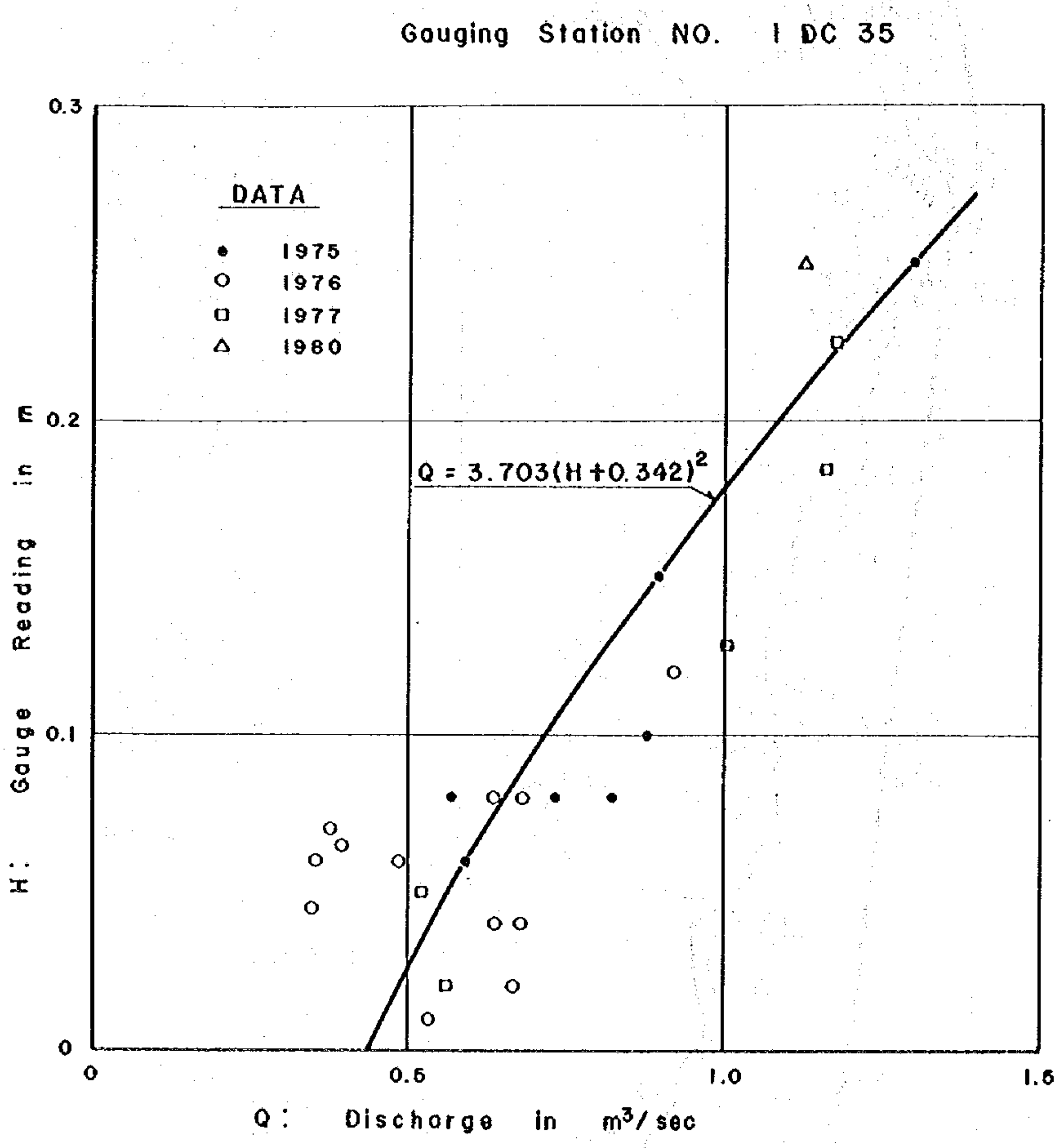


Fig. I-22 PROBABLE RUN-OFF PATTERN

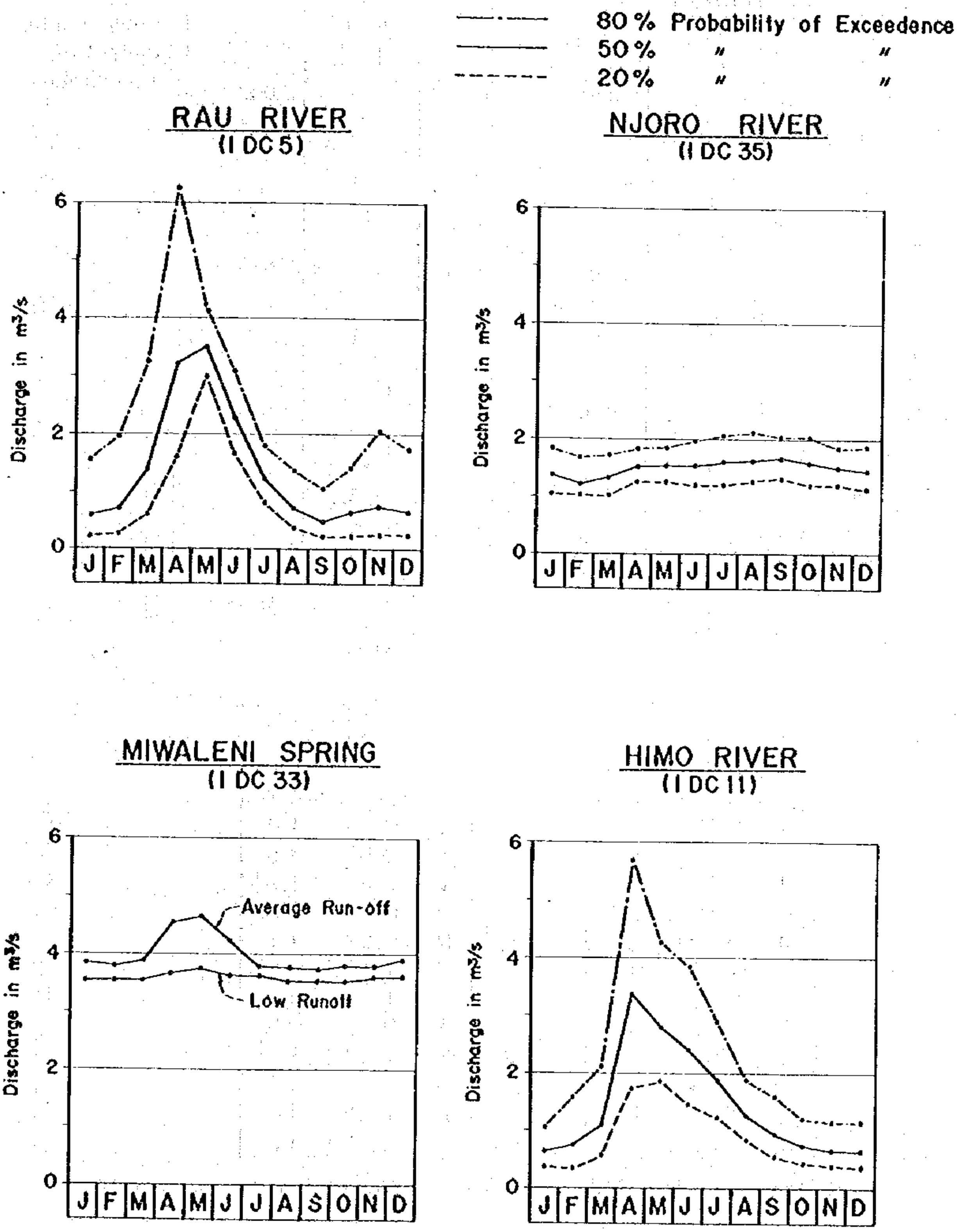
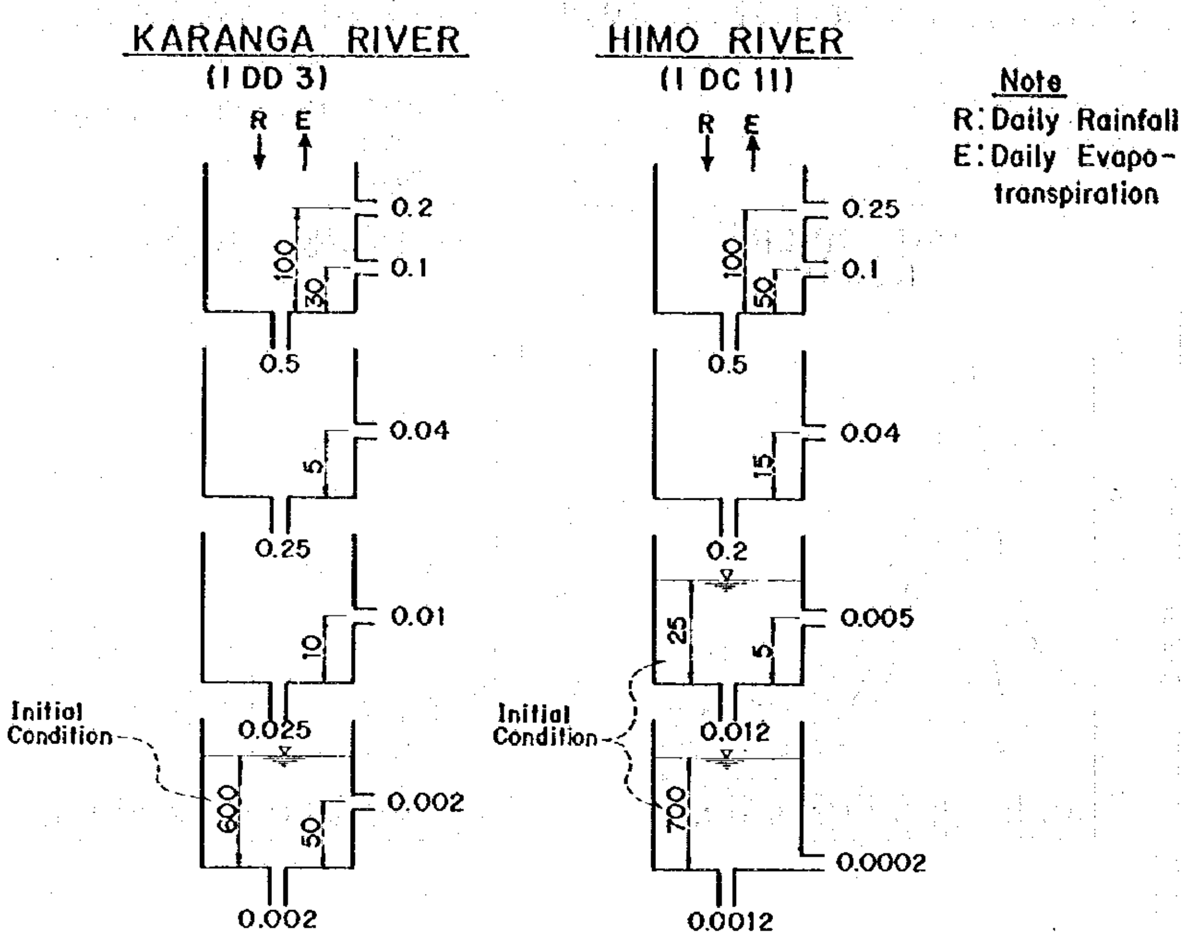


Fig. I - 23 SIMULATION MODEL

(SUGAWARA'S RESERVOIR MODEL)



	Conv. Rate for Rainfall	Areal E (mm/day)
J	1.35	1.4
F	1.56	1.4
M	1.31	1.6
A	0.55	1.3
M	0.48	1.1
J	1.58	0.9
J	2.33	0.8
A	1.25	0.8
S	1.54	1.0
O	1.44	1.2
N	1.06	1.4
D	0.89	1.5

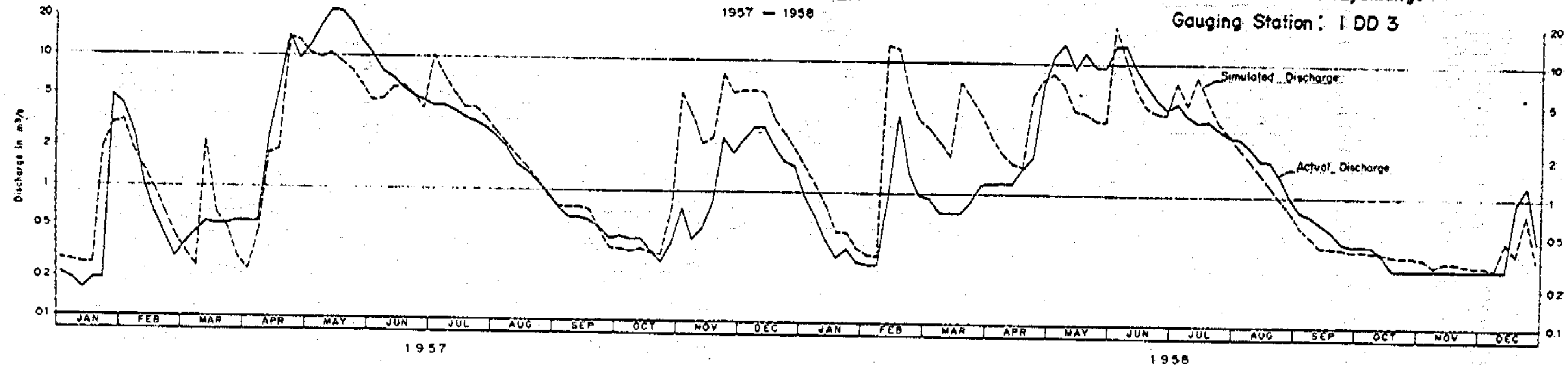
Rainfall: Lyamungu ARI (93.37/021)

	Conv. Rate for Rainfall	Areal E (mm/day)
J	0.85	1.4
F	0.99	1.5
M	0.67	1.6
A	0.58	1.3
M	0.62	1.1
J	1.13	0.9
J	1.39	0.8
A	0.72	0.8
S	1.02	1.1
O	0.68	1.2
N	0.46	1.4
D	0.65	1.5

Rainfall: Kilema Mission (93.37/015)

Fig. I-24 SIMULATION RESULTS FOR RIVER DISCHARGE

(5-day average)



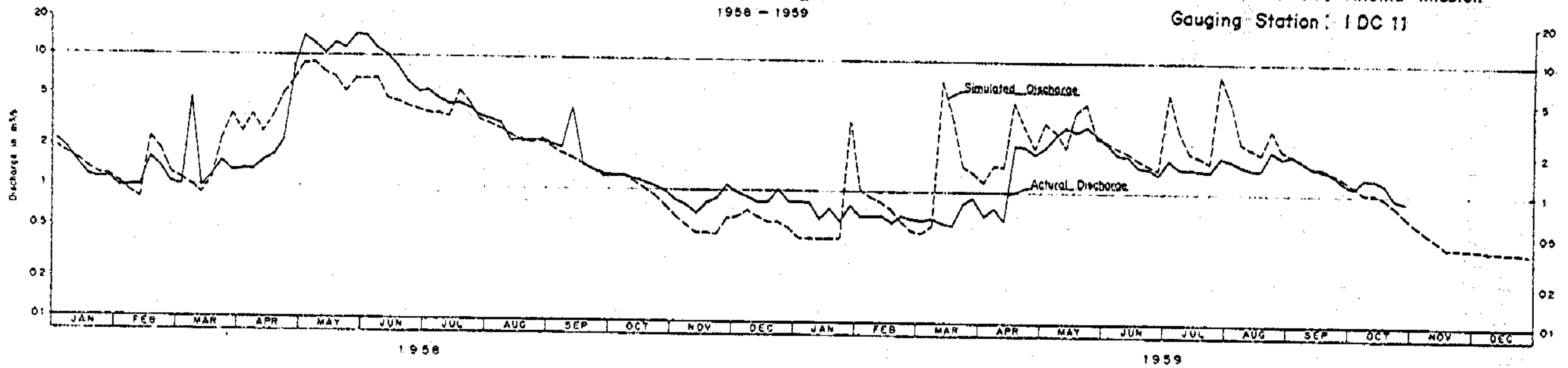
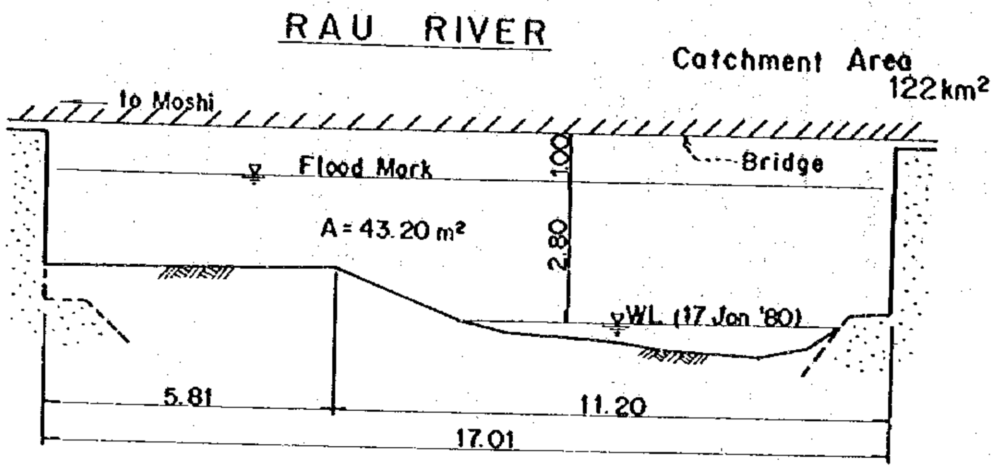
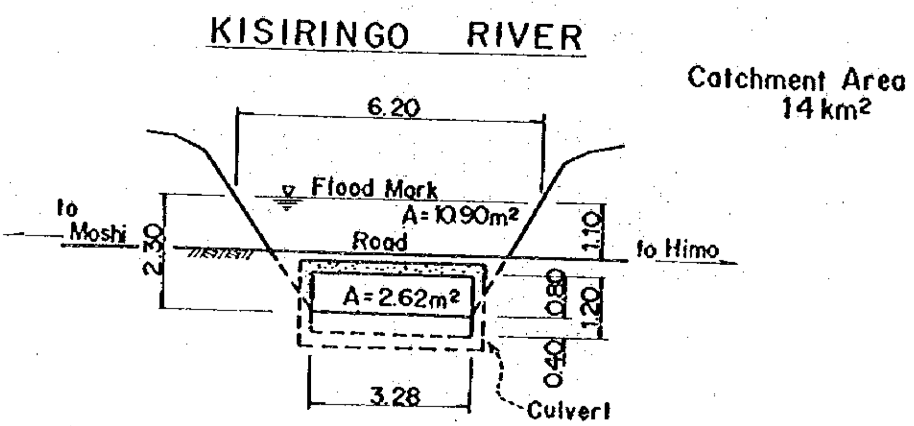


