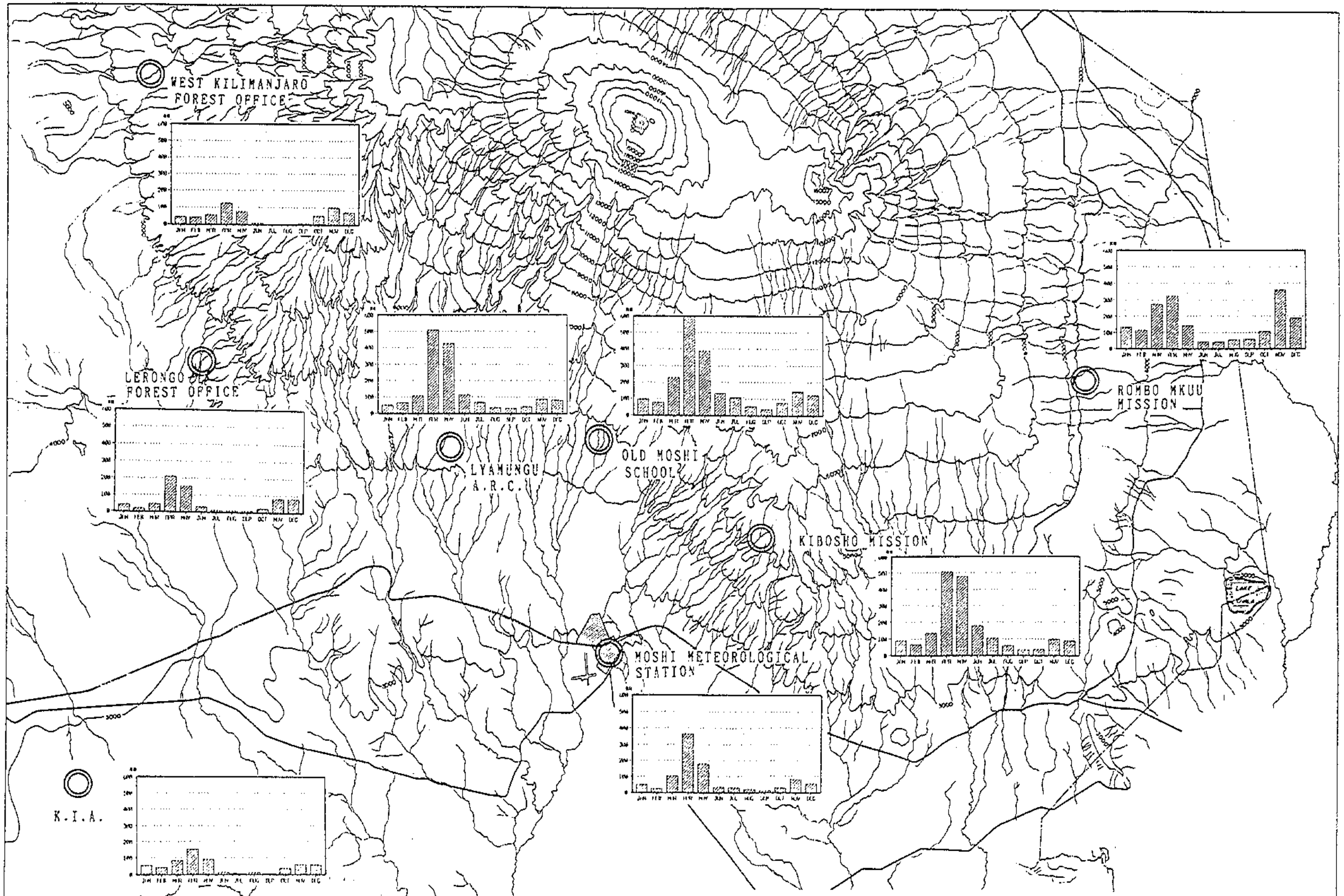


Fig. 2-3 MEAN MONTHLY RAINFALL AT PRINCIPAL STATIONS

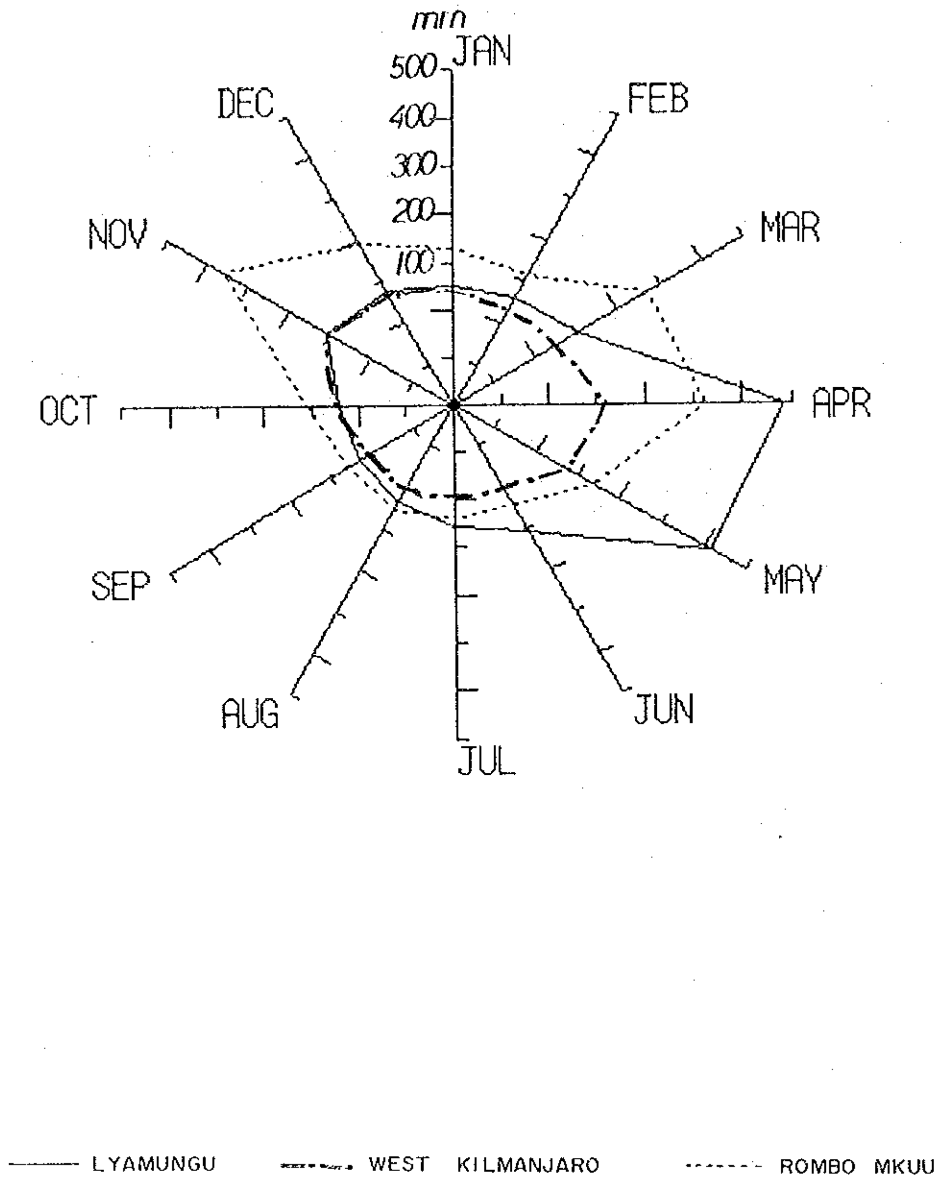


Fig. 2-4 RADARCHART OF MEAN MONTHLY RAINFALL

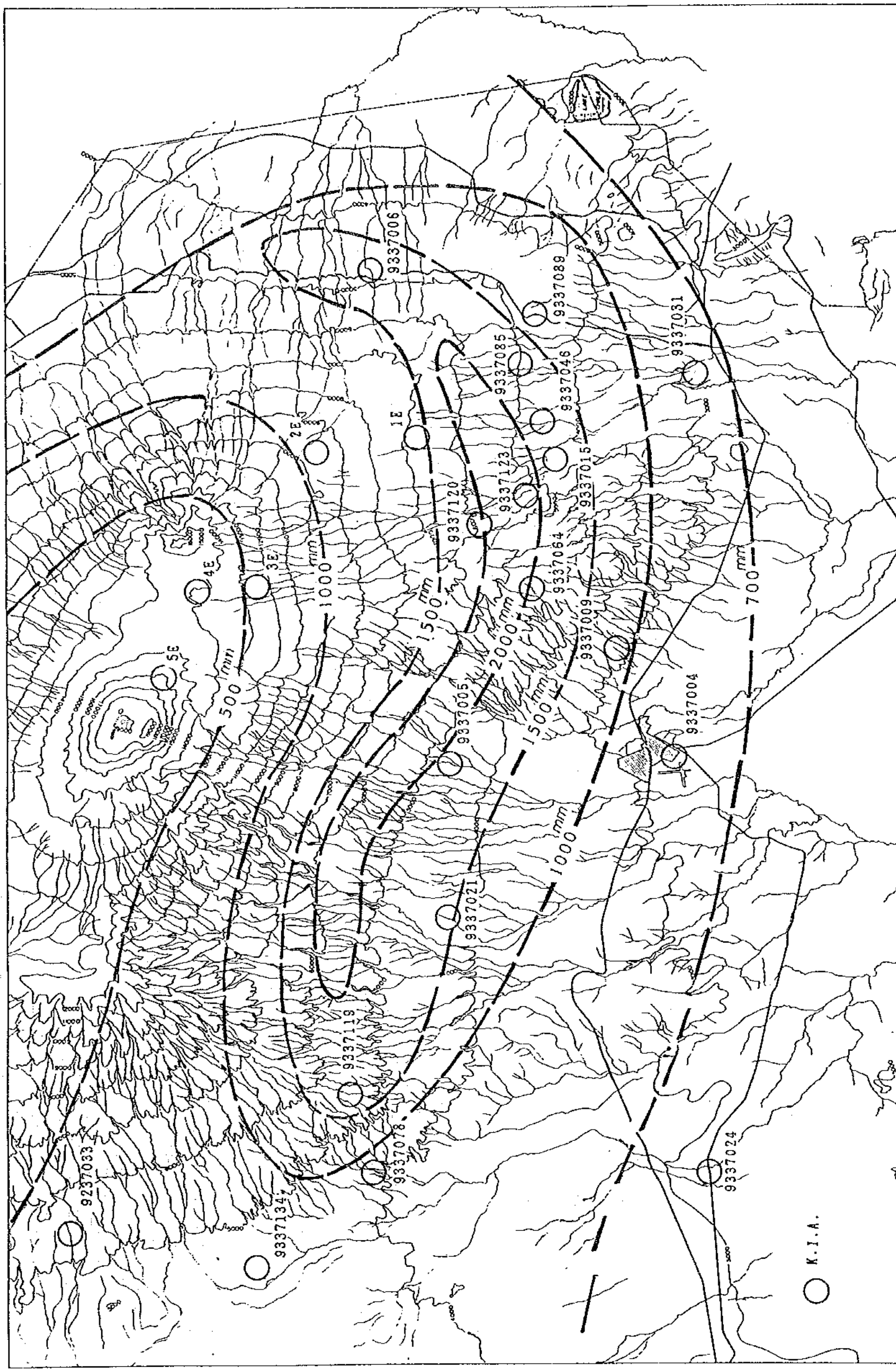


Fig. 2-5 LOCATIONS OF THE RAINFALL STATIONS AND ANNUAL ISOHYET

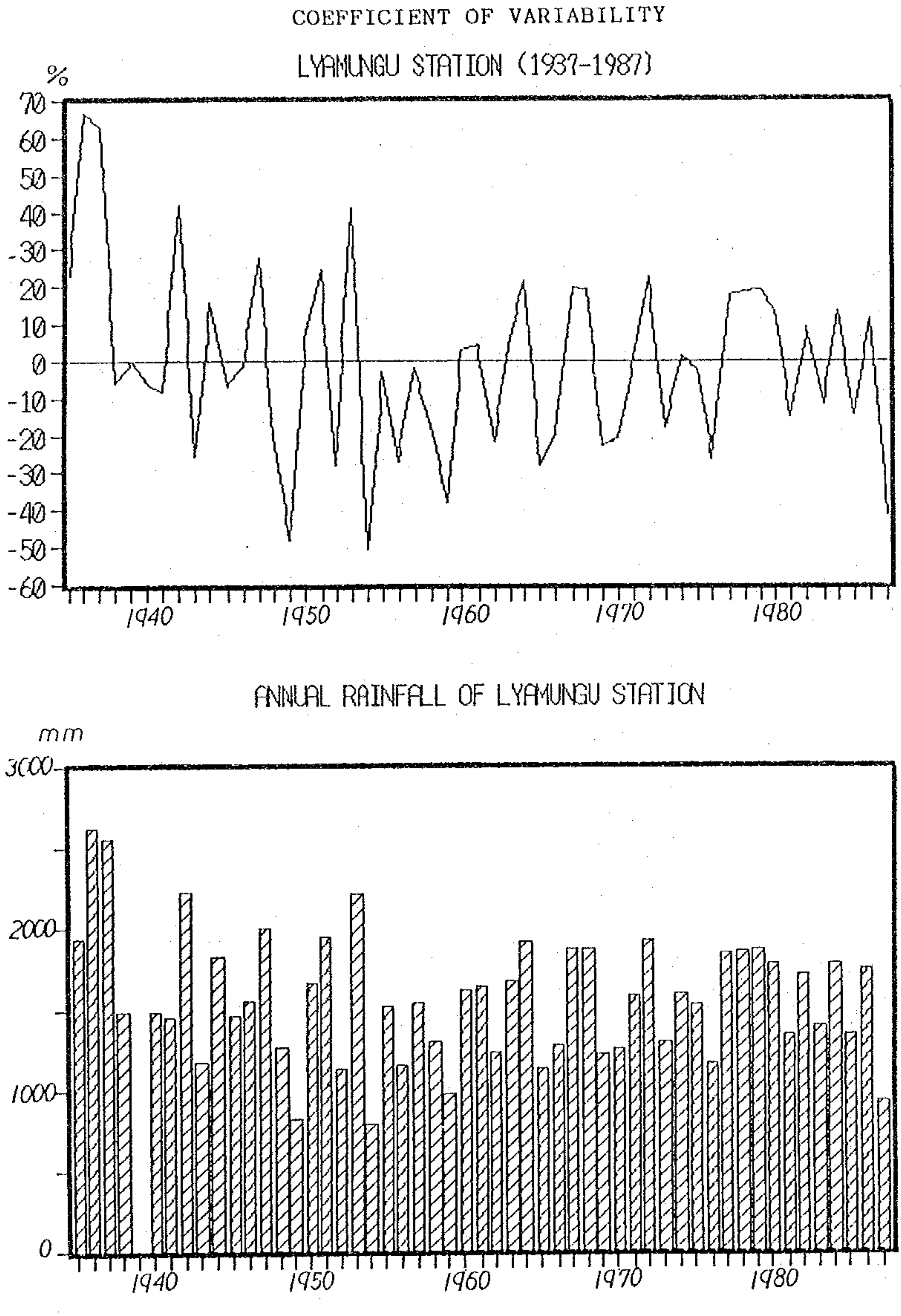


Fig. 2-6 RAINFALL VARIATION AT LYAMUNGU STATION

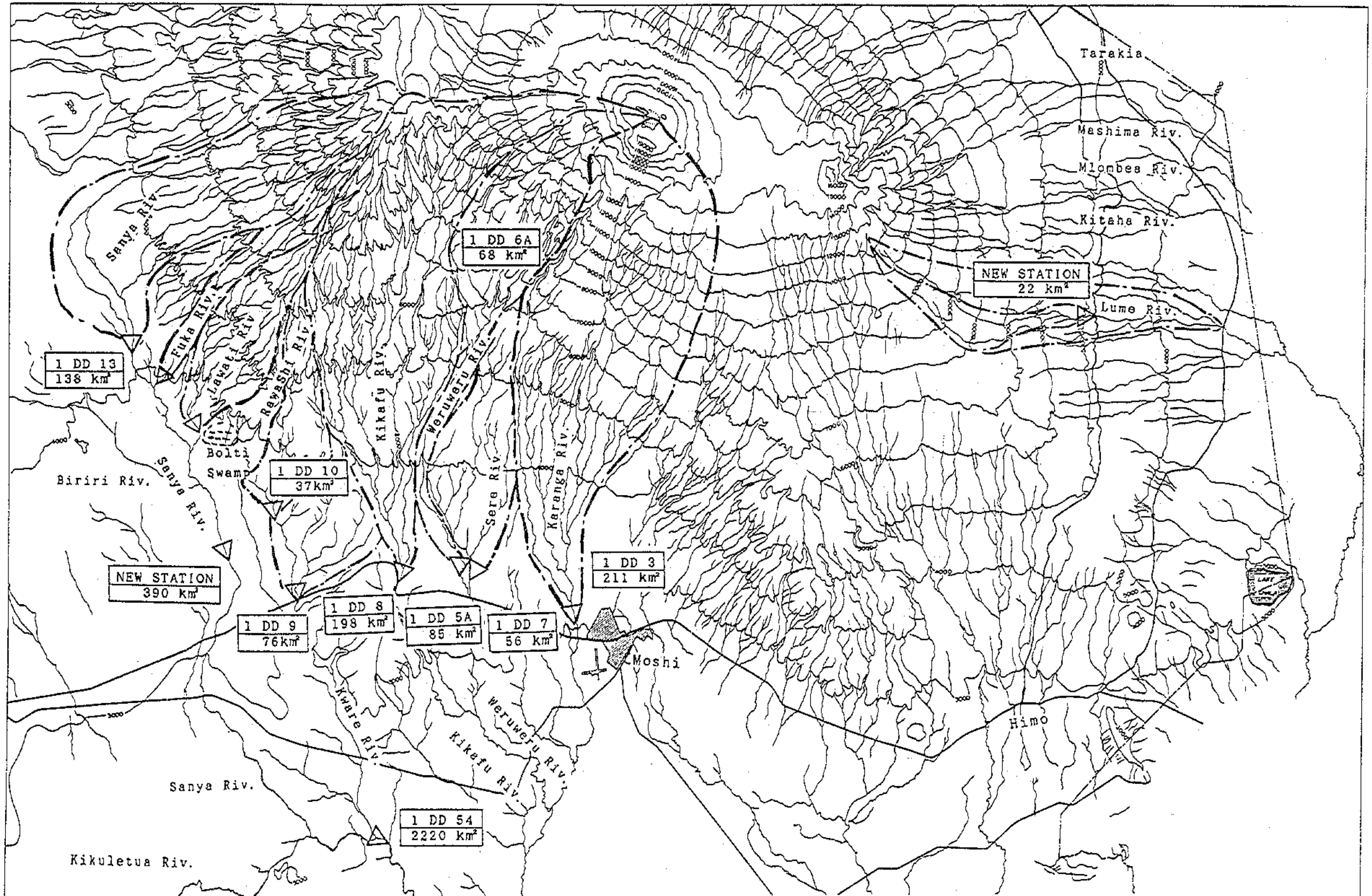


Fig. 3-1 GAUGING STATIONS AND THE CATCHMENT AREAS