Fig. I-24

Fig. I - 25
FLOOD MARK AND CROSS SECTION OF RIVERS
< Survey Date : Jan. 1980>





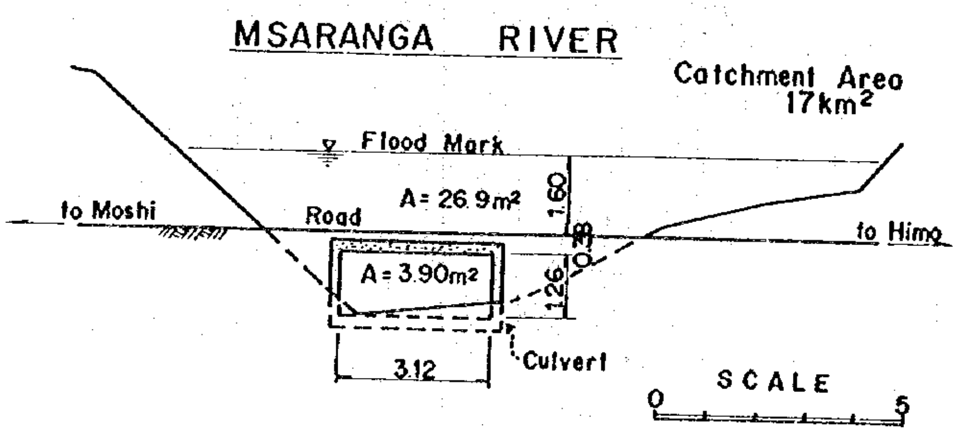
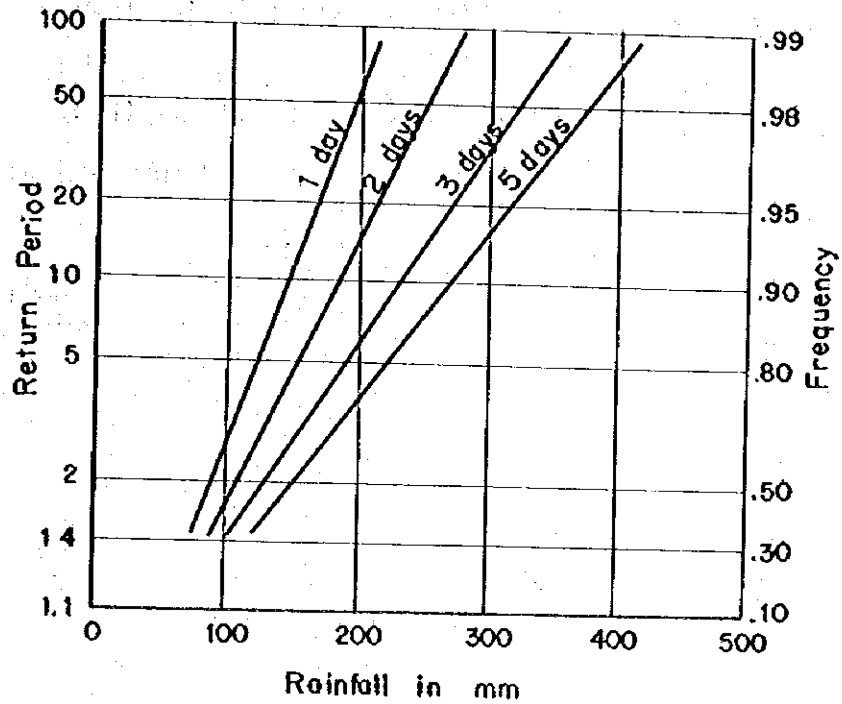


Fig. I-26

PROBABLE RAINFALL AT MOSHI METEO. STATION

CONSECUTIVE RAINFALL



MONTHLY AND RAINY SEASON RAINFALL

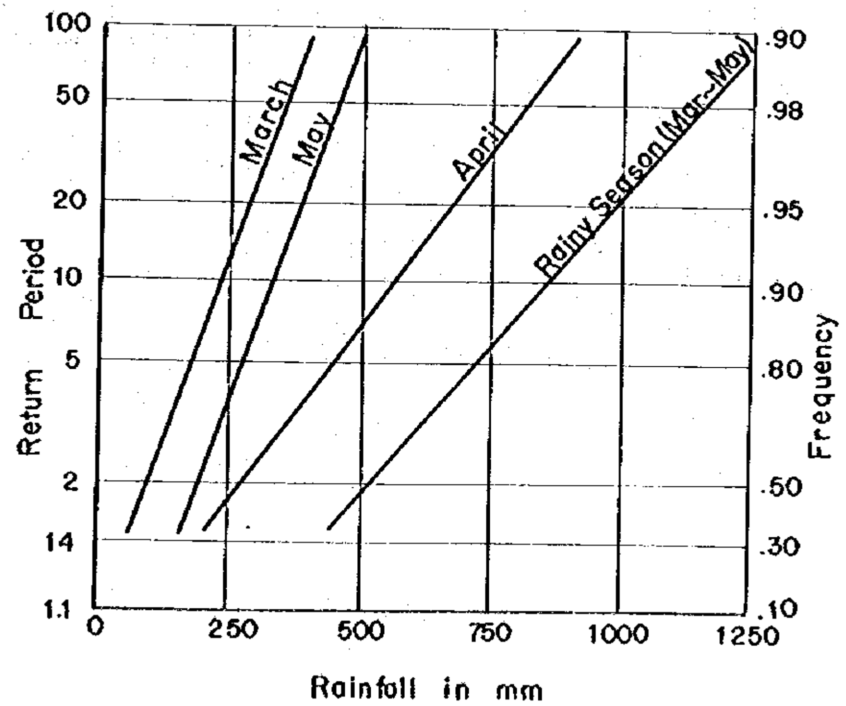


Fig. I-27 RATING CURVE FOR THE KIKAFU RIVER

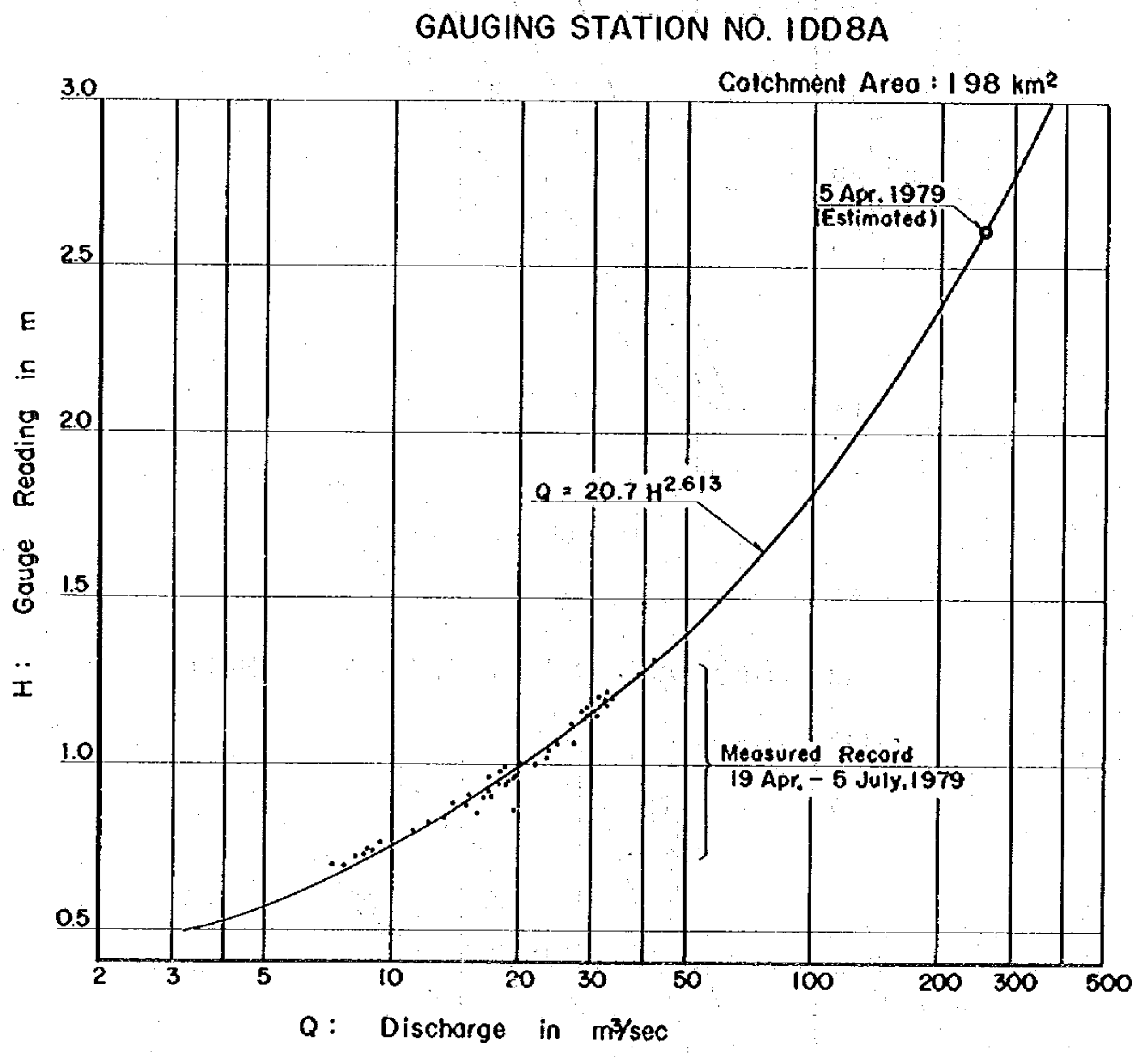


Fig. I-28 HYDROGRAPH FOR THE KIKAFU RIVER (1)

TIME		RAIN-FALL	GAUGE READ	DISCH-ARGE
Date	Hour			
	1	0.8	0.45	2.57
	2	–	0.46	2.72
	3	–	0.48	3.04
	4	–	"	"
	5	–	0.49	3.21
	6	–	0.48	3.04
	7	–	"	"
	8	10.3	"	"
	9	0.4	"	"
4th Apr.	10	3.0	"	"
	11	3.0	"	"
	12	6.0	"	"
	13	3.0	0.49	3.21
	14	3.8	"	"
	15	2.2	"	"
	16	0.5	0.48	3.04
	17	–	"	"
	18	–	0.47	2.88
	19	1.0	"	"
	20	27.5	0.60	5.45
	21	43.0	"	"
	22	3.0	"	"
	23	13.0	0.67	7.27
	24	16.0	0.70	8.15
	1	41.0	0.72	8.77
	2	32.0	2.09	142.07
	3	12.0	2.61	253.89
	4	7.0	2.13	149.29
	5	7.3	2.06	136.81
	6	4.7	2.22	166.34
	7	2.6	2.04	133.36
	8	–	1.98	123.35
	9	0.3	2.09	142.07
5th Apr.	10	4.0	1.81	97.56
	11	–	1.68	80.30
	12	–	1.52	61.82
	13	–	1.41	50.80
	14	–	1.31	41.92
	15	–	1.25	37.08
	16	–	1.19	32.61
	17	–	1.17	31.20
	18	–	1.27	38.66
	19	–	1.26	37.87
	20	2.5	1.19	32.61
	21	0.9	1.12	27.83
	22	0.3	1.07	24.70
	23	0.3	1.03	22.36
	24	1.2	0.99	19.12
	1	2.2	0.98	18.10
	2	3.2	"	"
	3	0.2	1.02	21.80
	4	–	0.99	20.16
	5	1.2	0.97	19.12
	6	2.3	0.93	17.12
6th Apr.	7	1.9	0.91	16.18
	8	1.5	0.89	15.27
	9	1.1	0.87	14.39
	10	NR	"	"
	11	"	"	"
	12	"	0.85	13.54
	13	"	0.84	13.13
	14	"	"	"
	15	"	0.83	12.72
	16	"	"	"

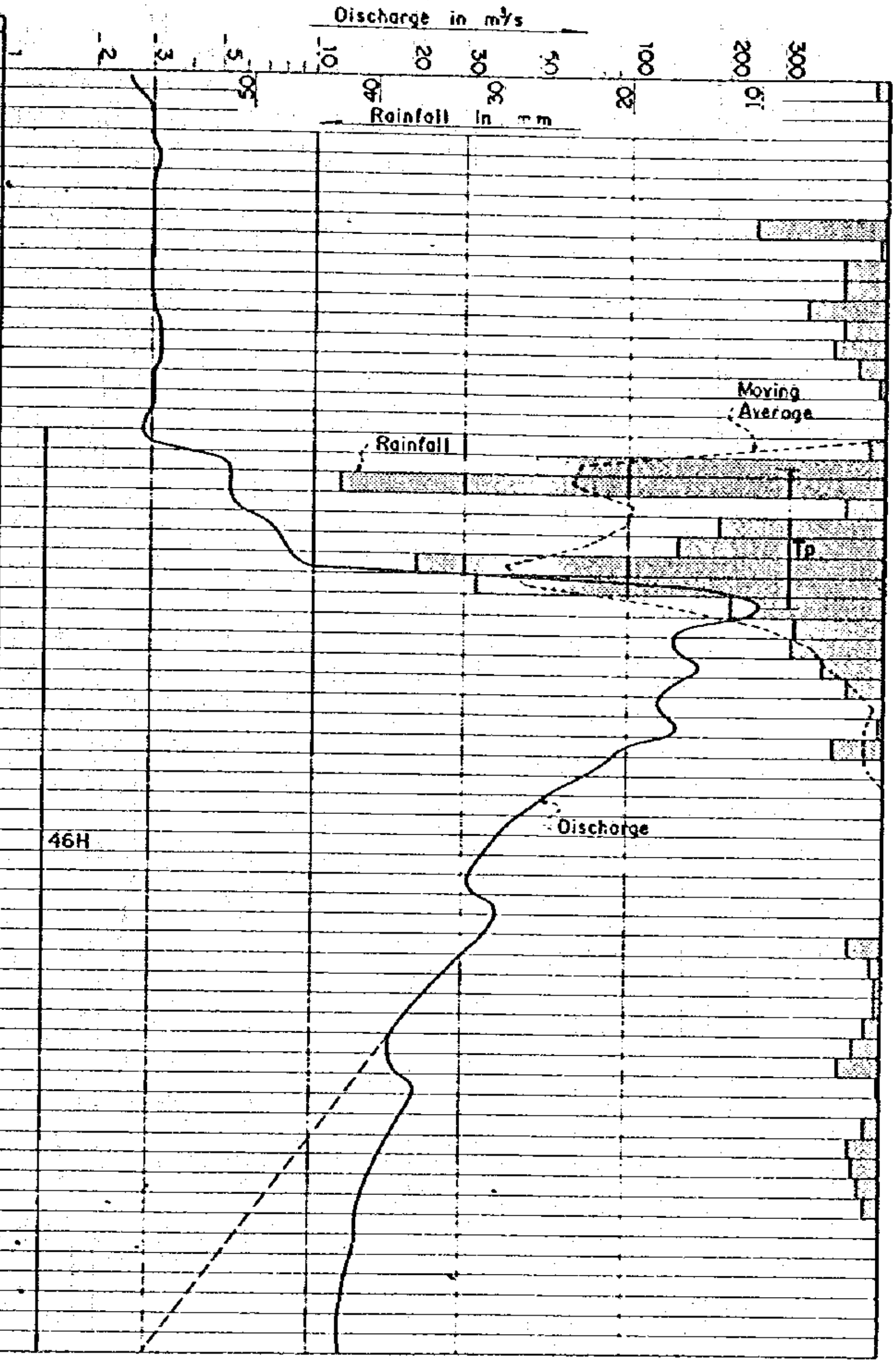
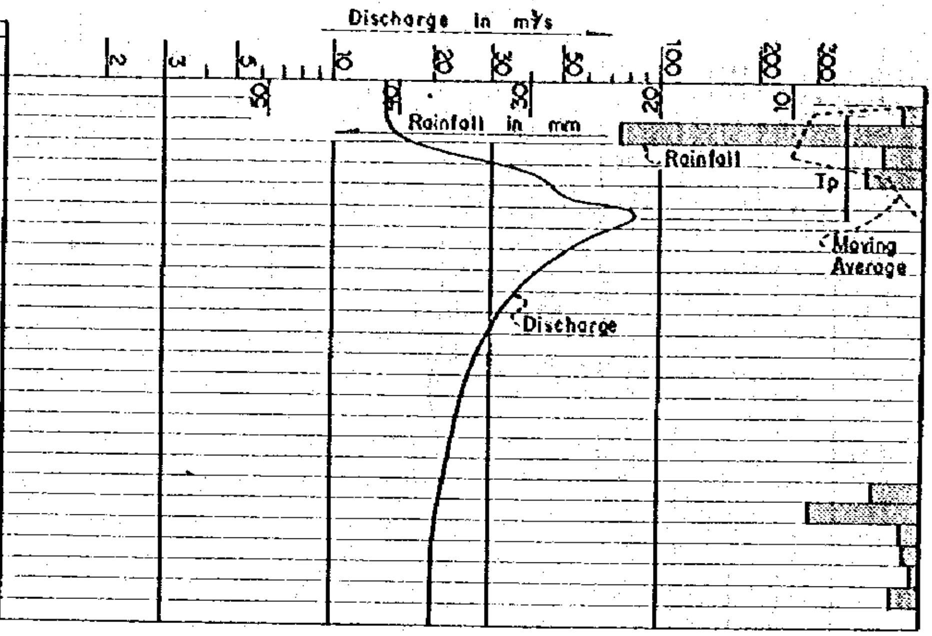


Fig. I-29 HYDROGRAPH FOR THE KIKAFU RIVER (2)

TIME Date	Hour	RAIN-FALL	GAUGE READ	DISCH-ARGE
30th Apr.	13		0.87	14.39
	14	1.7	〃	〃
	15	23.3	0.88	14.82
	16	3.0	1.02	21.80
	17	4.4	1.31	41.92
	18	–	1.38	48.03
	19	–	1.70	82.82
	20	–	1.51	60.76
	21	–	1.36	46.23
	22	–	1.27	38.66
	23	–	1.21	34.06
	24	–	1.16	30.51
1st May	1	–	1.13	28.43
	2	–	1.10	26.55
	3	–	1.06	25.31
	4	–	1.07	24.70
	5	–	1.05	23.51
	6	–	1.04	22.93
	7	–	1.03	22.36
	8	3.6	1.02	21.80
	9	8.6	1.01	21.25
	10	1.5	1.00	20.70
	11	1.2	0.99	20.16
	12	0.6	〃	〃
	13	2.2	〃	〃
	14	–	〃	〃



TIME Date	Hour	RAIN-FALL	GAUGE READ	DISCH-ARGE
7th Jun.	16	0.3	〃	23.51
	17	0.6	〃	〃
	18	–	〃	〃
	19	–	〃	〃
	20	0.3	〃	〃
	21	0.7	〃	〃
	22	2.0	〃	〃
	23	2.3	〃	〃
	24	1.3	1.06	24.10
8th Jun.	1	2.7	1.07	24.70
	2	4.1	1.08	25.31
	3	5.3	1.09	25.93
	4	4.0	1.11	27.19
	5	2.8	1.14	29.15
	6	5.6	1.17	31.20
	7	4.9	1.21	34.06
	8	5.2	1.26	37.87
	9	4.9	1.30	41.09
	10	0.9	1.31	41.92
	11	0.6	1.33	43.61
	12	1.2	1.31	41.92
	13	0.2	1.29	40.27
	14	–	1.28	39.46
	15	–	1.26	37.87
	16	–	1.25	37.08
	17	–	1.24	36.31
	18	–	1.23	35.55
	19	0.2	〃	〃
	20	0.8	〃	〃
	21	2.4	〃	〃
	22	1.1	〃	〃
	23	2.1	〃	〃
	24	0.3	1.24	36.31
9th Jun.	1	0.1	〃	〃
	2	–	1.25	37.08
	3	–	1.27	38.66
	4	–	1.28	39.46
	5	0.1	〃	〃
	6	0.2	〃	〃
	7	0.2	1.26	37.87
	8	0.1	1.25	37.08
	9	–	1.24	36.31
	10	–	1.22	34.80
	11	–	1.21	34.06
	12	–	1.19	32.61