MEAN MONTHLY DISCHARGE RECORDED AT GAUGING STATIONS

unit: m3/sec

STATION	NO.	PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
KARANGA	1DD3	53.11-58.10	0.637	0.938	0.474	4.888	10.74	6.523	3.184	1.384	0.432	0.271	0.458	0.718
RVARE	1DD10	54.11-58.02	0.057	0.072	0.082	0.285	1.844	1.278	0.448	0.113	0.048	0.04	0.087	0.117
	1DD9	54.11-58.10	0.045	0.134	0.038	0.770	2.110	0.514	0.280	0.120	0.055	0.022	0.023	0.130
SANYA	1DD13	54.12-58.10	0.142	0.088	0.140	0.708	1.242	0.332	0.055	0.008	0.002	0.001	0.284	0.487
KIKAFU	1DD8	54.11-58.10	1.854	2.173	1.882	13.91	21.82	9.141	4.941	2.582	1.454	0.985	2.148	2.988
VERUVERU	1DD5A	58.01-58.10	0.547	0.83	0.501	2.484	3.186	1.982	1.227	0.637	0.417	0.138	0.187	0.785
	1DD7	57.11-58.10	0.186	0.195	0.188	0.613	1.378	1.325	0.421	0.211	0.153	0.158	0.284	0.241
	1DD6A	60.03-70.12	1.65	1.45	2.19	2.93	4.41	3.845	4.15	1.645	1.345	1.44	2.01	1.425
TANESC	1DD54	67.02-70.12	12.05	12.02	12.61	14.38	15.68	12.41	12.32	11.81	11.14	11.21	12.29	13.3

unit: m3/sec

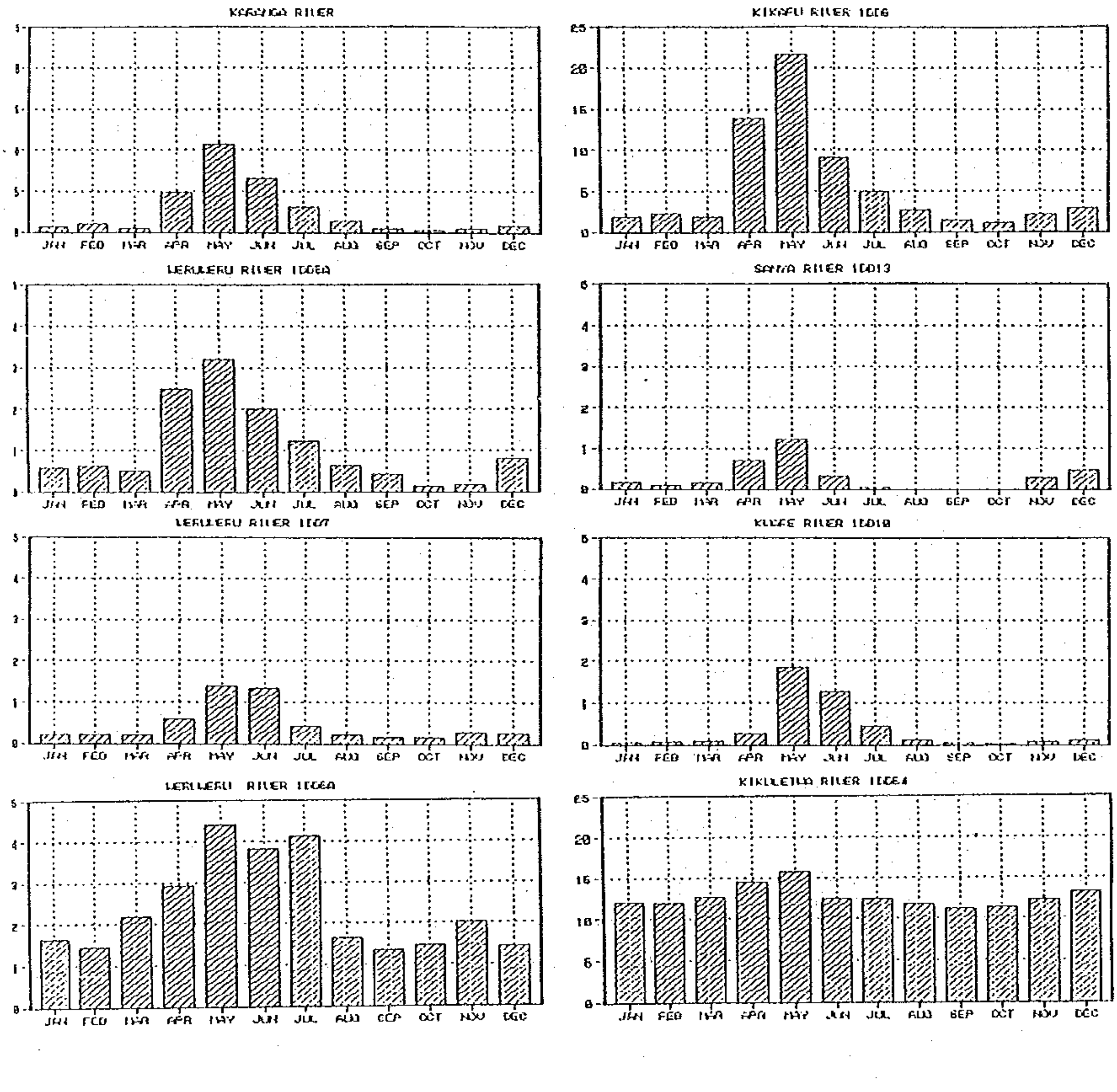


Fig. 3-2 MEAN MONTHLY DISCHARGE OF EACH RIVER

COMPARISON OF UNIT DISCHARGE PER UNIT BASIN (100 km**2)

unit: m3/sec/100km2

STATION	NO.	PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
KARANGA	1DD3	53.11-59.10	0.302	0.444	0.225	2.318	5.090	3.091	1.499	0.858	0.204	0.128	0.217	0.341
KWARE	1DD10	54.11-59.02	0.080	0.176	0.052	1.013	2.777	0.878	0.343	0.158	0.072	0.029	0.030	0.172
	1DD9	54.11-59.10	0.168	0.211	0.271	0.838	5.424	3.754	1.317	0.332	0.142	0.117	0.199	0.345
SANYA	1DD13	54.12-58.10	0.103	0.071	0.101	0.514	0.900	0.240	0.040	0.005	0.001	0.000	0.213	0.338
KIKAPU	1DD8	54.11-59.10	0.938	1.097	0.950	7.028	10.92	4.618	2.495	1.294	0.734	0.502	1.085	1.509
WERUWERU	1DD5A	58.01-59.10	0.362	0.361	0.349	1.135	2.553	2.454	0.780	0.390	0.284	0.288	0.545	0.448
	1DD7	57.11-58.10	0.844	0.741	0.59	2.822	3.780	2.344	1.443	0.749	0.481	0.182	0.188	0.836
	1DD8A	69.03-70.12	2.420	2.132	3.220	4.308	6.485	5.654	6.102	2.419	1.977	2.117	2.955	2.095
TANESC	1DD54	67.02-70.12	0.542	0.541	0.568	0.648	0.705	0.559	0.555	0.523	0.501	0.505	0.553	0.599