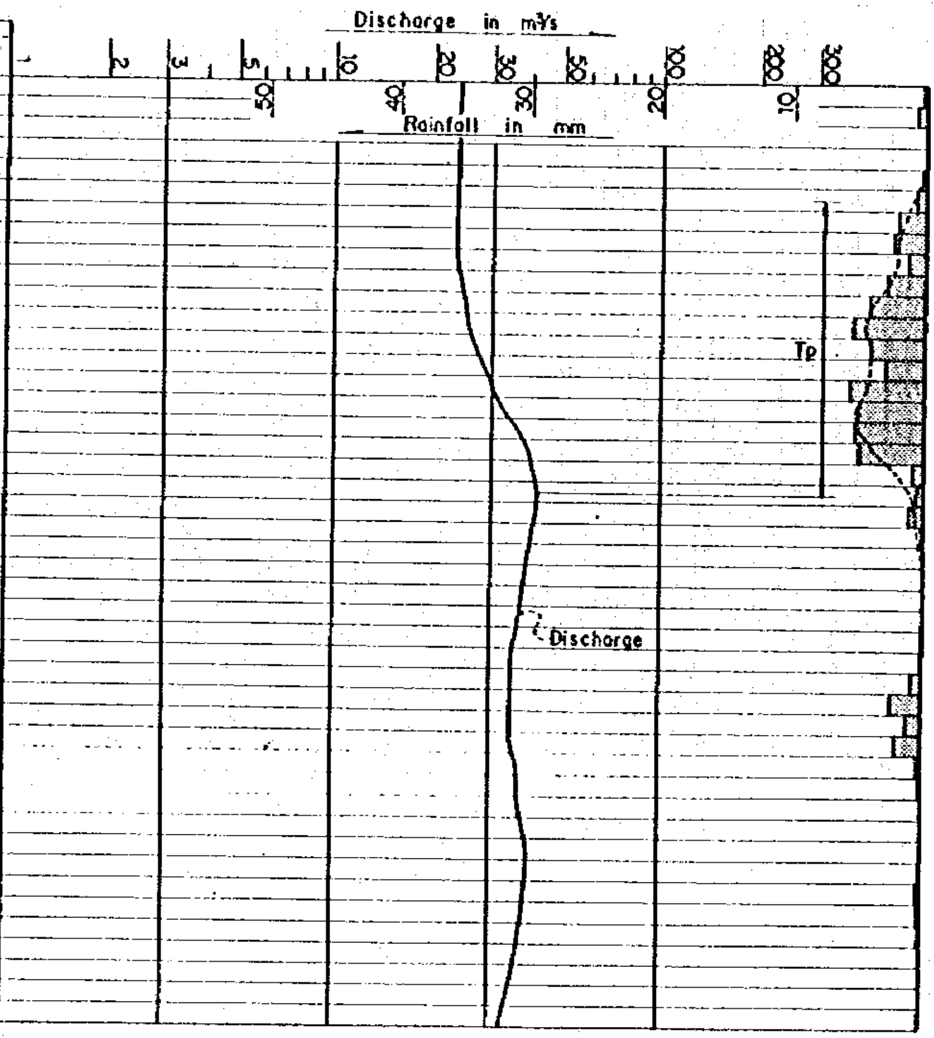
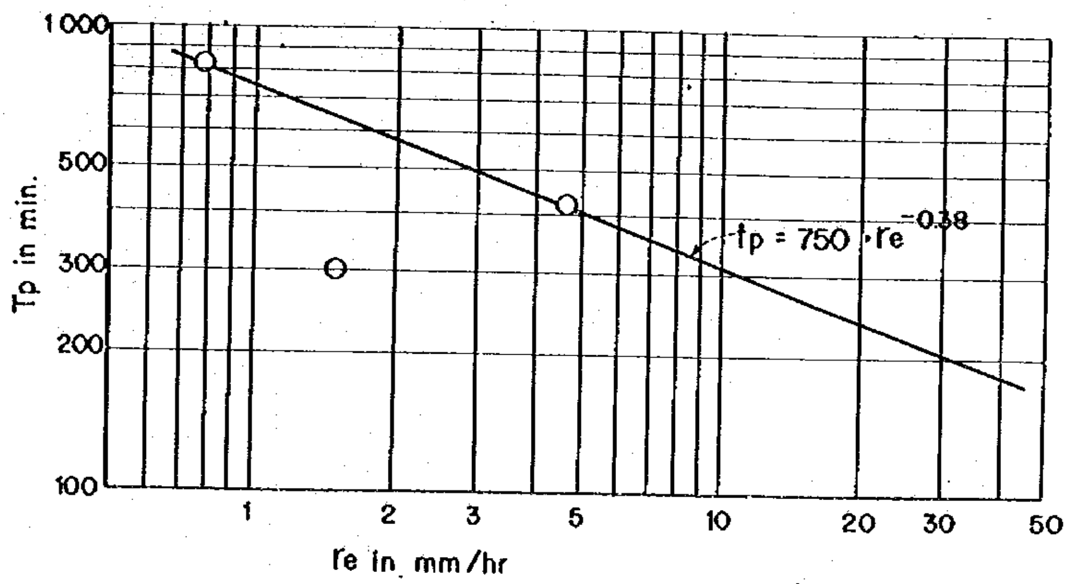


Fig. I-30

RELATION BETWEEN RAINFALL INTENSITY AND TIME OF CONCENTRATION

Kikafu River

Gauging Station = 1DD8A
Rainfall Station = Lyamungu A.R.I



Note. Tp = time from start of rise to peak rate (min)

re = effective rainfall intensity during Tp (mm/hr)

ANNEX II

HYDROGEOLOGY

FEASIBILITY REPORT

ON

THE LOWER-MOSHI AGRICULTURAL DEVELOPMENT PROJECT

ANNEX II HYDROGEOLOGY

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ANNEX II

HYDROGEOLOGY

1. Introduction

1.1 General

Hydrogeological investigations were carried out from December 1979 to March 1980 aiming at development of groundwater resources for irrigation use. The survey area totals about 500 km^2 including not only the Project area but also the Arusha Chini area (TPC and Kahe Estates) where most production wells in the survey area are in operation.

In order to achieve the objectives, the following works were conducted.

a. Surface geological investigation based on an available topographic map (scale: 1:50,000),

b. Sub-surface lithologic study based on existing geological map and available lithologic logs for existing production wells,

c. Geo-electric prospectings covering the whole survey area of about 500 km^2 at 115 survey points (200 m deep),

d. Pumping tests by using existing production wells, and

e. Water quality investigation and analysis.

Studies on each item mentioned above are described hereunder briefly. Conclusion and recommendation for further studies are written in the final section.

1.2 Previous Investigations

The comprehensive survey and study on groundwater resources in the Lower-Moshi area was commenced in 1966 as a part of the Pangani and Wami Rivers Basin Project by FAO1/. The main objective of the survey in the Lower-Moshi area was to confirm the availability of the Miwaleni spring discharge for irrigation use. Based on this study, the Kahe irrigation scheme was planned and implemented using the Miwaleni spring as a water source for the project.

In 1976, the groundwater potential in the Lower-Moshi area was investigated aiming at agricultural development around the Miwaleni area under the technical cooperation programme by the Japanese Government2/.

1/ FAO, "Hydrogeological Investigation of the Miwaleni Spring, Near Moshi, Northern Tanzania", LA/SF:TAN-4, October 1968

2/ JICA, "Survey Report for Agricultural Cooperation Project in Kilimanjaro Region, Tanzania", 1976

Investigations were carried out by means of geo-electric prospecting (49 points), pumping test by using an existing production well and data analysis, and the promising area for groundwater development of about 25 km^2 was delineated from the surveyed area of 35 km^2.

In 1977, a comprehensive study on groundwater resources in the Lower-Moshi area was described in the Integrated Development Plan in Kilimanjaro prepared by JICA1/. In this Plan, irrigation schemes using groundwater were recommended in the Miwaleni, Kitereni, Mabogini and Chekereni areas.

1/ JICA, "Integrated Development Plan, Kilimanjaro Region", 1977

2. Geology in the Lower-Moshi Area

Geological map[1/] (scale 1:125,000) and lithologic logs for 25 production wells are available in the survey area as shown in Figures II-1 and II-2 respectively. Based on surface geological investigation, previous study reports and the above available data, geological features in the Lower-Moshi area are described hereunder.

2.1 General Features

The Lower-Moshi area consists geologically of thick alluvial deposits and pyroclastic flows overlying precambrian crystalline metamorphic rocks. Faulting and volcanism continued from place to place throughout the Miocene and Pliocene times, and the major part of these activities terminated in Recent time.

Fault-trough associated with rift movement is the most important structural feature in the Lower-Moshi area. The general fold direction is NNW-SSE. On this trough, a lake existed during Neogene times.

Precambrian rocks are the basement of this area, which are exposed on the ground surface in Nymba Ya Mungu and dip steeply northward. In the Lower-Moshi area, basement rocks lie more than 200 m deep.

2.2 Geological Formations

Major geological formations found in the Lower-Moshi area are shown in Figure II-1. The principal features of each formation are explained below in the order of their age.

(1) Precambrian

Biotite gneiss: The oldest formation underlying the survey area is precambrian biotite gneiss of metamorphic rocks. The structure of these basement rocks in the survey area gradually subsides from the Nyumba Ya Mungu area diping to the north, and is presumed to be distributed down far from surface in the Lower-Moshi area. This formation is exposed in a limited area along a faulting zone in the northern part of Pare Mountains and western part of Lelatema Mountains.

(2) Neogene

i) Pyroclastic flow: Pyroclastic flow cropout in an area of approximately 180 km^2 in the southern slopes of Kilimanjaro, north of the Miwaleni upland. This formation is composed of much weathered lava, agglomerate, scoria etc. This area is easily eroded in places, and some fragmented landscape are recognizable.

1/: Geological Map of Kilimanjaro-Moshi, Geological Survey of Tanzania, 1965

ii) Mawenzi Lava: The Mawenzi group is so named because all the principal peaks of Mawenzi are built of its members. It is a sequence of effusions, including considerable amounts of pyroclastic rocks, showing the following range of types: olivine trachybasalt and trachybasalt - olivine trachyandesite and trachyandesite - basalt - andesite.

iii) Kibo Lahar: Kibo Lahar has the largest exposure in the southwest of Moshi. This deposit was formed by enormous debris flows during the development of the Kibo peak. It is composed of porphyry pebbles of 1 - 10 cm in size.

iv) Kibo Lava: The more recent lavas have tended to flow down the north and east flanks and in this region no older structure is found. Most of the Kibo lavas belong to the earlier part of the Pleistocene. The Kibo lavas show strong alkaline differentiation and range from trochy andesite, through trachyte to nepheline-rich phonolite. A wide range of these rock-types occurs, and a detailed succession is well-established, especially in the south-west. Individual flows, which may exceed 15 m in thickness, are known to extend more than 40 km from their probable point of origin. They moved by characteristic tunnel-flow mechanism.

v) Volcanic Cones: Associated with the Kilimanjaro volcanicity are small but numerous adventitious cones. The cones are usually only 100 m in diameter and about the same in height, but several reach one km in diameter and over 150 m in height. They are composed of mainly of scoria and ash with some lava flow. The activity is most strongly recognized in a NWN-SES direction which crosses the row of main peaks.

vi) Superficial Deposits: These deposits may be classified into Alluvium, Redsoils, Residual Redsoil and outwash, depending on the mode of origin of the material. Among them, Alluvium has the largest exposure in south of Lower Moshi area followed by redsoils, mainly derived from volcanic rocks, and residual redsoil and outwash derived from precambrian rocks.

3. Geo-electric Prospecting

3.1 Method

The geo-electric prospecting was carried out covering whole Lower-Moshi area in order to clarify the hydrogeological conditions in the area during January to February in 1980.

The survey was carried out to cover the whole survey area of about 500 km^2 by 8 survey lines on which 115 survey points were laid out as shown in Figure II-3. During the survey period, soil condition was generally good for geo-electric prospecting.

The technique applied is itemized below.

1) Measuring points; 115 points (8 lines)
2) Measuring depth; 200 m deep
3) Measuring method; Wenner's method
4) Equipment used; ES-D2 (OYO)

Results of measurement are summarized in the form of ρ-a curves in the Data Book. Analyses for ρ-a curves were made principally by the method of "standard curve analysis", but in some cases, by means of empirical judgement. The result of ρ-a curve analysis are shown in the Data Book in the form of resistivity logs.

3.2 Hydrogeological Formations

Based on the results of ρ-a curve analyses, hydrogeological formations in the survey area are classified into nine (9) types as follows.

No.	Formation Name	Material Contained	Availability of Groundwater	Resistivity (ohm-m)
1	Fan deposits	sand, gravel, and boulder.	low	60 - 250
2	Superficial deposits	clay (dominant), red soils, sand, calcareous (partially).	low to moderate	8 - 30
3	Kibo lava	lava and boulder of basalt.	moderate	120 - 2,000
4	Pyroclastic flow	sand gravel, basaltic flow and rhyolite.	moderate to high	100 - 200
5	Lacustrine deposits	calcareous agglomerate, limestone, clay and sand.	low to moderate	25 - 60
6	Kibo lahar	mud flow and debris flow.	none	6 - 60
7	Volcanic rocks	parastic cone, scoria, ash and olivine basalt.	low to moderate	80 - 1,800
8	Volcanic mud flow	mud flow.	none	16 - 40
9	Precambrian rocks	biotite gneiss.	none	100 - 1,440

3.3 Geo-electric Profile

Based on analyzed results for each survey point, 10 geo-electrical profiles (i.e. 8 survey lines and two crossing lines) are presented as shown in Figure II-4 (1) to II-4 (6). Locations of each profile are shown in Figure II-3. Characteristics for each profile are briefly described in the order from north to south as follows.

(1) East-west profile (across survey lines)

Section A-A': This section runs crossing the southern area of Moshi Town. As shown in Figure II-4 (2), Kibo lava is dominant extending from 5 m to 60 m in thickness, which is regarded as a good aquifer from the viewpoint of both quantity and quality.

Section B-B': This section runs 2 km south of Section A-A'. As shown in Figure II-4 (2), Kibo lava unconformably underlain by Kibo lahar is extensively distributed in the north-western survey area. A representative production well on Kibo lava is the W-1 well which yields medium amounts of water (33 to 57 lit/sec) with the best quality among production wells in the survey area. Hence, Kibo lava is judged to be a good aquifer.

Section C-C': This section stretches from the Weru Weru river to Uchira village. In the eastern portion, Volcanic rocks is dominant extending up to 200 m in thickness as shown in Figure II-4 (3). In the western portion, both Kibo lava and lahar are dominant. Between these two portions, formations may consist of both Superticial and Pyroclastic flows.

Section D-D': This section crosses the existing Miwaleni boreholes. From the western to middle portion of this section, Superficial deposits exist extending from 10 to 100 m thick as confirmed by lithological logs at Miwaleni boreholes. Below these deposits, Kibo lahar and Pyroclastic flow are lying in the eastern and middle portions respectively. In the eastern portion, Volcanic rocks are dominant as in Section C-C'.

Section E-E': This section is located from Kikafu ya Chini to Kifumbo through Checkereni. In the western portion, Lacustrine deposits are dominant extensively from the ground surface to 200 m deep. In the middle portion, Superficial deposits underlain by Pyroclastic flow or Lacustrine deposits exist extensively ranging from 50 to 130 m deep. In the eastern portion, Volcanic rocks underlain by Volcanic mud flow and Precambrian rocks are the representative formations.

Section F-F': This section is located 3 km south of Section E-E'. The section is covered extensively by Superficial deposits underlain by Kibo lahar, Lacustrine deposits and Precambrian in the western, middle and eastern portions respectively. In the eastern side, Volcanic rocks underlain by Volcanic mud flow are common.

Section G-G': This section is stretches from TPC to Kifaru Sisal Estate through Kahe. As shown in Figure II-4 (5), Superficial deposits are common in this section. They are as deep as 150 m in the middle portion, but in both sides they become shallow. Superficial deposits in both side are underlain mainly by Lacustrine deposits. In the eastern side, Volcanic rocks underlain by Precambrian rocks are shown.

Section H-H': This is at the southern extremity of the survey area. Superficial deposits become thicker than the upper sections. They range from 60 to 100 m deep in the eastern half portion and from 150 to 200 m deep in the western half portion. They are mainly underlain by Lacustrine deposits as shown in Figure II-4 (5).

(2) North-south profile (crossing line)

Section I-I': This section stretches from north to south maintaining 3 to 5 km distance westward from the Rau river. The upper area of this section is characterized by Kibo lava underlain by Kibo lahar and Pyroclastic flow as shown in Figure II-4 (6). The above Kibo lava and Pyroclastic flow terminate suddenly at the site at a ground surface elevation of 760 m (almost the same elevation of the junction between the Rau and the Njoro rivers). The lower area of this point is wholly covered by thick Superficial deposits ranging from 60 to 200 m or more in depth. In the Lower-Moshi area, they are underlain by Kibo lahar, Pyroclastic flow and Lacustrine deposits.

Section J-J': This section runs in a north-south direction crossing the Miwaleni spring. In the northern portion (or upper portion), Volcanic rocks are found on the ground surface but they dip into the ground steeply in the south direction as shown in Figure II-4 (6). In the Lower-Moshi area, Superficial deposits are dominant (50 to 150 m deep) underlain by Pyroclastic flow and Lacustrine deposits which are considered to be a promising aquifers for groundwater development.

4. Groundwater

4.1 Present Conditions

4.1.1 Production well (Deep well)

There are 25 production wells in the survey area; 14 wells in TPC estate and 11 wells in the Lower-Moshi area as shown in Figure II-5. Data and information on these wells are summarized in Table II-1. Principal features of these wells are as follows.

Location	No. of Wells (nos.)	Diameter (mm)	Depth (m)	Discharge (lit/sec)	Electric Conductivity (μ S/cm)
TPC	14	280-686	61-98	20-145	155-2,000
Miwaleni	4	150-250	59-75	17-58	370-420
Chekereni	2	150-200	61-91	3-8	580-1,250
Kahe	4	150-200	55-61	28-47	1,300-2,200
Kiomu	1	150	60	17	-

The total production yield for all wells are estimated at about 56,000 m^3 per day or 20.4 MCM per year.

The depth of water bearing formation ranges between 10 and 90 m in most of the survey area. The static water level ranges from 2 to 6 m below the ground surface.

4.1.2 Shallow well

Nine shallow wells are scattered in the Lower-Moshi area as shown in Figure II-5. The static water level is around 3 m (2.0 to 5.8 m) below the ground surface before the rainy season. Data on shallow wells are summarized in Table II-2. Electric conductivity of shallow wells is generally very high (2,000 - 6,000 μ S/cm) and hence, they are not suitable for irrigation use.

4.1.3 Springs

There are 20 springs in and around the Lower-Moshi area as shown in Table II-3 and Figure II-5. In the Kibo area 14 springs exist including the group of Njoro spring. Spring water emerges as a fracture type spring from the lava. Discharge of these springs ranges from 55 to 275 lit/sec which are classified into grade-3 spring (÷ 283 28.3 lit/sec) according to "Meinzer classification".

On the other hand, the biggest spring exists in the Miwaleni area. The average discharge of this spring is about 3,850 lit/sec which is classified into grade-1 spring (÷ 2,000 lit/sec or more)according to "Meinzer classification".

4.2 Pumping Test

Pumping test was carried out by using No. W-19 well at Chekereni on 12 March 1980. In addition, previous records on pumping test were also collected as shown in the Data Book.

These records are analyzed by using the Theis non-equilibrium formula as shown in Figure II-10. Transmissibility and permeability coefficients are calculated by using the Jacob method as follows.

Area	Well No.	Date	Screen Length	Transmissibility 1/	Permeability 2/
			(m)	(m^2/day)	(cm/sec)
TPC	W - 5	June 1972	-	187	-
"	W - 6	June 1972	26.5	203	8.9×10^{-3}
Miwaleni	W - 15	Feb. 1976	4.5 3/	1,426	3.7×10^{-1}
Chekereni	W - 19	Mar. 1980	16.5	244	1.7×10^{-2}
"	W - 20	June 1970	-	922	-
Kiomu	W - 25	Apr. 1979	20.0	3,385	2.0×10^{-1}

1/: refer to Figure II-10,
2/: Permeability = Transmissibility/Screen Length,
3/: thickness of aquifer.

As shown in this table, permeability of artesian aquifers in the Lower-Moshi area range between 2×10^{-1} and 1.7×10^{-2} cm/sec.

4.3 Aquifer Characteristics

4.3.1 Phreatic aquifer

The phreatic aquifer in the survey area is composed of clay and sandy clay layers with thin strings of sand, and calcareous hard pan. The clay and sandy clay layers show low permiability. Permeable sand is irregular in distribution.

Groundwater in the phreatic aquifer flows downwards along the ground slope as typically shown in Figure II-6 observed by piezometer network in TPC estate. The water table exists 2 to 3 m below the ground surface in the survey area.

Annual fluctuation of groundwater level has been observed in a series of observation wells at Chekereni village and the piezometer network at TPC estate. As shown in Figure II-7, annual fluctuations of groundwater level range from one to two meters. They peak mainly in June and reach lowest level in February before the rainy season. The water level moves with a lag of about two months behind the rainy season.

Variation of groundwater level in TPC estate during 7 years (1972-79) are shown in Figure II-7. The water table has risen from 0.1 to 1 m in these 7 years at the middle area of TPC estate. This may be caused by excess water due to furrow irrigation.

4.3.2 Artesian aquifer

An artesian aquifer exists throughout the project area. The water bearing formation is composed of lava, sand and gravel, probably up to 40 m thick in the Kibo lava area and Miwaleni upland area. In the southern part of the survey area, the artesian aquifer consists of sand and gravel with clay.

Groundwater of artesian aquifer originates from the flank of Mt. Kilimanjaro and flows from north to south toward Nyumba ya Mungu reservoir over an average gradient of 1:200 to 1:330 as shown in Figure II-8. Groundwater contour lines shown in this figure are almost in parallel with ground contour lines. Figure II-9 shows variation of a groundwater level profile from No. W-1 well near Moshi to No. W-23 well at Kahe. Level of groundwater varies from 18 to 2 m below ground surface.

Specific capacity of existing production wells ranges widely from 0.2 to 167 lit/sec/m as shown in Table II-1. Because of unsuitable screen position and/or insufficient bore diameter, many production wells in the Lower-Moshi area indicate low specific capacity. As shown on lithologic logs for existing wells (refer to Figure II-2), production wells having suitable screen position produce enough groundwater like No. W-18 well at Miwaleni area. Permeability of the artesian aquifer ranges from 2×10^{-1} to 1.7×10^{-2} cm/sec as mentioned in the previous section. Accordingly, the artesian aquifer in the Lower-Moshi area is generally considered to have high potentiality for development.

4.4 Delineation of Groundwater Area

The lower-Moshi area can be divided into five groundwater areas based on the results of geo-electric prospecting and data analysis as shown in Figure II-5. Characteristics of each groundwater area are described below.

(1) Kibo lava area

The Kibo lava lies directly on the mud flow around Moshi town. Almost all springs around Moshi emerge from this groundwater body with good quality. Aquifers of this area are capable of yielding a moderate quantity of water.

(2) Arusha chini area

Based on the results of the geo-electric prospecting, it can be said that an impermeable formation exists at the depth of around 100 m. This impermeable formation is overlain by moderate to large quantities water bearing formations.

(3) Miwaleni upland area

This area extends on the southern mountain slope of Mt.Kilimanjaro. Drilling information on existing wells suggest that the high resistivity (ρ = 80 to 720 ohm-m) indicates probability of a good aquifer. For example, a large specific capacity appears on well number 18. Aquifers of this area are capable of yielding moderate to large quantities of water.

(4) Kahe area

Geological formation in this area seems to be alternating formations of clay and sand. In this area, both deep and shallow ground water resources are characterized by the presence of salinity with high electric conductivity. Aquifers in this area are capable of yielding a moderate quantity of water.

(5) Kiomu area

There are a number of scattered hills of precambrian basement rocks in this area. According to the drilling data for existing well, the Precambrian formation is covered by the unconsolidated formation. An existing well has shown a yield of 1.0 m^3/min in the unconsolidated formation. Aquifers in this area are capable of yielding a moderate quantity of water.

4.5 Groundwater Balance between Recharge and Discharge

4.5.1 Recharge mechanism

The aquifer within the project area is recharged by lateral flow from the flanks of Mt. Kilimanjaro covered by the weathered lavas and pyroclastic flows.

Figure II-11 shows that groundwater in the Lower-Moshi area flows from north to south through this aquifer. The average gradient of the flow is about 1:400 and is somewhat steeper in the north than in the south.

The recharging area can be divided into four sub-areas based on topographical and geological conditions as shown in Figure II-11. Based on this figure, the groundwater balance between recharge and discharge is studied hereunder aiming at estimating groundwater resource potential for development.

4.5.2 Estimation of recharge volume

Recharge volume of groundwater is estimated for each sub-area using two approaches, i.e. water balance analysis and flow pattern analysis, as explained hereunder.

(1) Estimation by water balance

The following equation is used to estimate recharge volume of groundwater:

$$P \cdot A = A\ (P \cdot C + E) + G$$

where; A = Recharging area,
P = Rainfall,
E = Evapotranspiration,
C = Run-off coefficient, and
G = Recharging volume of groundwater

According to the above equation, recharge volume of groundwater is estimated on an annual basis as follows.

	(A)	(P)	(E)	(C)	(G)
Sub-area	Area	Annual Rainfall 1/	Evapo-trans-piration 2/	Runoff Coeffi-cient 3/	Recharge Volume
	(km^2)	(mm/y)	(mm/y)		(MCM/y)
1. Himo	247	1,288	444	0.20	145
2. Miwaleni	344	1,345	596	0.20	165
3. Kibo Lava	397	1,338	460	0.29	195
4. Kikafu	208	1,385	522	0.55	21
Total	1,196				526

1/ : refer to Table I-10, 2/ refer to Table I-12,
3/ : refer to page I-16 in Annex I.

(2) Estimation by flow pattern

Flow volume in the ground can be estimated by using Darcy's law as shown below.

$$Q = K \cdot A \cdot i$$

where; Q = discharge,
K = coefficient of water permeability,
A = flow area, and
i = Hydraulic gradient.

Using this equation, estimation is made for each sub-area as follows based on assumptions footnoted.

Sub-area	(A) Flow Area Width1/ (km)	Thickness2/ (m)	Area ($x10^3 m^2$)	(k) Permea-bility3/ (cm/sec)	(i) Gradient4/	(Q) Recharge Volume (MCM/y)
1. Himo	3.5	30	105	$1.0 x 10^{-1}$	0.0075	25
2. Miwaleni	18	40	720	$3.7 x 10^{-1}$	0.0031	260
3. Kibo Lava	12	40	480	$2.0 x 10^{-1}$	0.0055	166
4. Kikafu	4	20	80	$1.0 x 10^{-1}$	0.0090	23
Total						557

1/: Measured on Figure II-13,
2/: result of geo-electric prospecting and geological map,
3/: "k" for Miwaleni is based on data at No.W-15 well.
Other k values are inferred.
4/: measured on the Groundwater Contour Map (Figure II-8)

4.5.3 Recharge-discharge balance

Based on the above estimations, remaining volume of groundwater resource is presumed as follows.

Presumption of Remaining Groundwater

(Unit = MCM/years)

Sub-area	Recharging Volume: Water Balance	Flow Pattern	Volume1/	Discharge Volume2/	Remaining Volume
1. Himo	145	25	25	Sp. (6)	19
2. Miwaleni	165	260	165	Sp.(121) Well (3)	41
3. Kibo Lava	195	166	166	Sp.(124) Well(18)	24
4. Kikafu	21	23	21	Unknown	21
Total	526	557	430	272	158

1/: Smaller value is selected.
2/: Sp. = springs. Volume is calculated based on Table II-3.

4.5.4 Development potential

(1) Evaluation

Based on studies mentioned above, development potential for each groundwater area is evaluated broadly as follows.

Evaluation of Groundwater Area

Groundwater Area	Recharging Area	Remaining Volume	Aquifer Capacity	Water Quality	Development Potential
Outsite the Lower-Moshi area					
1. Kibo lava	Kibo lava		moderate	good	high
2. Arusha chini (western half)	Kibo lava		large	good to poor	high
In the Lower-Moshi area		24			
1. Arusha chini (eastern half)	Kibo lava		moderate	poor	low
2. Kahe	Kibo lava & Miwaleni	41	moderate	poor	low
3. Miwaleni upland	Miwaleni		moderate to large	good	high
4. Kiomu	Himo	19	moderate	good	medium

In the Lower-Moshi area, the most promising area for groundwater development will be Miwaleni upland area. The Kiomu area, recharging from Himo river basin, is also recommendable for development.

(2) Development measurements

Recommendable groundwater areas, i.e. Miwaleni upland and Kiomu area, are represented by the existing Miwaleni boreholes and the Kiomu well respectively.

Miwaleni upland area

Representative production wells in the Miwaleni upland area are four Miwaleni boreholes located about 2 km north or northeast of the Miwaleni springs. At present, the discharge rate of these boreholes range from 11.2 to 58.1 lit/sec. Specific capacity of three wells (BH 1, BH 2, BH 3) is only from 0.9 to 2.0 lit/sec/m because of unsuitable screen position as shown in Figure II-2. On the other hand, specific capacity of the remaining well (BH 4), which is the newest one, is as high as 167 lit/sec/m because screens were set in suitable positions as shown in Figure II-2.

Accordingly, the artesian aquifer at Miwaleni upland area is judged to have high development potential. Yield more than 60 lit/sec per well will be assured if production wells are planned to be spaced at least 1,000 m apart. Possible volume for groundwater development in the Miwaleni upland area is estimated at 41 MCM/year, or 1.3 m^3/sec. If production wells are distributed at selected locations, a certain percentage of the above volume will be available for irrigation.

Kiomu area

Kiomu well, a representative well in Kiomu area, is located 2 km west of Kiomu village. The well has a specific capacity of 20.9 lit/sec/m and permeability of the aquifer evaluated by pumping test is 2 x 10^{-1} cm/sec. These data assure high development potential of the artesian aquifer in Kiomu area.

The discharge rate of Kiomu well is only 16.7 lit/sec because the diameter of the well is as small as 150 mm. If the well diameter is enlarged to permit a submersible motor pump to be installed, yield of the well should more than double the rate according to the specific capacity mentioned above.

Taking topographical and geological conditions into consideration, possible volume for groundwater development in the Kiomu area is estimated at 9 MCM/year assuming that a half of remaining groundwater from the Himo river basin flows into the Kiomu area.

(3) Conclusion

Decision of development technique should depend on further study based on test well drilling as recommended in the final section in this Annex. Although available data and information are limited, development parameters are summarized below as a tentative conclusion at present.

Groundwater Area	Available Amount (MCM/y)	Condition of Well			
		Discharge (lit/sec)	Bore Dia. (mm)	Depth (m)	Spacing (m)
Miwaleni upland	41	60	300	100	1,000
Kiomu	9	30	300	100	1,000

5. Quality of Water

5.1 Field Survey and Chemical Analysis

Field measurement of electric conductivity was made during the survey period from January to March 1980 by using a portable E.C. meter. In parallel with this survey, water temperature was also measured. The survey results are shown in Table II-1 to II-4.

Chemical analyses for 13 samples from 4 wells, 6 springs and 3 rivers were made in Japan on the following items;

PH, RPH, E.C., Sodium, Potassium, Calcium, Magnesium, Bicarbonate, Chloride, Sulfate, Silica, Manganese, Fluoride, Iron, Total residue, and SAR.

Analyzed results are shown in Table II-5. Locations of sampling points are shown in Figure II-12.

5.2 Electric Conductivity

(1) Springs

Measured E.C. values range from 105 to 365 μS/cm as shown in Table II-3. As shown in this table, springs are divided into two types; i.e. the Njoro spring type and the Miwaleni spring type.

The former emerges as a fractuate spring from the Lava. The quality of water is excellent with an E.C. value from 105 to 170 μS/cm. The latter, including Soko and Kileo springs, emerges through subsurface migration and storage processes, and their quality is relatively lower than the former with an E.C. value from 290 to 365 μS/cm.

(2) Deep wells

Measured E.C. values range from 155 to 2,200 μS/cm as shown in Table II-1. In general, the water quality of deep wells located in the southern area of the survey area is worse than that in the northern area. The best quality of water is found in well W-1 with an E.C. value of 155 μS/cm.

(3) Shallow wells

Generally, E.C. values for shallow wells excluding No.2 well are very high ranging from 1,980 to 6,000 μS/cm. No.2 well with an E.C. value of 262 μS/cm, seems to emerge from underflow of the Rau river.

(4) River water

Measured E.C. values range from 79 to 1,380μS/cm as shown in Table II-4. In general, E.C. values as low as 79-250μS/cm were observed upstream in each river, while E.C. values of water downstream (near the southern boundary of the survey area) of rivers are 310μS/cm or more. In particular, the Kikuletwa river water indicated an E.C. value of 1,100μS/cm.

5.3 Water Quality Classification

Chemical analysis for 13 water samples were carried out in Japan in March 1980. The results are summarized in Table II-5. Based on these results, water quality of each sample can be classified into three groups using a key-diagram as shown in Figure II-13.

Classification of Artesian Water

Name of Group	Sampes	Type
1. Kibo Lava	Njoro spring, TPC N 100 well	Carbonate hardness
2. Miwaleni	Miwaleni BH 3 well Miwaleni spring Soko spring Kileo spring	Carbonate alkali
3. Chekereni	Chekereni well TPC N 90 well	Noncarbonate alkali (rich in chlorides)

Among the above types, carbonate hardness type is generally found in fresh groundwater like the Njoro spring. On the other hand, artesian water belonging to the Miwaleni group seems to have undergone considerable chemical alternation during subsurface migration and storage processes.

River water sampled from the Rau and Himo rivers is categorized as carbonate alkali type as shown in Figure II-5.

5.4 Evaluation of Water Quality for Irrigation

In order to evaluate water quality for irrigation use, sodium-absorption-ratio (SAR) is calculated as shown in Table II-5. Evaluation can be made by use of a classification diagram as shown in Figure II-14 which is made by plotting the SAR value against the E.C. value.

According to the figure, all river water and artesian water categorized as Kibo Lava group is classified into C1-S1 class which is regarded as low salinity and low sodium hazard water, and hence it can be used for irrigation without problem.

On the other hand, artesian water categorized as Miwaleni group is classified into C2-S1 class which is regarded as medium salinity and low sodium hazard water. It is noted that careful attention should be paid during irrigation planning when crops with low salt tolerance are to be cultivated.

6. Conclusion and Recommendation

6.1 Conclusion

Through hydrogeological survey and study, two promising groundwater areas, i.e. Miwaleni upland area and Kiomu area, are selected for development. Recommendable pumping rate is 60 and 30 lit/sec for Miwaleni upland and Kiomu areas respectively. Production wells are recommended to have 300 mm diameter, 100 m depth and 1,000 m spacing, in order to assure the above yield. At least 75 % of the aquifer thickness should be screened.

The above conclusion should be verified or modified based on further study by using the recommended test wells.

6.2 Recommendation for Further Study

Through geo-electric prospecting and data analysis, it is understood that at least 5 test wells are needed to verify the complete groundwater potential for development in Miwaleni upland and Kiomu areas.

Before detailed design of groundwater irrigation schemes, further study using test wells is deemed indespensable. Through test well drilling and pumping tests, lithology, resistivity and spontaneous potential logging, static water level, water quality and estimation of hydrological constant (transmissibility coefficient, storage coefficient of aquifer, etc.) should be checked and studied in order to construct durable production wells. Specification of test wells is recommended as follows.

(1) Specification of test wells

Design of standard test well is shown in Figure II-15. The size of bore hole shall be at least 150 mm larger than the size of casing and have well screens installed. The test well shall be drilled down to 100 m depth.

Submersible motor pump with a capacity of 60 lit/sec will be fitted in 300 mm casing pipe. The length of pump chamber shall be decided carefully, taking the pumping water level and drawdown into consideration.

Well screen shall be the continuous slot screen type of the same size as the casing pipe. Material for screen shall be of fabricated double galvanized low carbon steel. In order to determine the screen position, electric logging shall be conducted in the uncased bore hole. Determination of slot size of screen and proper size of packing gravel shall be made by means of sieve analysis of samples obtained during drilling from the aquifer.

The allowable velocity in the screen shall be 3 cm/sec or less in order to minimize the friction losses in the screen during operation of well.

(2) Monitoring system

An automatic water level recorder should be installed each test well after the pumping test is completed, in order to verify the groundwater situation in the project area.

Table II-1

LIST OF PRODUCTION WELLS

Location* Number	B.H. No.	Altitude (m)	Name	Diameter (mm)	Depth (m)	S.W.L. (m) Existing Data	S.W.L. (m) Feb 1980	P.W.L. (m) Existing Data	P.W.L. (m) Feb 1980	DRAWDOWN (m) Existing Data	DRAWDOWN (m) Feb 1980	DISCHARGE RATE (ℓ/sec) Existing Data	DISCHARGE RATE (ℓ/sec) Feb 1980	SPECIFIC CAPACITY (ℓ/sec/m) Existing	SPECIFIC CAPACITY (ℓ/sec/m) Feb 1980	T (m^2/d)	k (Cm/sec)	** E.C. (MS/cm)	** Water Temp. (°C)	*** Log	Operating Cond.
W-1	281/75	745.85	T.P.C. N100	457 280	60.9 90		2.19					56.7	32.5					155	20.5	O	O
W-2	244/74	753.59	" N90	460	96	23.13		43.1		19.97		53.8	40.0	2.7				2000	24.5	O	O
W-3	95/74	755.30	" N70	558 482	68.7 96	23.09		41.28		18.19		45.3	19.5	2.5				310	22.5	O	O
W-4	33/74	744.02	" N40	600		12.07	14.20	34.27		22.20		116.2		5.2				400	24.5	X	O
W-5	52/71	722.01	" Q	460	96	2.75		13.28		10.53		113.3	85.0	10.8		187		630	25.5	O	O
W-6	21/72	719.20	" R	460	90	3.45	5.05	13.25	8.60	9.80	3.55	119.0	102.0	12.1	28.7	202.7	8.85×10^{-3}	1200	28.0	O	O
W-7	73/69	732.53	" D9	460	61	7.00	1.58	38.00		31.00		28.3		0.9						X	X
W-8	55/69	716.13	" B11	480		2.76	6.57	18.06	18.65	15.30	12.08	136.0	84.0	8.9	7.0			590	25.0	X	O
W-9	221/73	708.67	" 03	559 300	91.4	2.59	3.64					144.5	79.0					658	24.5	O	O
W-10	210/73	706.59	" 5D	500 300	69 90	3.58		9.05		5.47		110.5	84.0	20.2				740	25.0	O	O
W-11	230/74	709.09	" 19	460	97.5	0.79	1.80	7.83		7.04		133.2		18.9				700	27.5	O	O
W-12		704.70	" 20	300		2.59	2.03	13.26		10.67		70.8		6.6						X	X
W-13		702.50	" 21	460	97.5		2.00					141.7								O	X
W-14	143/74	707.00	" Factory	686 482	90				21.03									680	25.5	O	O
W-15	36/64	724.59	MIWA-LENI BH1	250	67.1	4.00		16.38		12.38		23.4	34.0	1.9		1425.6	3.67×10^{-1}	370	22.0	O	O
W-16	27/65	729.50	" BH2	150	74.7	7.80		21.50		13.70		27.3	11.2	2.0				370	22.0	O	O
W-17	29/65	731.00	" BH3	250	59	2.13	6.72	25.30		23.17		21.8	58.1	0.9				420	22.5	O	O
W-18	254/77	731.00	"	200 150	61.2 75.3	7.20		7.30		0.10		16.7		167						O	X
W-19	204/77	723.60	CHEKERENI	150	60.5	5.40	3.52	19.50	8.47	14.10	4.95	3.3	4.0	0.2	0.8	243.7	1.7×10^{-2}	1250	24.0	O	X
W-20	49/70	726.00	"	200	91.4	6.17		7.14		0.97		7.6		7.8		922		580	25.0	X	X
W-21		709.05	KAHE	150			2.77													X	X
W-22	22/65	704.51	" BH3	150	54.9	6.30		9.90		3.60		47.2		13.1						O	X
W-23	12/65	705.41	" BH2	200	54.9	6.60	1.47	11.80		5.20		27.8		5.3				2200	26.0	O	X
W-24	8/65	706.25	" BH1	200	61	7.80		10.50		2.70		27.8		10.3				1300	25.0	O	O
W-25	43/79	713.23	KIOMU	150	60	3.20		4.00		0.80		16.7		20.9		3384.6	1.96×10^{-1}			O	x