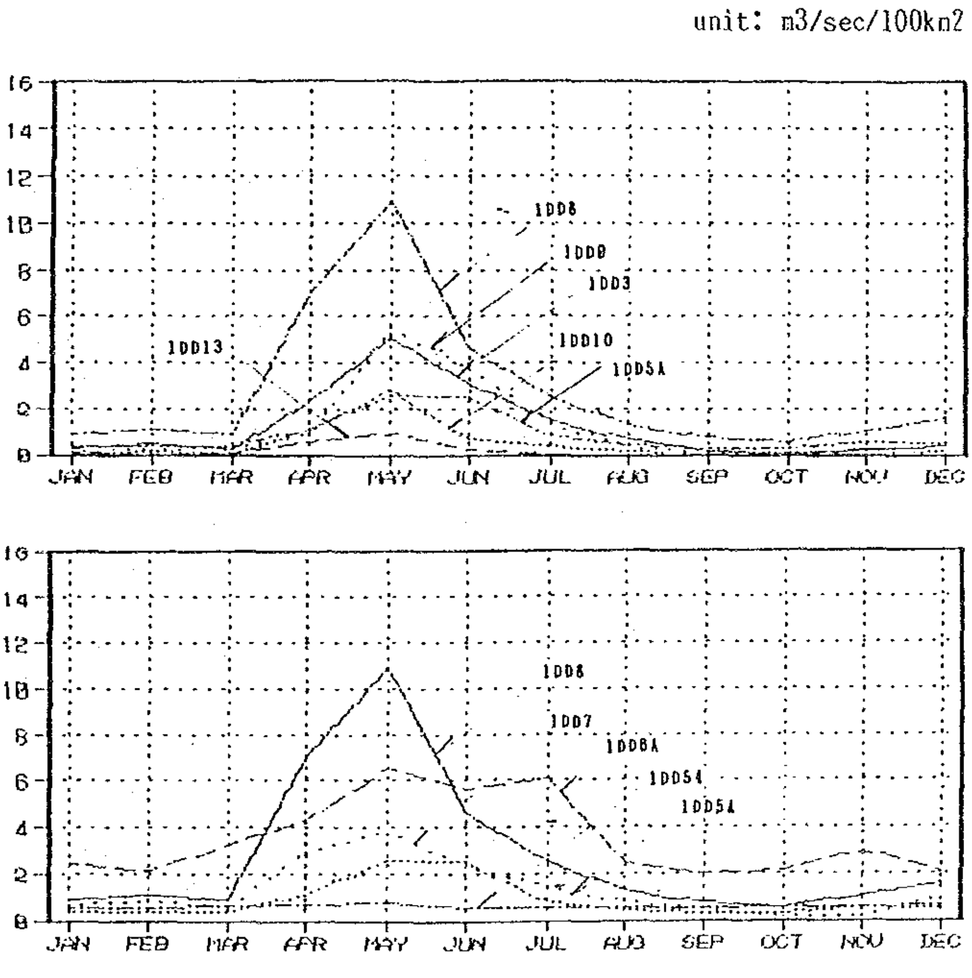
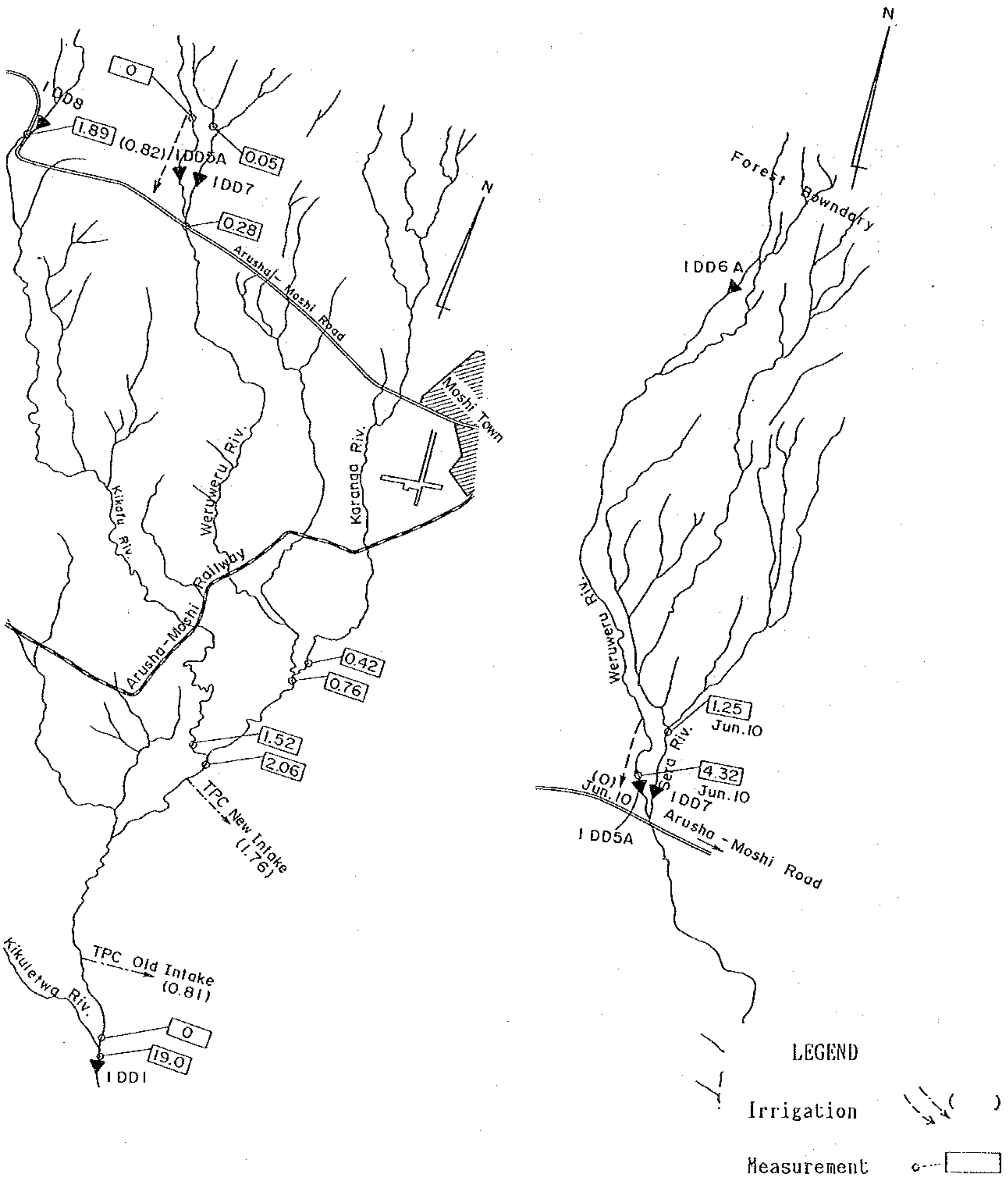


Fig. 3-3 MEAN MONTHLY DISCHARGE PER 100 KM^2 OF CATCHMENT AREA



(a) Phase I (1988, Dec. 11-13)　　(b) Phase II (1989, Jun. -10)

Fig. 3-4 RESULTS OF DISCHARGE MEASUREMENT(KARANGA, WERU WERU, AND KIKAFU RIVERS)