* Shows Figure II-5
** Measuring at Field (Feb 1980)
*** Shows Figure II-2

Table II-1

Table II-2 LIST OF SHALLOW WELLS

No.	LOCATION	DIAMETER mm	DEPTH m	S.W.L m	E.C. $\mu S/cm$	TEMPERATURE ^oC
1	MABOGINI	1400	7.25	5.75	1980	26
2	RAUSUGAR ESTATE	2000	3.47	1.99	262	24
3	KAHE	"	5.60	3.06	3000	24.5
4	"	"	5.70	3.81	6100	28
5	"	"	4.99	3.46	2400	25
6	MTAKUJA	"	2.90	2.30	2750	25.5
7	"	"	2.50	2.20	3800	26.5
8	"	"	2.55	2.40	3950	25
9	"	"	3.10	2.60	3150	27

Table II-3

LIST OF SPRINGS

NO.	NAME	LOCATION	DISCHARGE RATE		E. C.	TEMPERATURE	ALTITUDE	STRUCTURE
			l/sec	Meinzer unit	μ S/cm	°C	m	
1	NJORO SPRING	NJORO	169	3	105	17.5	810	Fracture, LAVA
2	BIG DOBI	"	372	2	105	18	779	" , 3 Eyes, LAVA
3	SMALL DOBI	"	106	3	105	18	785	" , LAVA
4	S-4	"	146	3	120	18	774	" , 2 Eyes, LAVA
5	S-5	"	84	3	115	18	774	" , LAVA
6	S-6	"	136	3	140	21	770	Contact
7	S-7	"	250	3	150	21	765	" , 3 Eyes
8	S-8	KALOLENI	105	3	140	19.5	765	Fracture, 3 Eyes
9	S-9	"	66	3	150	19	768	Fracture
10	KALOLENI SPRING	"	182	3	170	20	770	Contact
11	MANDAKA SPRING	MANDAKA	199	3	140	18.5	745	Contact
12	MIWALENI SPRING	MIWALENI	3850	1	350	21	715	Depression
13	SOKO SPRING	SOKO	189	3	365	24	713	" , 2 Eyes
14	KILEO SPRING	KILEO	344	3	290	21	705	"
15	KIKAFU YA CHINI	KIKAFU YA CHINI	6	5	260	22	723	Contact Spring
16	PRISON SPRING	PRISON	100	3	155	18.5	915	Fracture
17	KARANGA SPRING	KARANGA	110	3	220	20.5	870	Contact Spring, 2 Eyes
18	SHIRI SPRING	SHIRI	200	3	115	17.5	960	Fracture
19	MNINI SPRING	MNINI	1	5	190	21.5	960	Contact Spring, 2 Eyes
20	NSERI SPRING	NSERI	220	3	170	19.5	1005	Fracture

Table II-4 **WATER QUALITY OF RIVERS**

No.	RIVER	LOCATION	E. C. µ S/cm	TEMPERATURE °C
1	HIMO	HIMO	110	22
2	"		125	26
3	RUVU		420	24
4	KARANGA	GOLF COURSE	145	23
5	"	KARANGA	170	21.5
6	WERU WERU		150	23
7	"	WEIR OF TPC	200	22
8	"	KIKAFU YA CHINI	230	22
9	"	JUNCTION	360	25
10	KIKULETA	"	1100	25
11	"	GAUGE STATION	1380	24
12	KIKAFU	ARUSHA ROAD	79	22.5
13	RAU	HIMO ROAD	160	25.5
14	"	JUNCTION	250	24
15	"	NAFCO FURROW	240	24
16	"		220	22
17	NJORO	FOREST	120	20
18	NAFCO FURROW	MIWALENI	320	21
19	"	KAHE	310	22
20	MUA	SOKO	355	21.5
21	KYOYO	MNINI	140	21
22	KALIDEDA		340	23

Table II-5

RESULT OF WATER QUALITY ANALYSIS

No.	Sampling point*	Temperature** °C	PH	RPH	E.C μS/cm	Na^+ mg/ℓ	K^+ mg/ℓ	Ca^{2+} mg/ℓ	Mg^{2+} mg/ℓ	HCO_3^- mg/ℓ	Cl^- mg/ℓ	SO_4^{2-} mg/ℓ	SiO_2 mg/ℓ	Mn^{2+} mg/ℓ	F^- mg/ℓ	Fe^{2+} mg/ℓ	Total Iron mg/ℓ	Total Residue mg/ℓ	SAR	Sampling Date
1	TPC N90 WELL	24	7.6	9.1	2275	286.4	58.3	108	5.3	756.4	227	151	42	0.11	0.61	0.13	0.14	1410	6.83	15 Mar. 1980
2	TPC N100 WELL	20.5	7.8	8.4	154	17.6	5.5	6.5	3.0	73.2	6.3	4.8	52	0.13	0.27	0.11	0.19	163	1.44	18 Mar. 1980
3	RAU RIVER	25.5	7.59	8.38	106	6.5	2.0	7.4	4.2	48.8	5.7	4.6	37.7	0.15	0.16	0.11	0.56	96	0.47	13 Mar. 1980
4	RAU RIVER	24	7.58	8.4	195	18.2	5.5	10.8	5.0	91.5	7.9	9.1	38.6	0.29	0.23	0.83	2.19	182	1.14	13 Mar. 1980
5	SOKO SPRING	24	7.8	8.9	343	20.3	3.7	24	16.5	201.3	14.7	4.7	50.9	0.11	0.32	0.11	0.94	241	0.78	12 Mar. 1980
6	HIMO RIVER	22	7.72	8.1	105	4.6	1.3	8.0	4.7	54.9	3.8	2.6	35.8	0.11	0.22	0.11	0.38	99	0.32	12 Mar. 1980
7	SHIRI SPRING	17.5	7.5	8.3	136	17.9	5.3	4.9	2.1	67.1	3.8	3.0	54.2	0.17	0.32	0.11	0.25	154	1.68	14 Mar. 1980
8	NSERI SPRING	19.5	7.2	8.3	189	19.7	7.5	8.6	3.8	103.7	3.8	2.5	63.6	0.14	0.15	0.11	0.13	213	1.41	14 Mar. 1980
9	KILEO SPRING	21	7.64	8.8	311	20.0	3.0	20	14.4	176.9	10.5	4.7	46.1	0.11	0.19	0.11	0.16	225	0.84	12 Mar. 1980
10	MIWALENI SPRING	21	7.75	8.7	325	24.7	4.7	21	13.3	158.6	22.1	5.4	36.1	0.11	0.40	0.11	0.60	227	1.04	12 Mar. 1980
11	MIWALENI-BH3	22.5	8.0	9.01	453	20.5	3.0	34	25.3	274.5	15.8	5.8	55.5	0.11	0.19	0.11	0.16	303	0.65	13 Mar. 1980
12	CHEKERENI WELL	24	7.3	9.03	1190	97.4	8.3	80	3.8	341.6	196	16.4	88.8	0.46	0.41	0.11	0.50	785	2.88	12 Mar. 1980
13	NJORO SPRING	17.5	7.35	8.45	126	13.9	5.0	5.9	2.2	54.9	4.4	2.5	49.1	0.11	0.18	0.11	0.30	138	1.26	13 Mar. 1980

* Showing Figure II-14

** Measuring at Field, Sampling Time

Analyses by Nippon Koei Laboratory

Fig. II-1 GEOLOGICAL MAP

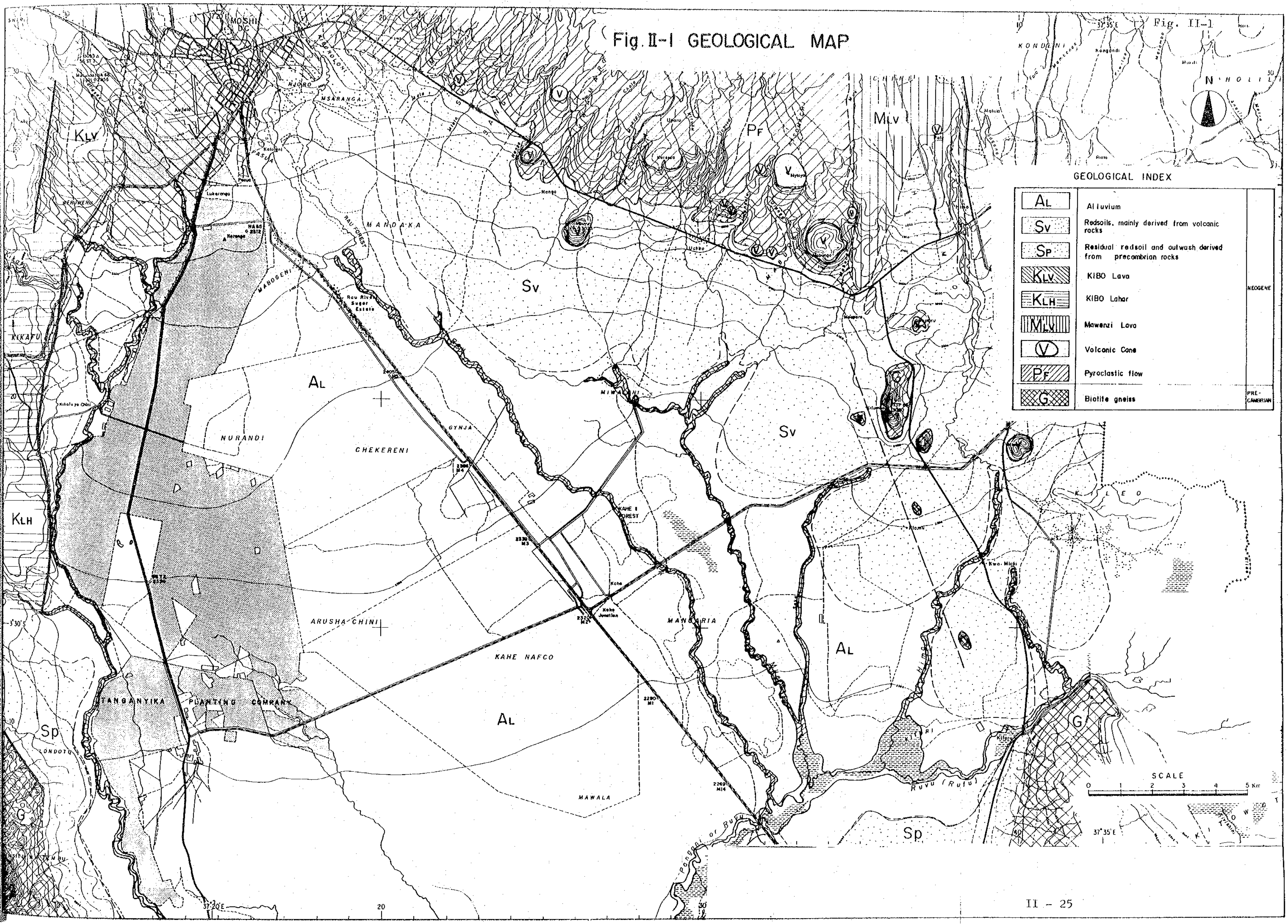
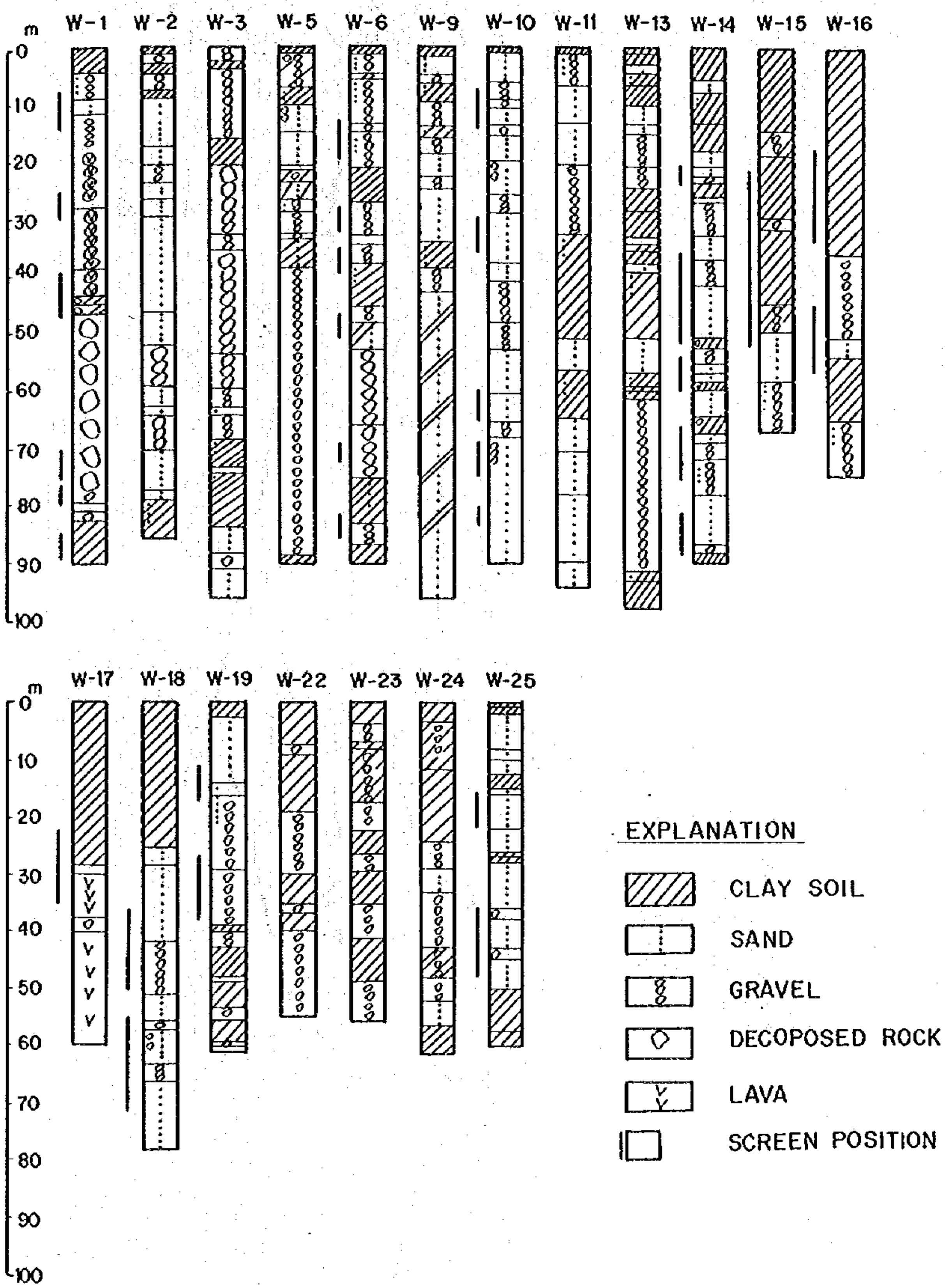


Fig. II-2 LITHOLOGIC LOGS FOR PRODUCTION WELLS



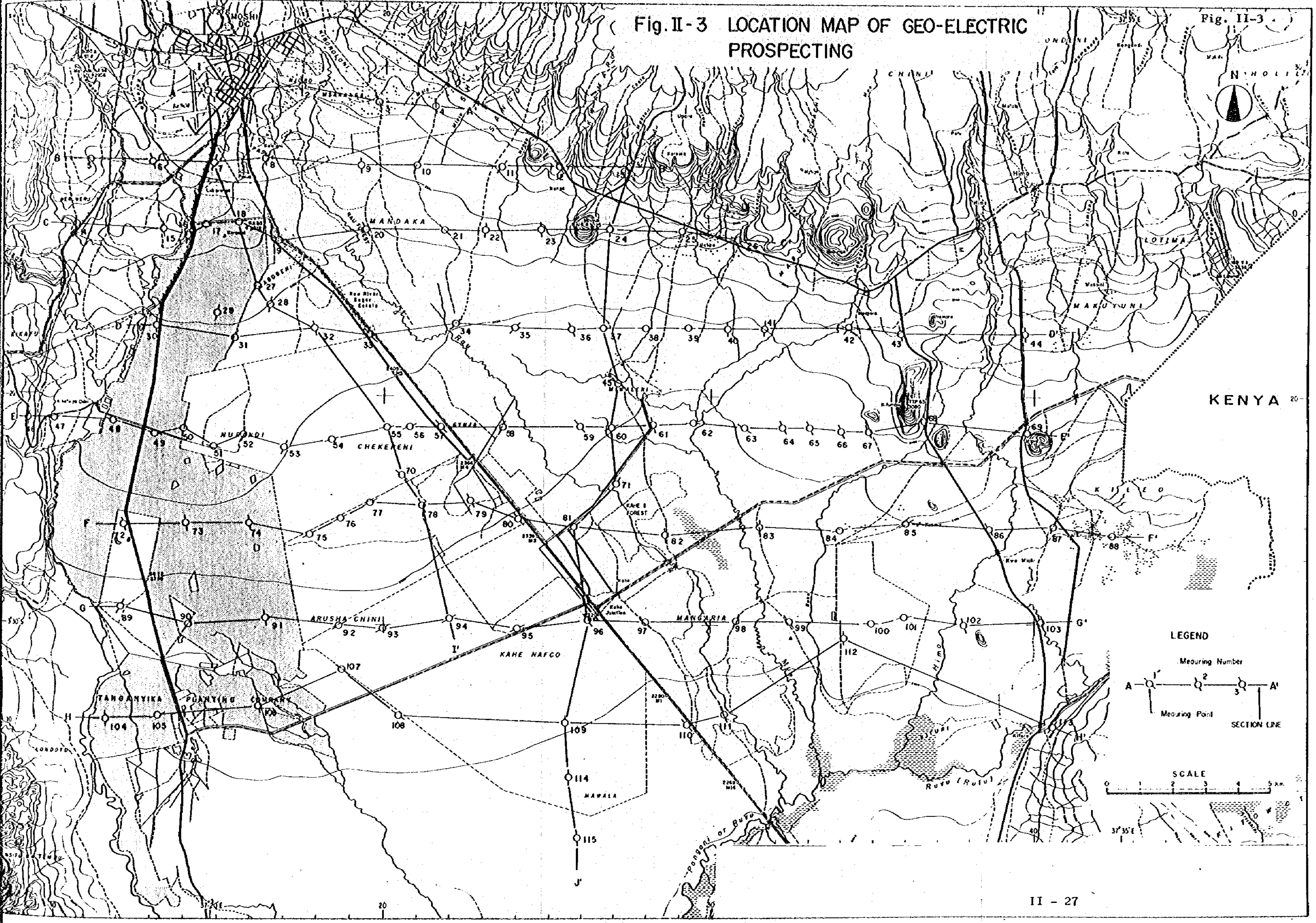
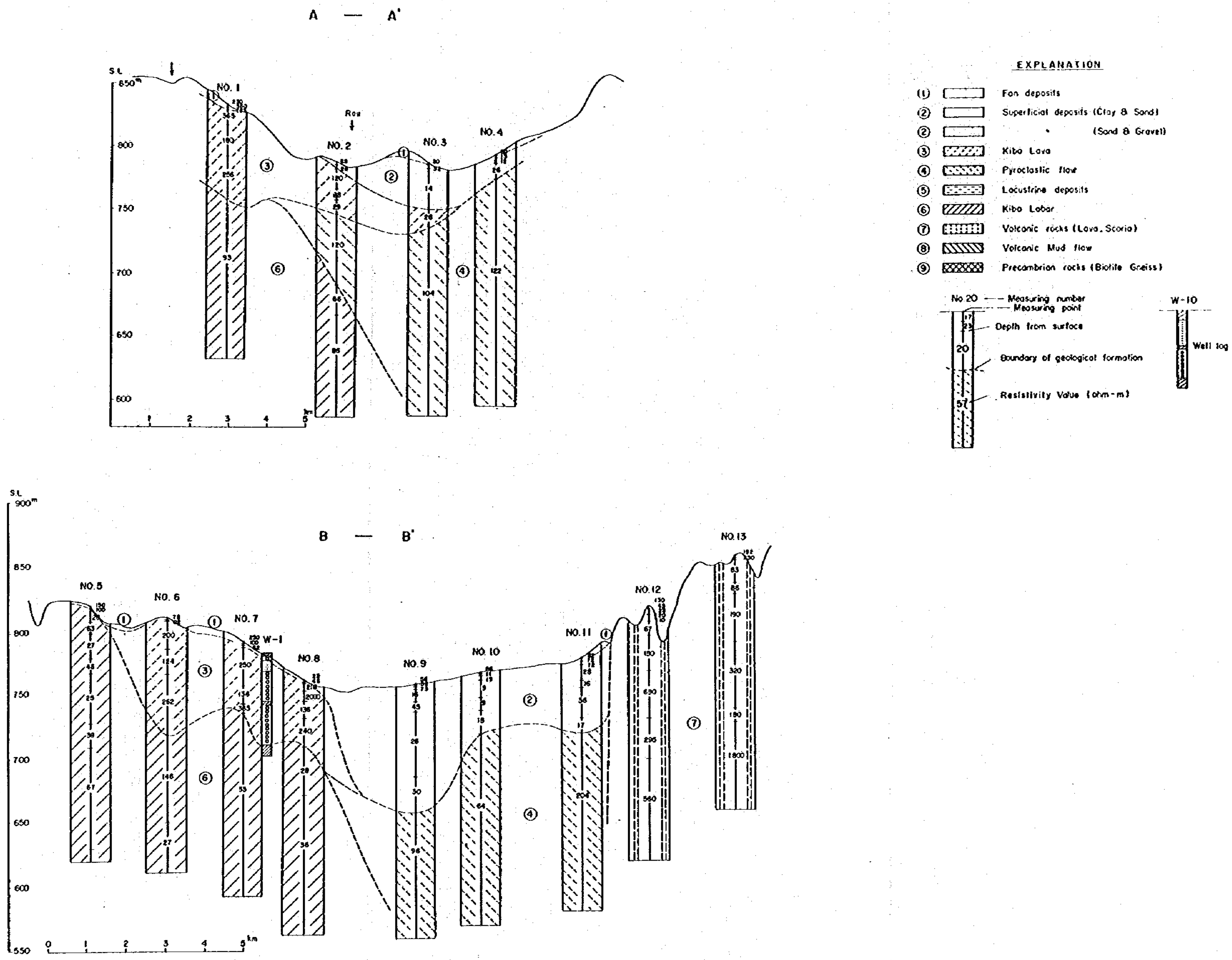
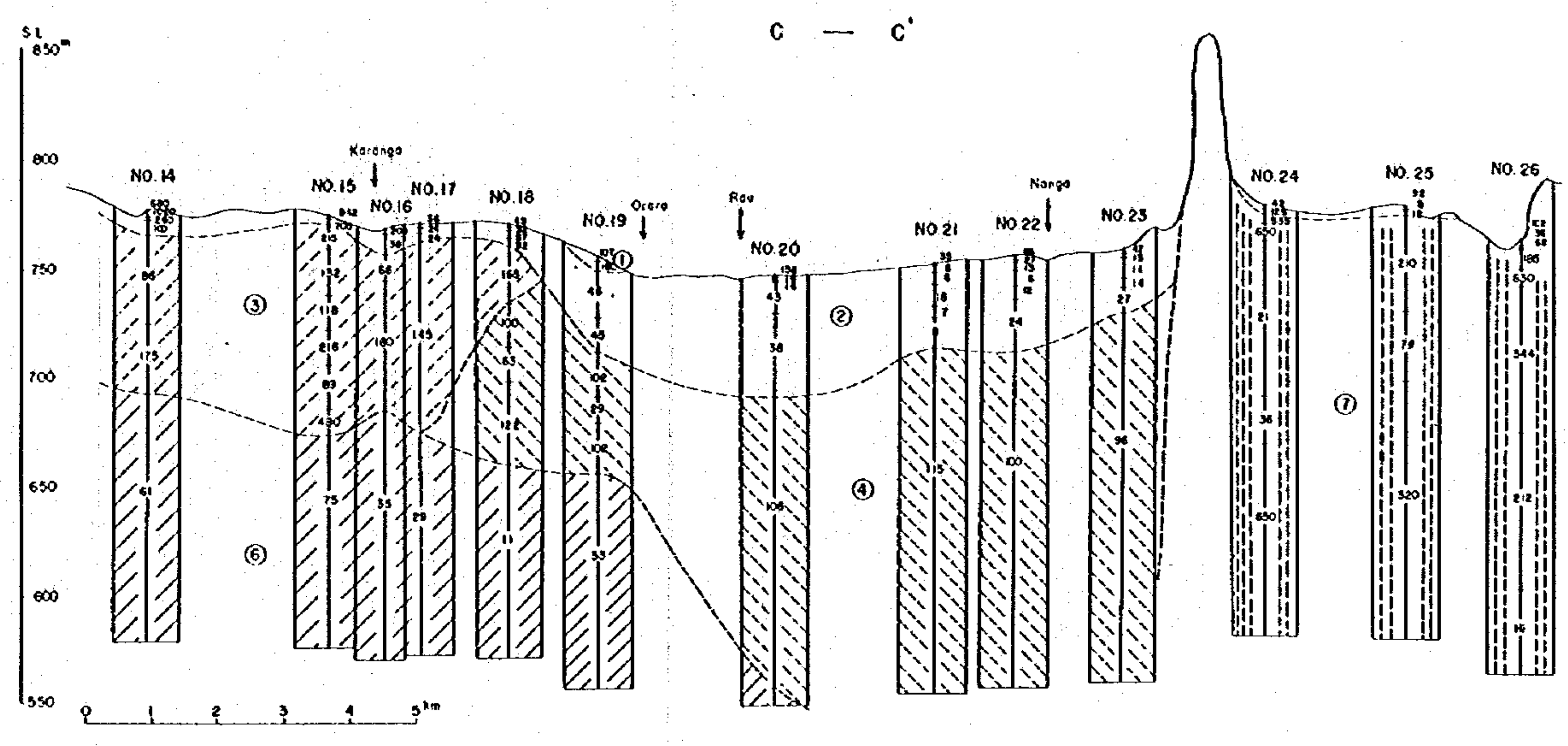


Fig. II-3 LOCATION MAP OF GEO-ELECTRIC PROSPECTING

Fig. II - 4 GEO - ELECTRIC PROFILES




C — C'
SL
850m
800
750
700
650
600
550
NO.14
NO.15
NO.16
NO.17
NO.18
NO.19
NO.20
NO.21
NO.22
NO.23
NO.24
NO.25
NO.26
Karanga
Ocare
Rau
Nanga
0 1 2 3 4 5km

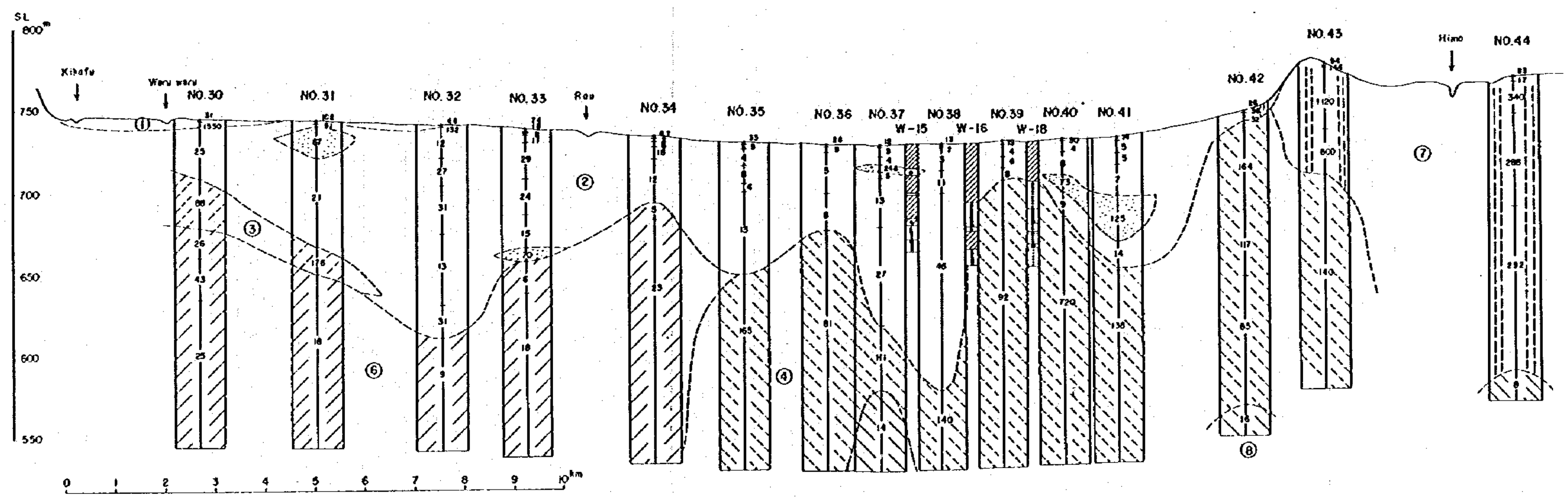
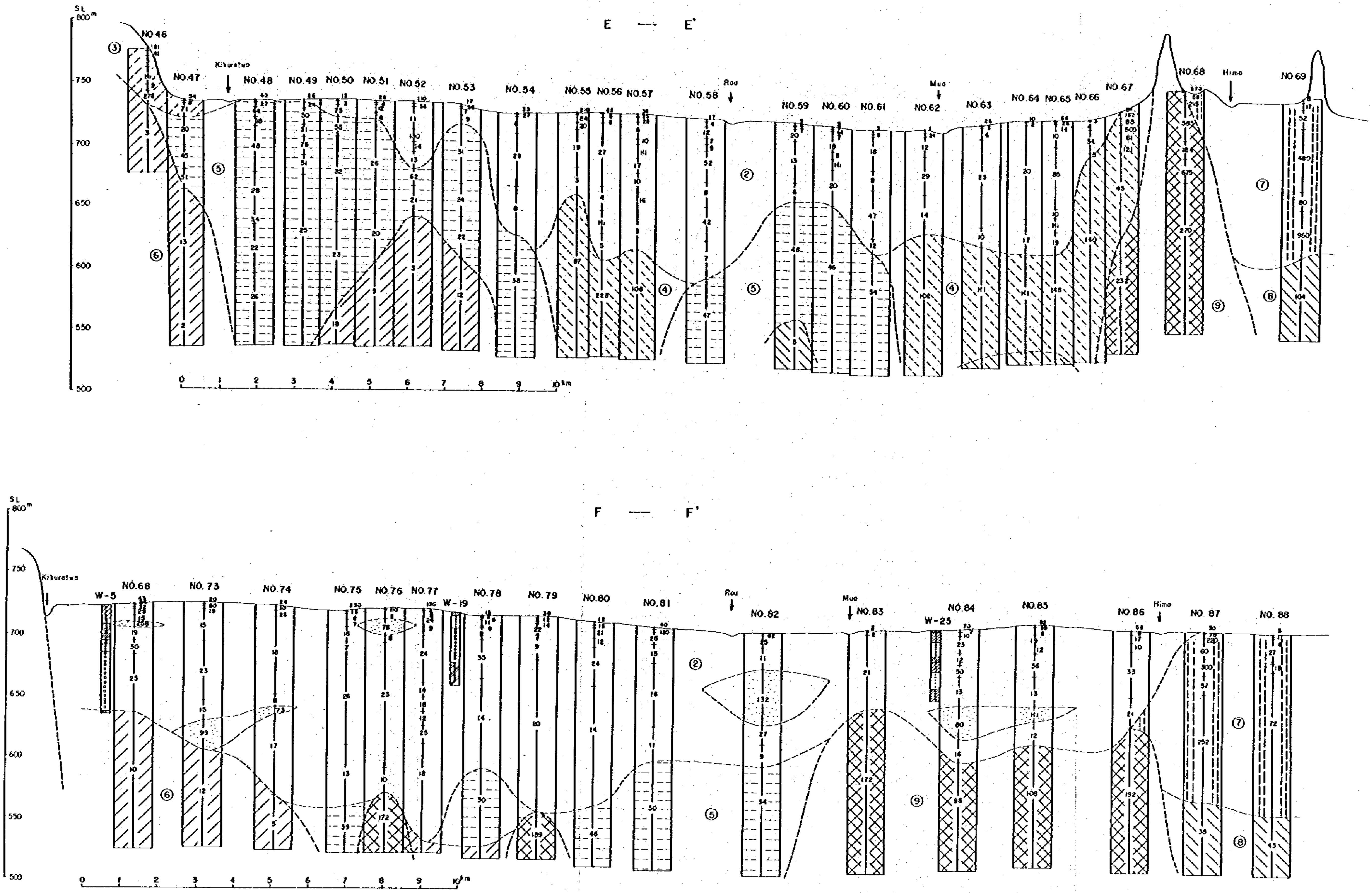
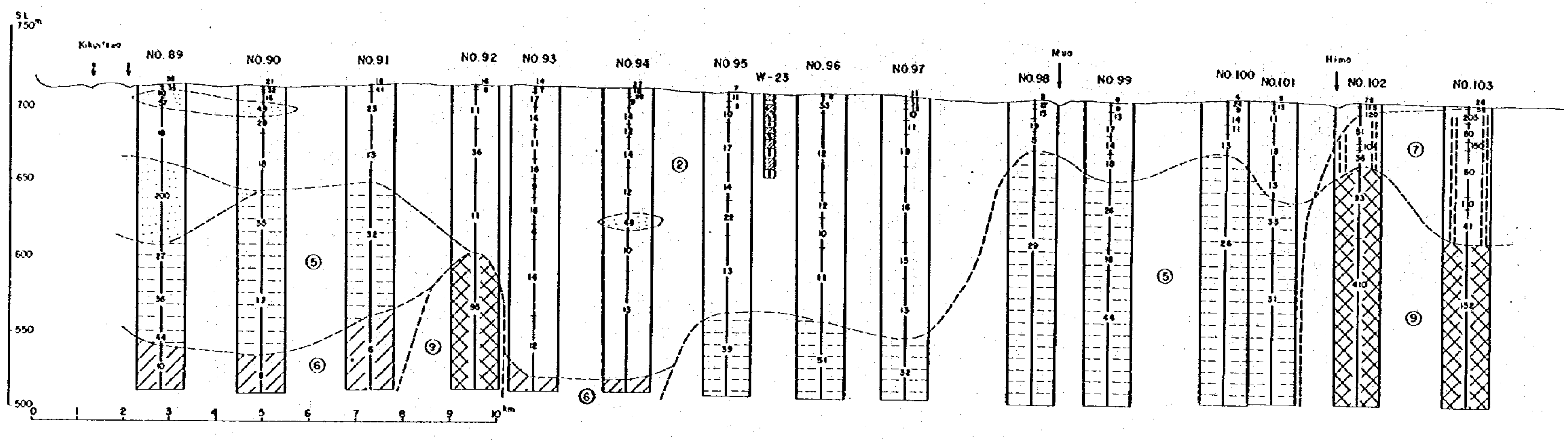

D — D'
SL
800m
750
700
650
600
550
Kikafu
Waru waru
Rau
Himo
NO.30
NO.31
NO.32
NO.33
NO.34
NO.35
NO.36
NO.37
NO.38
NO.39
NO.40
NO.41
NO.42
NO.43
NO.44
W-15
W-16
W-18
0 1 2 3 4 5 6 7 8 9 10km

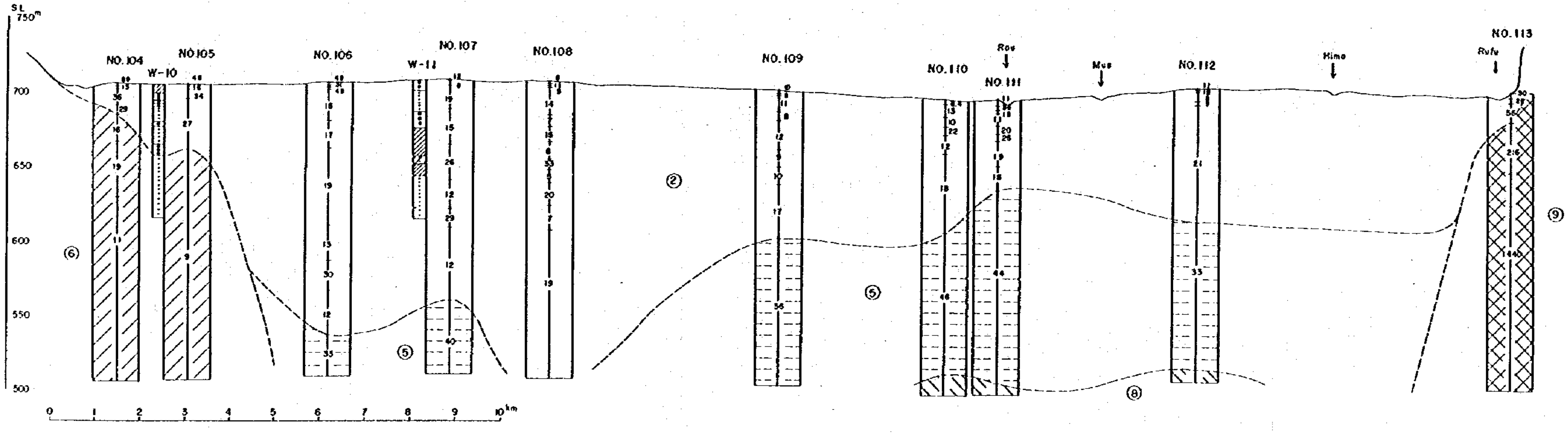
Fig. II - 4 (3)