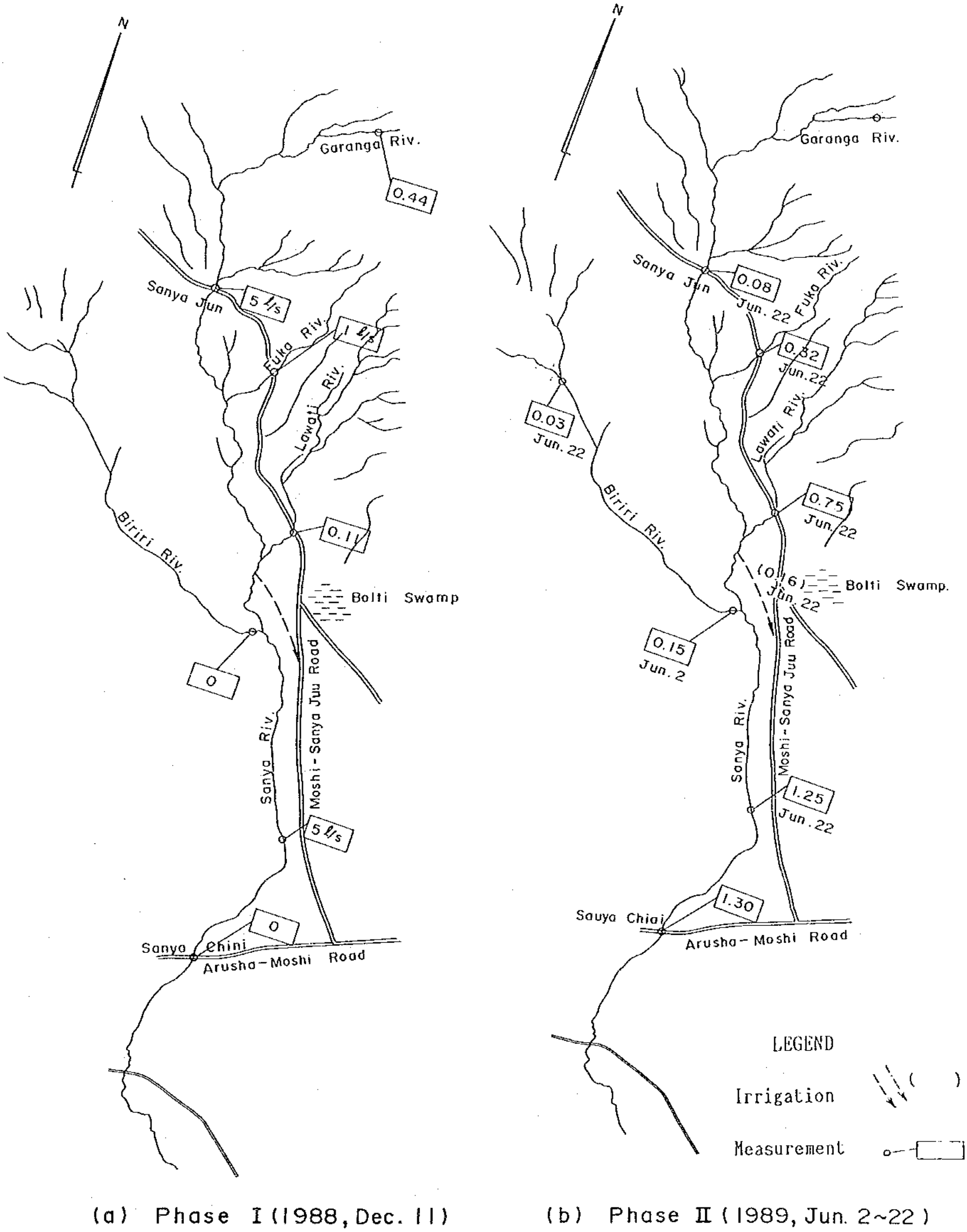
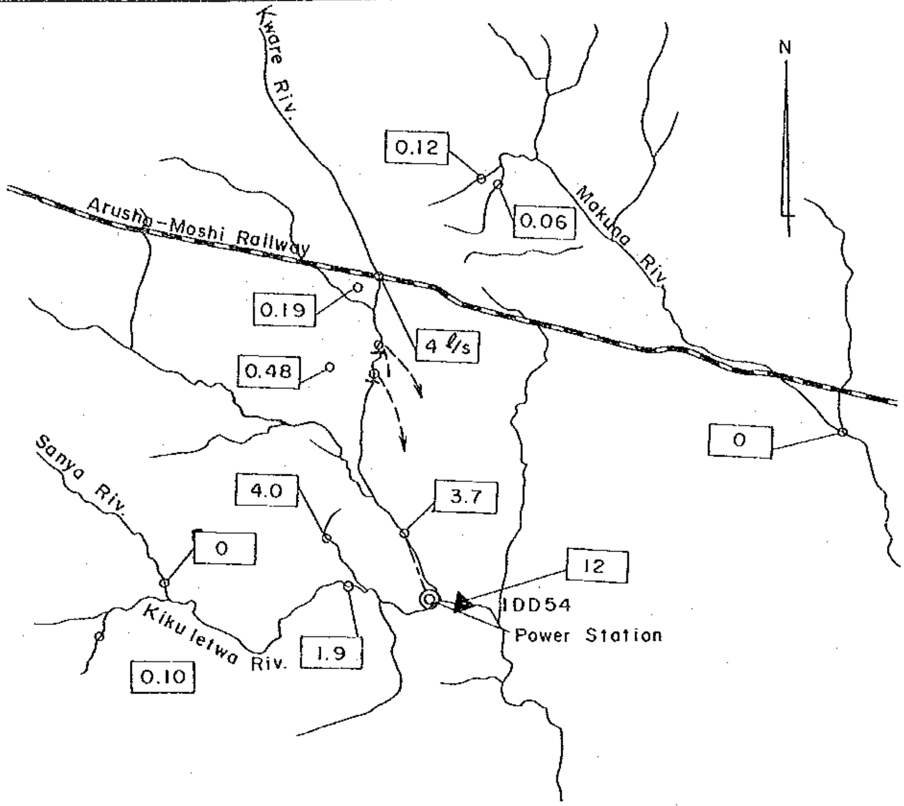
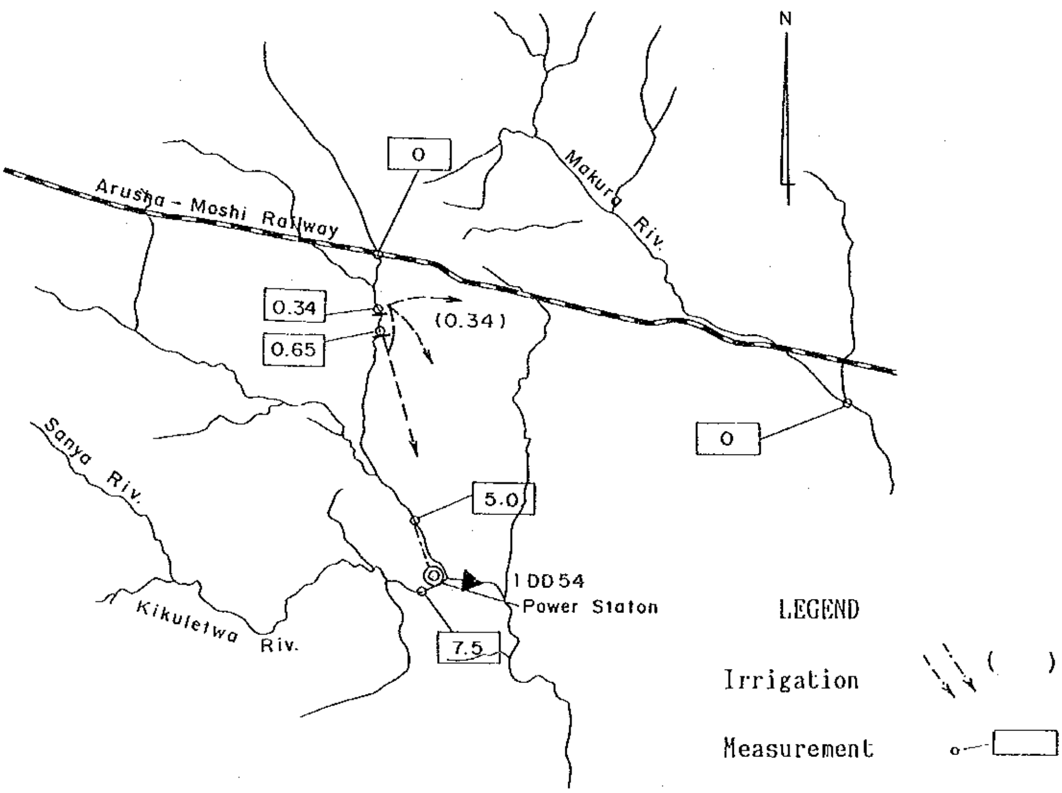


Fig. 3-5 RESULTS OF DISCHARGE MEASUREMENT (SANYA RIVER)



(a) Phase I (1988, Dec. 10 - 11)



(b) Phase II (1989 Jun. 7-10)

Fig. 3-6 RESULTS OF DISCHARGE MEASUREMENT (RUNDUGAISPRINGS)

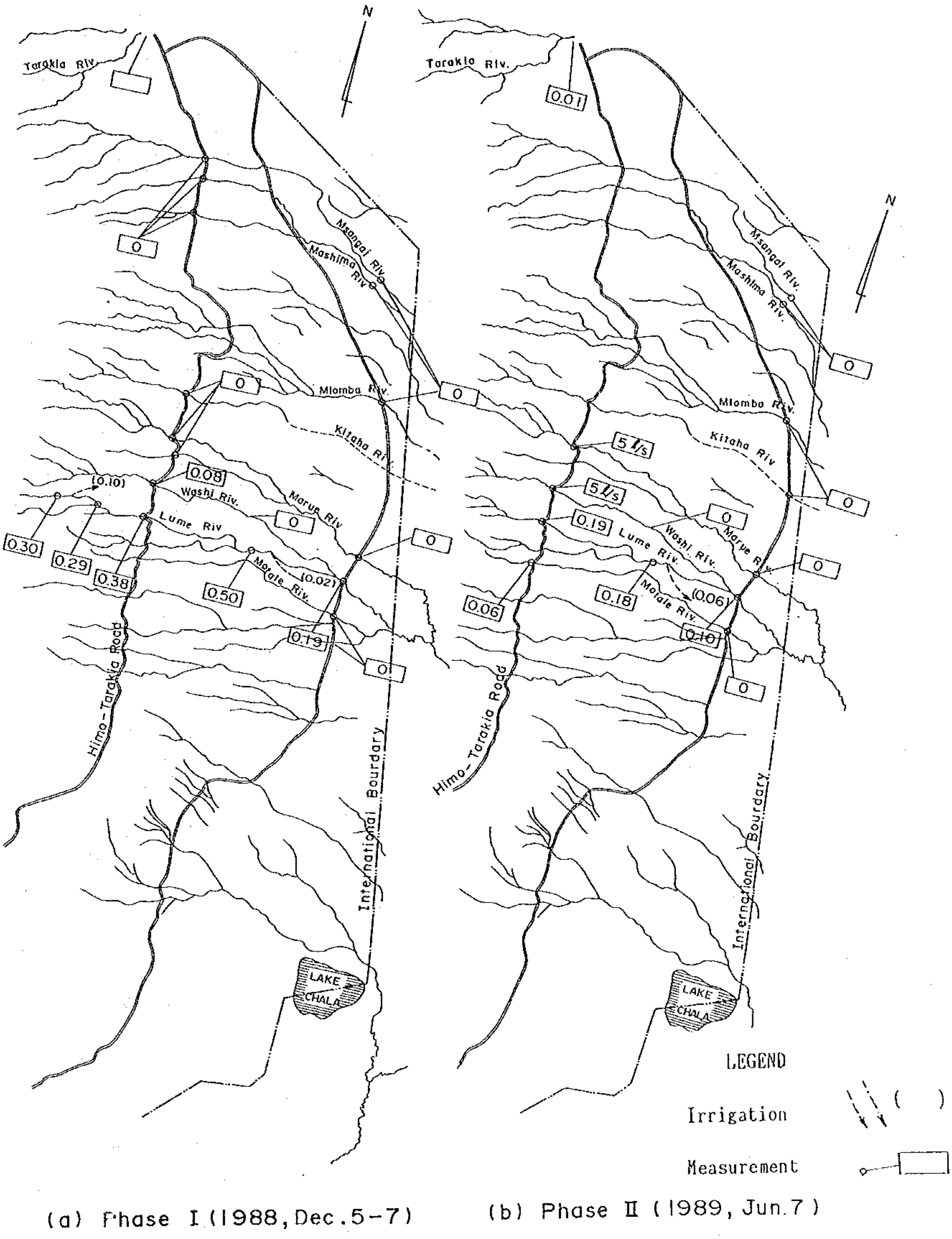


Fig. 3-7 RESULTS OF DISCHARGE MEASUREMENT (LOWER ROMBO)