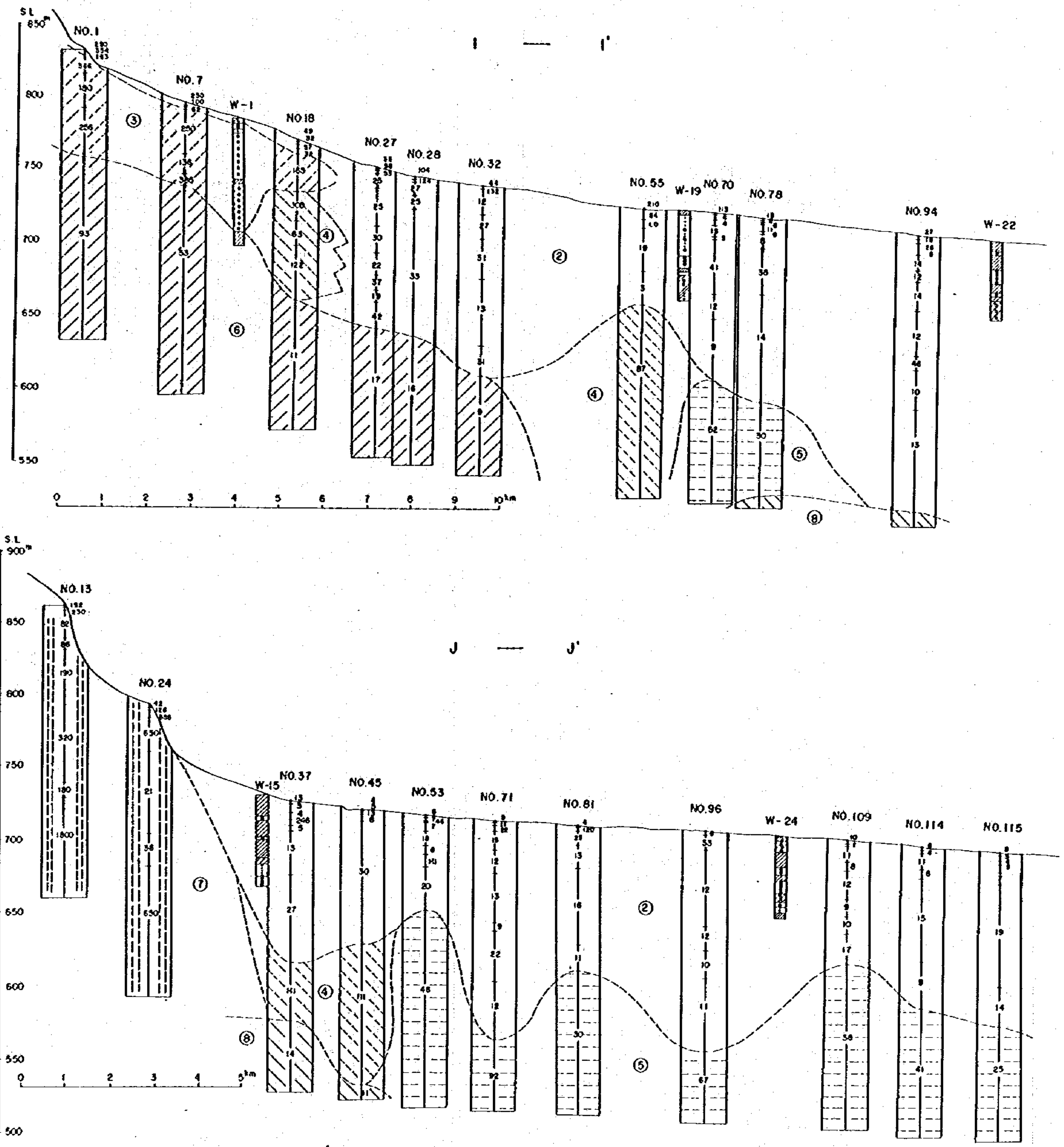

E — E'
SL 800m
750
700
650
600
550
500
NO.46
NO.47
Kiburatwo
NO.48
NO.49
NO.50
NO.51
NO.52
NO.53
NO.54
NO.55
NO.56
NO.57
NO.58
Rou
NO.59
NO.60
NO.61
NO.62
Mua
NO.63
NO.64
NO.65
NO.66
NO.67
NO.68
Himo
NO.69
0 1 2 3 4 5 6 7 8 9 10 km
F — F'
SL 800m
750
700
650
600
550
500
Kiburatwo
W-5
NO.68
NO.73
NO.74
NO.75
NO.76
NO.77
W-19
NO.78
NO.79
NO.80
NO.81
Rou
NO.82
Mua
NO.83
W-25
NO.84
NO.85
NO.86
Himo
NO.87
NO.88
0 1 2 3 4 5 6 7 8 9 10 km

G — G'


SL 750m
Kikuyu
NO. 89
NO. 90
NO. 91
NO. 92
NO. 93
NO. 94
NO. 95
W-23
NO. 96
NO. 97
Mua
NO. 98
NO. 99
NO. 100
NO. 101
Himo
NO. 102
NO. 103
700
650
600
550
500
0 1 2 3 4 5 6 7 8 9 10km

H — H'


SL 750m
NO. 104
W-10
NO. 105
NO. 106
W-11
NO. 107
NO. 108
NO. 109
NO. 110
Rau
NO. 111
Mue
NO. 112
Himo
Rufu
NO. 113
700
650
600
550
500
0 1 2 3 4 5 6 7 8 9 10km



I — I'
S.L
NO.1
NO.7
W-1
NO.18
NO.27
NO.28
NO.32
NO.55
W-19
NO.70
NO.78
NO.94
W-22
J — J'
NO.13
NO.24
W-15
NO.37
NO.45
NO.53
NO.71
NO.81
NO.96
W-24
NO.109
NO.114
NO.115

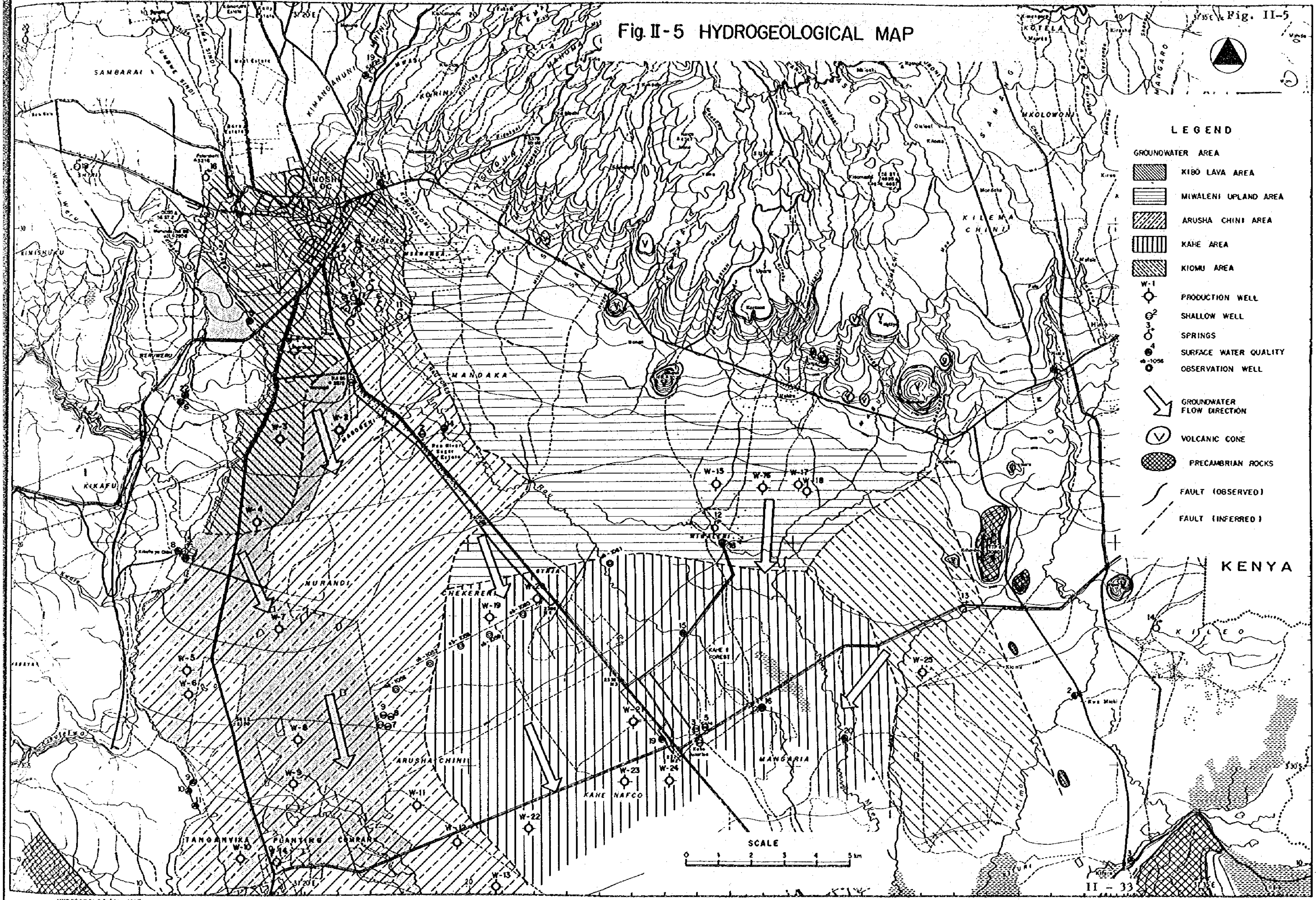
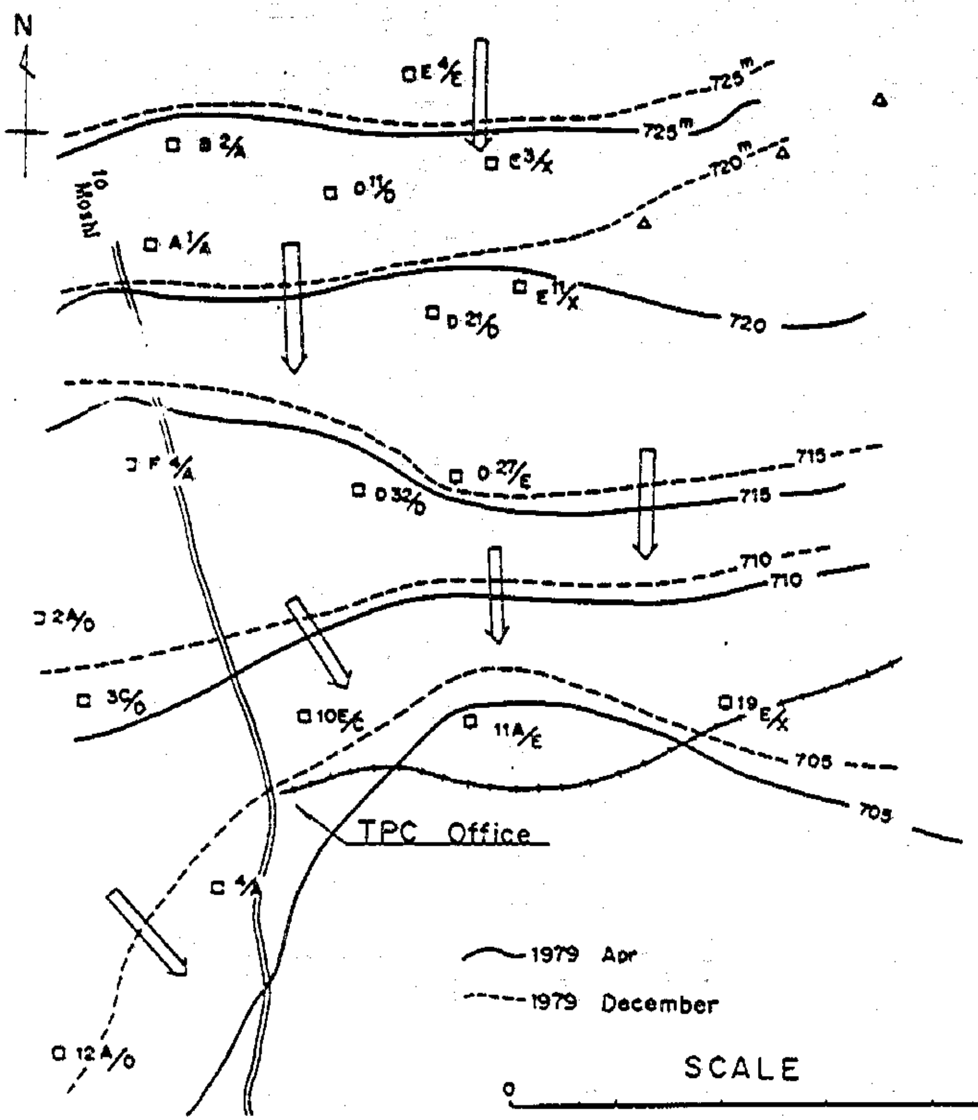


Fig. II-5 HYDROGEOLOGICAL MAP

HYDROGEOLOGICAL MAP

Fig. II-6 WATER TABLE AT TPC ESTATE

(A) GRUNDWATER CONTOUR LINE



(B) WATER TABLE FLUCTUATION

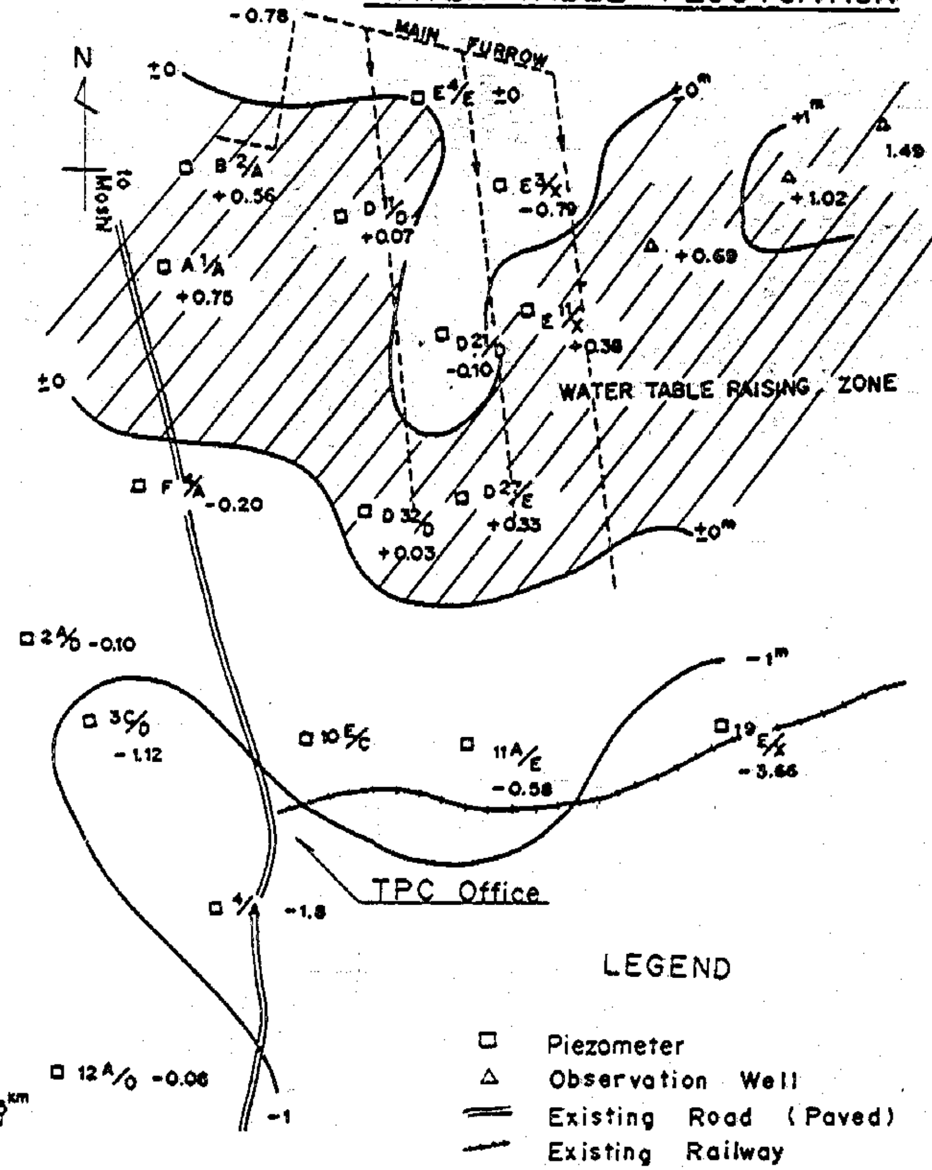
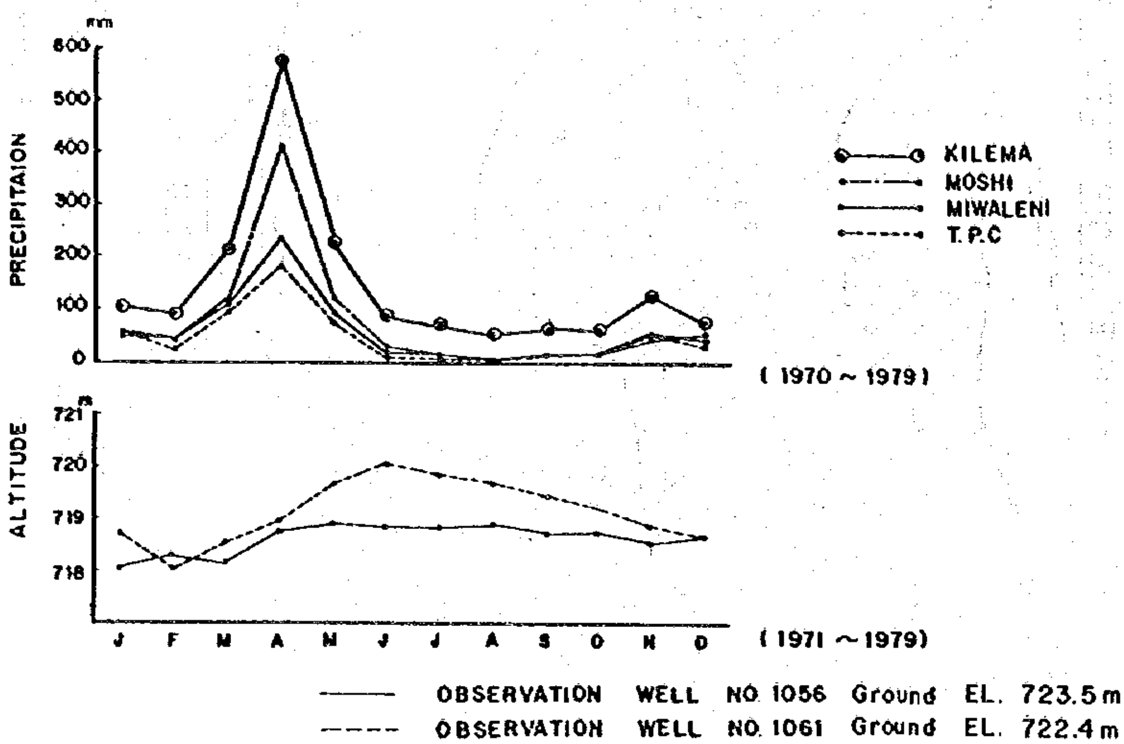


Fig. II-6

Fig II-7 ANNUAL VARIATION OF WATER LEVEL

CORRELATION OF MANTHLY RAINFALL
AND GROUND WATER LEVEL



GROUNDWATER LEVEL PROFILE

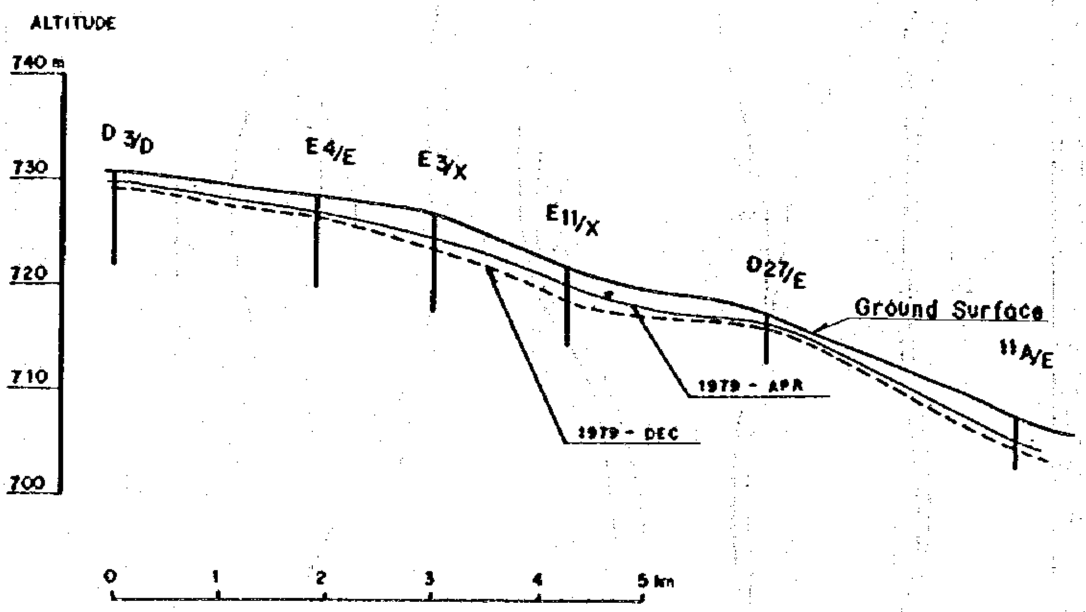


Fig II-8 GROUNDWATER COUNTOUR MAP (ARTESIAN AQUIFER)

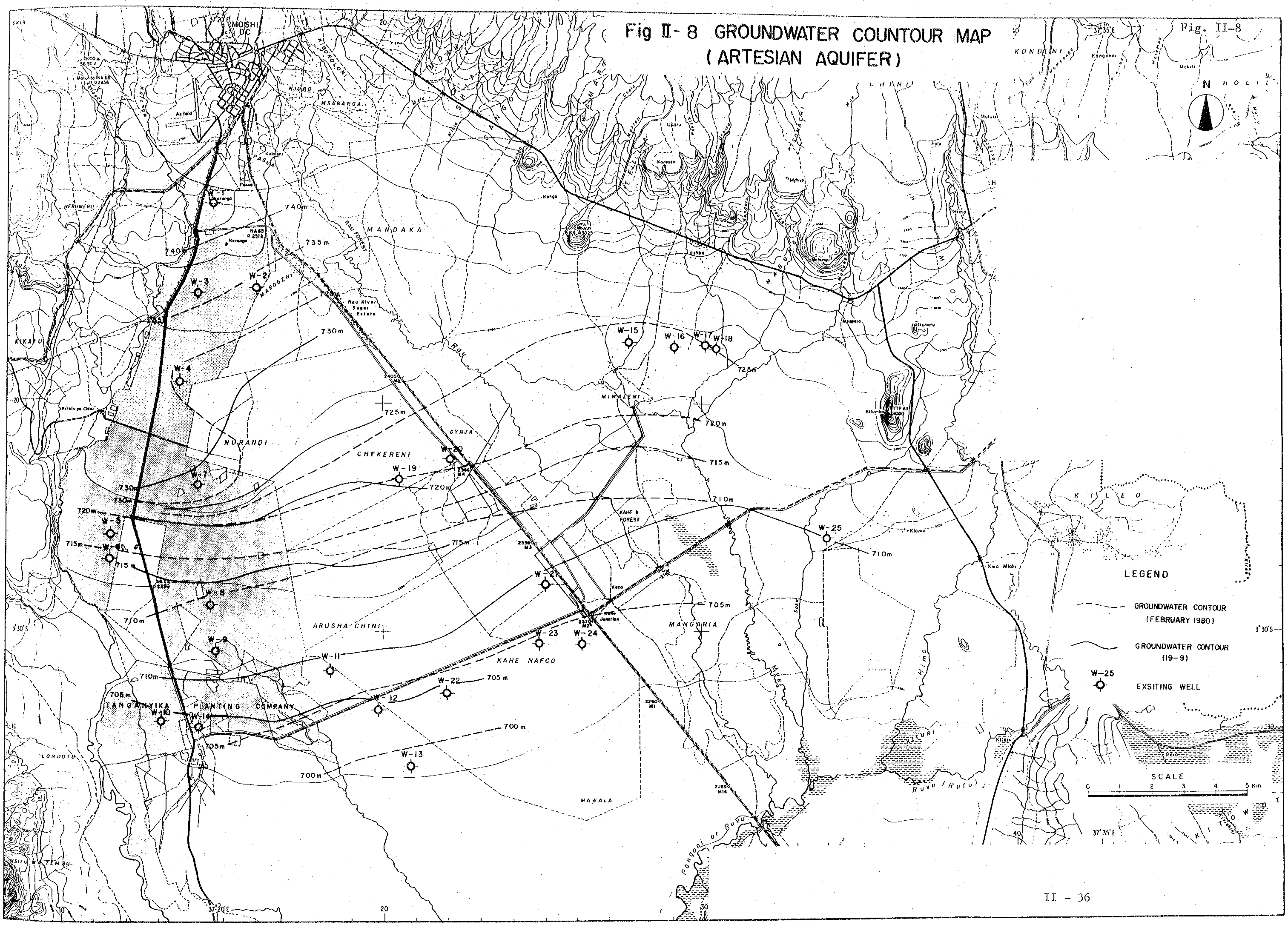


Fig. II - 9

Fig II - 9 GROUNDWATER LEVEL PROFILE (ARTESIAN WELL)

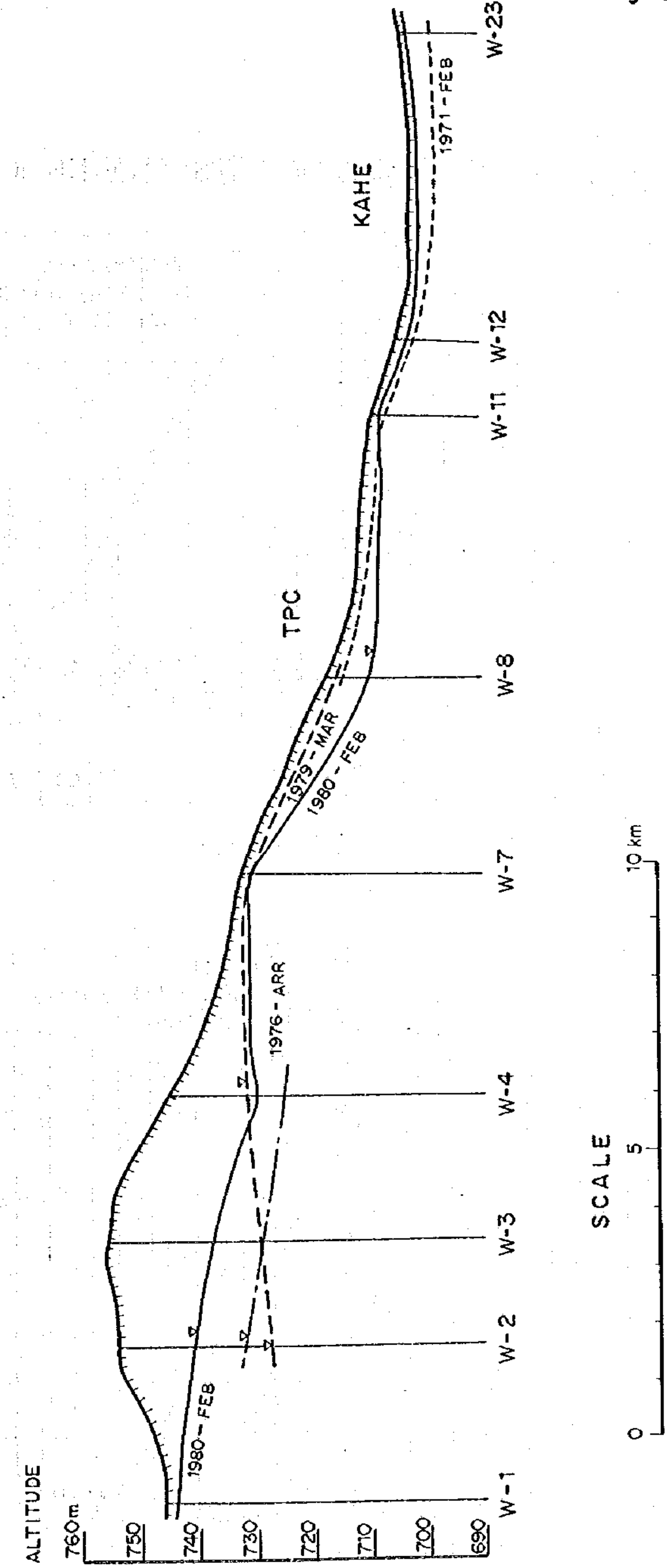
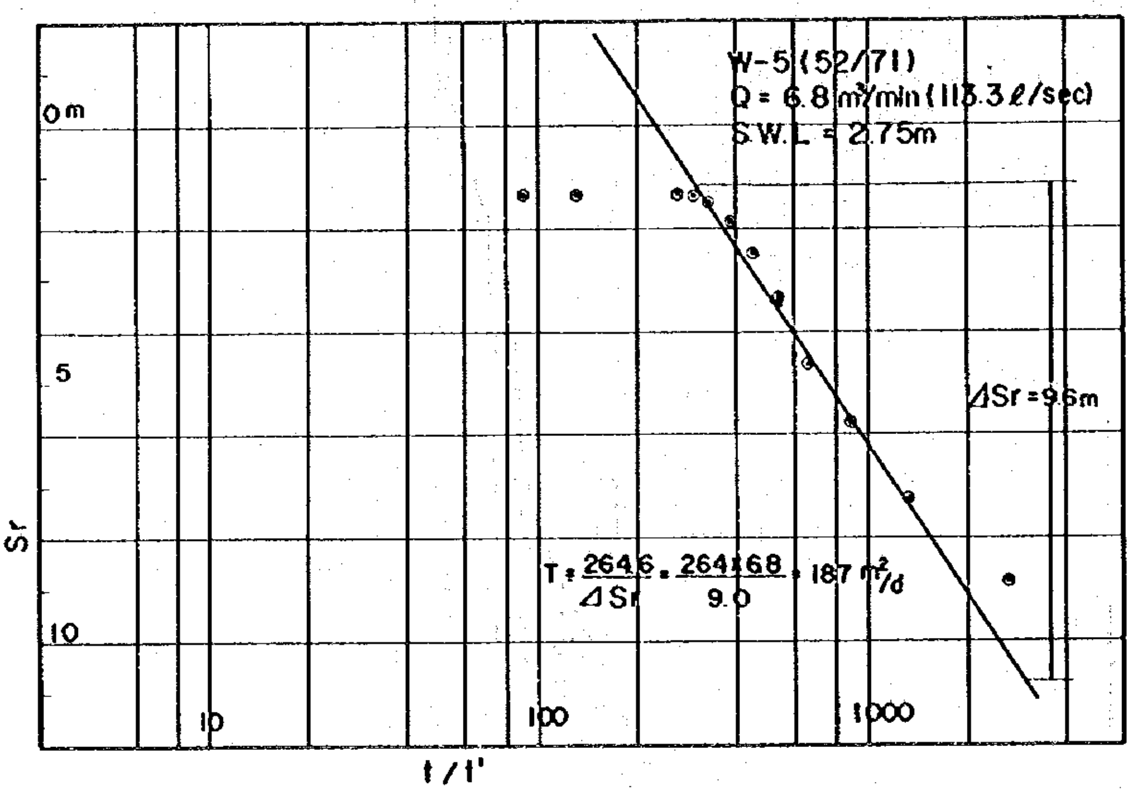


Fig. II-10 PUMPING TEST ANALYSIS GRAPHS (I)



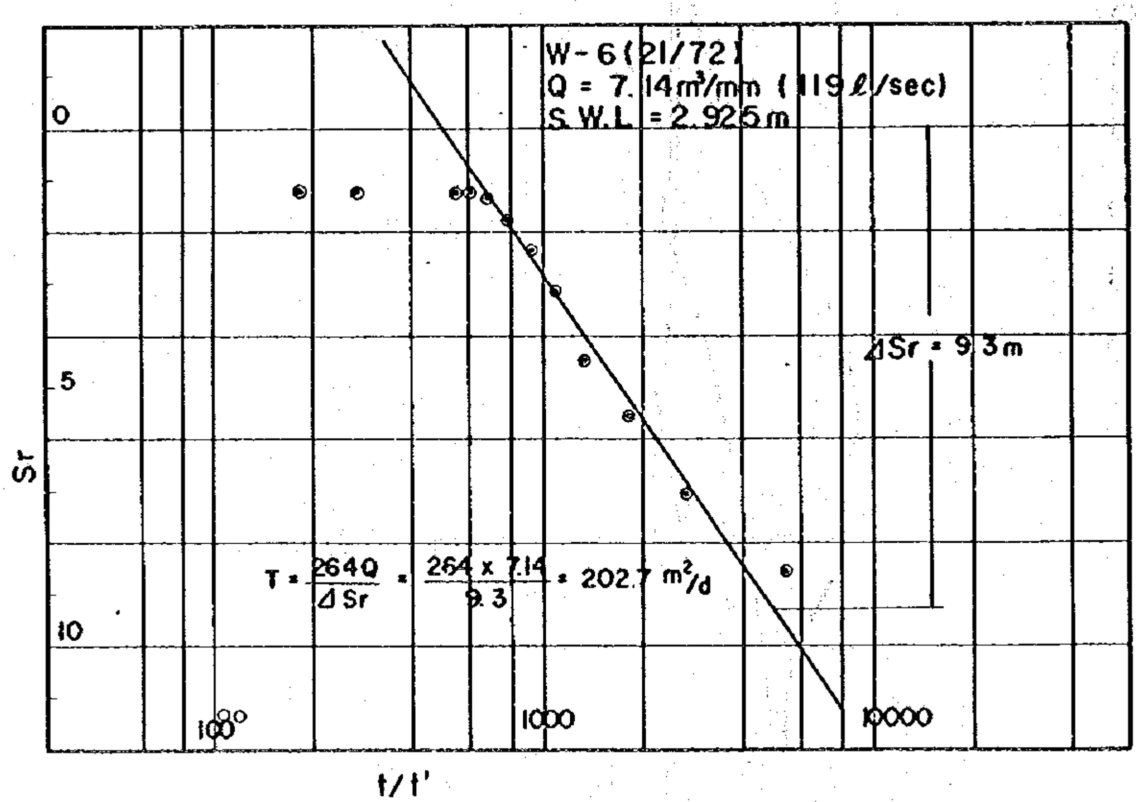
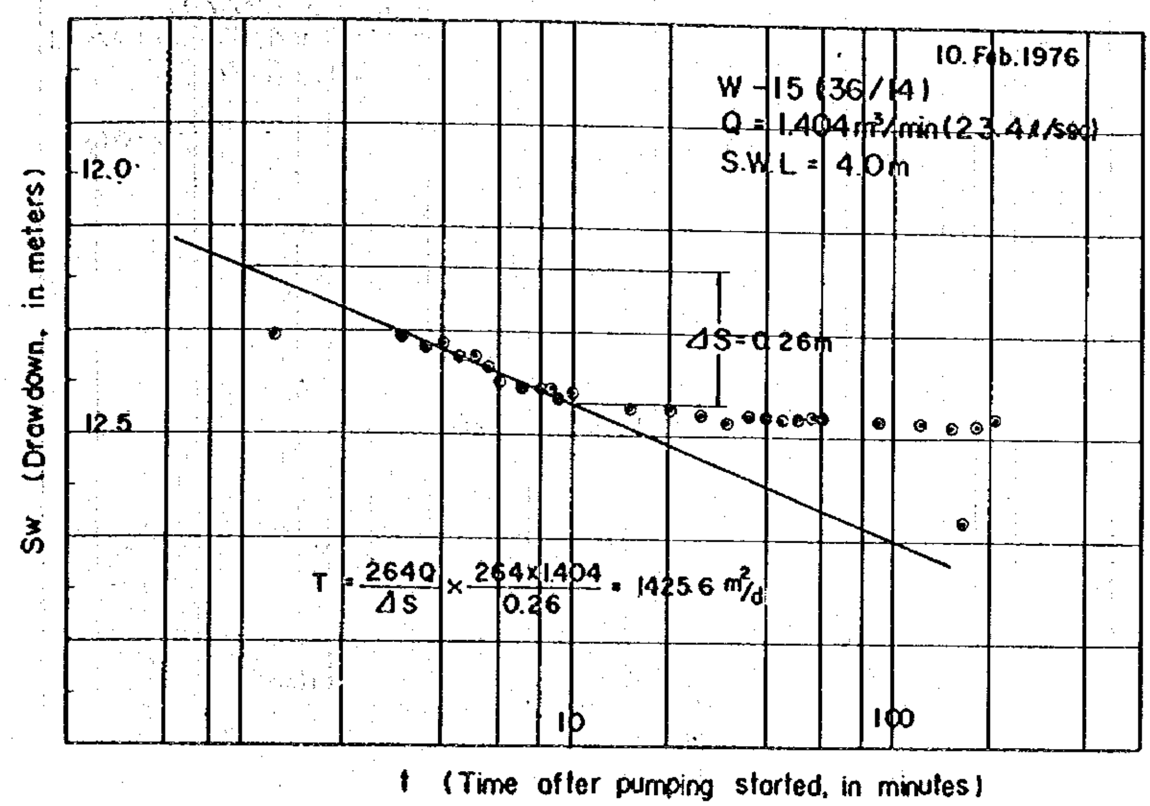


Fig. II - 10 PUMPING TEST ANALYSIS GRAPHS (2)



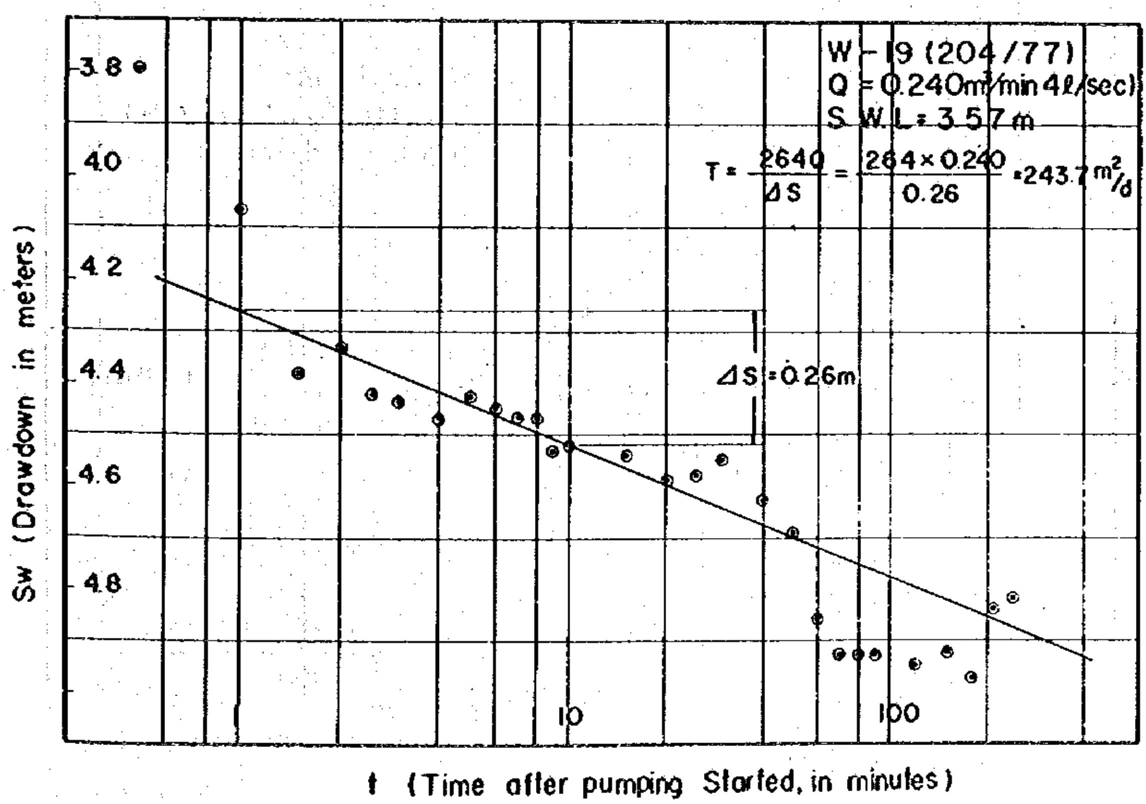


Fig. II-10 PUMPING TEST ANALYSIS GRAPHS (3)