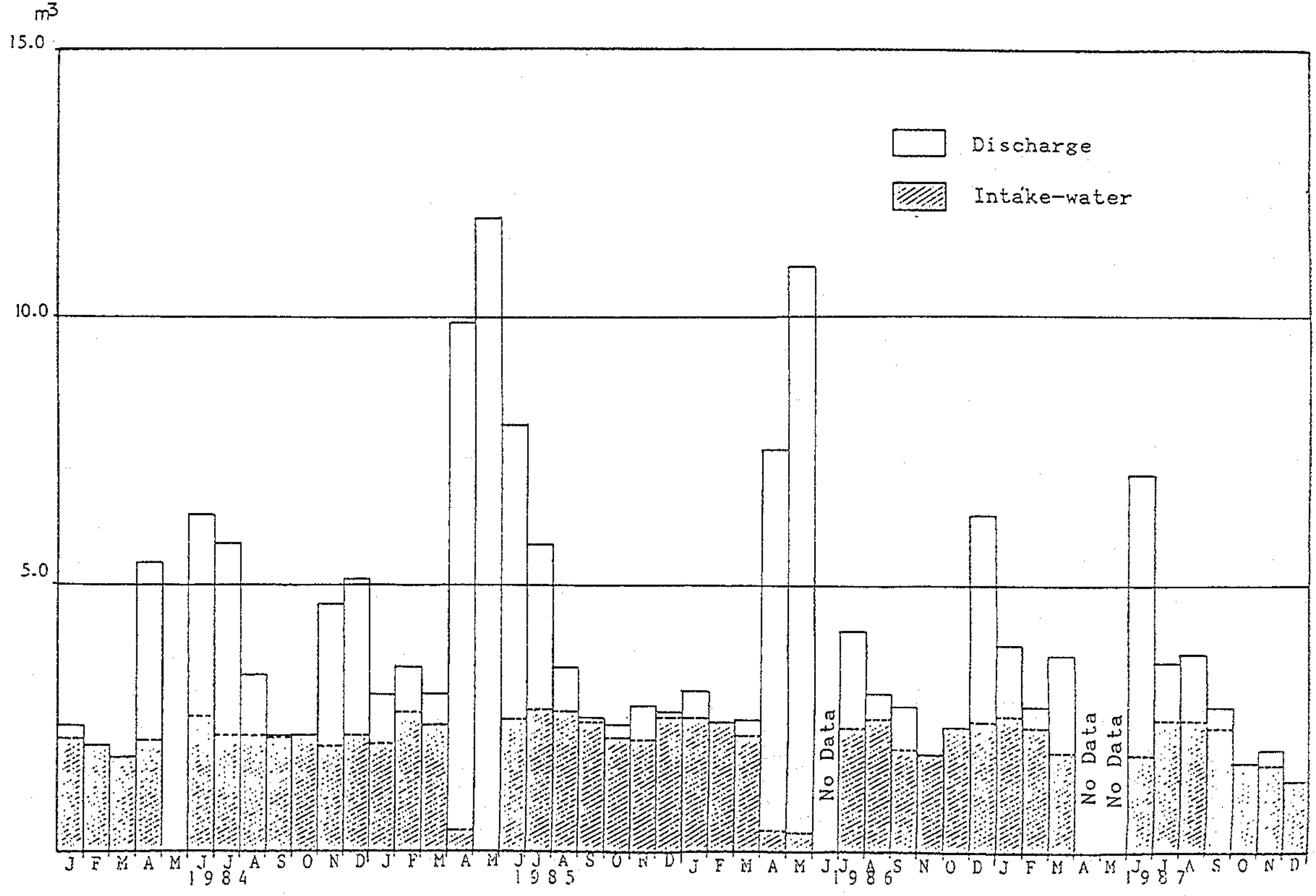


Fig. 3-8 RIVER DISCHARGE AND INTAKE WATER BY TPC

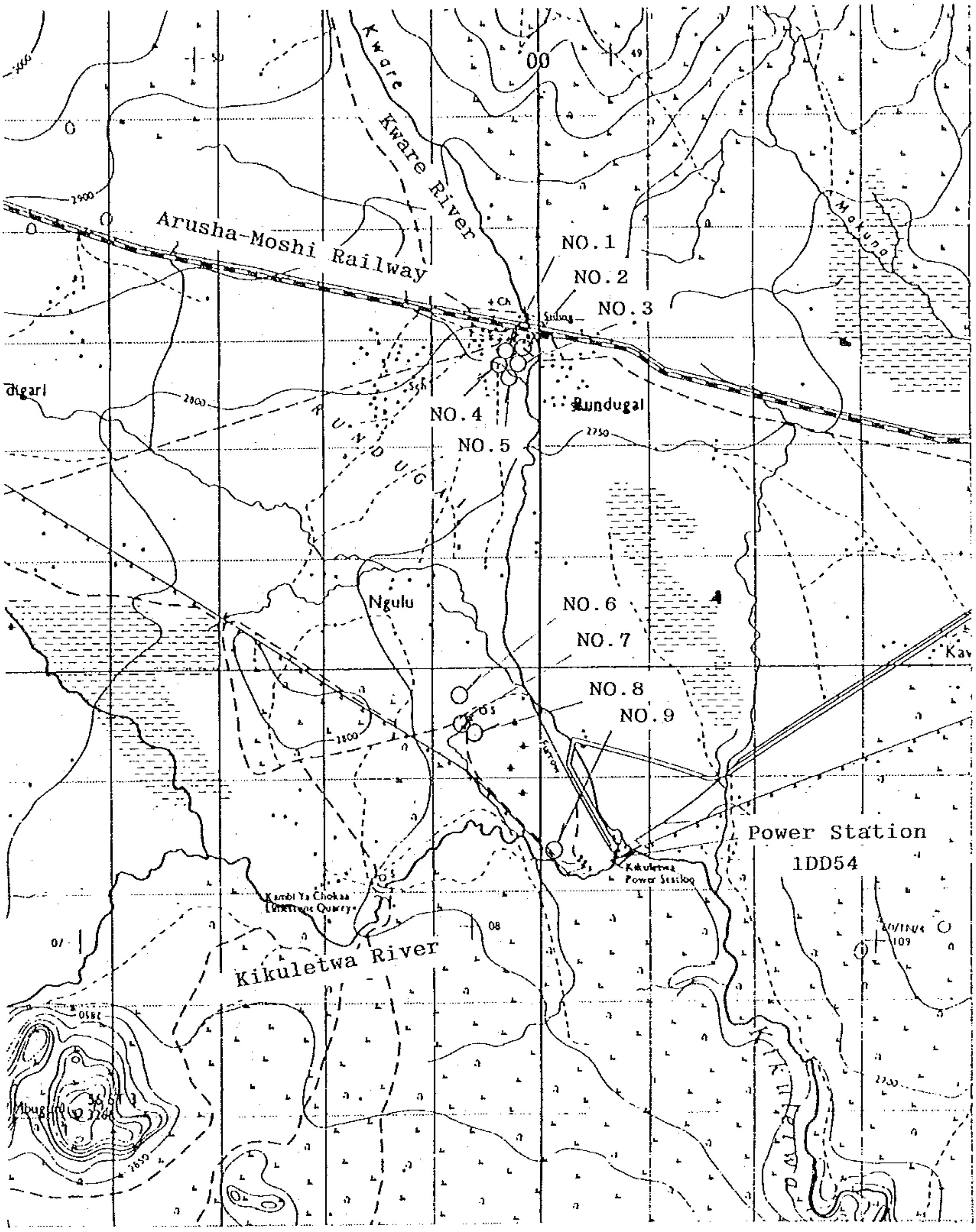
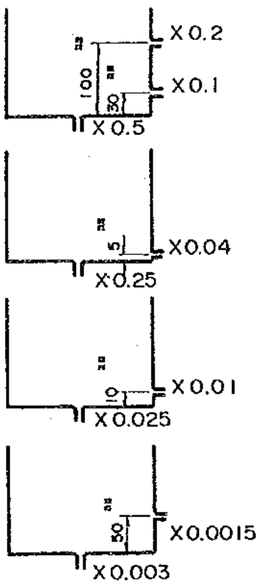


Fig. 3-9 LOCATION OF WATER SAMPLING POINTS IN RUNDUGAI

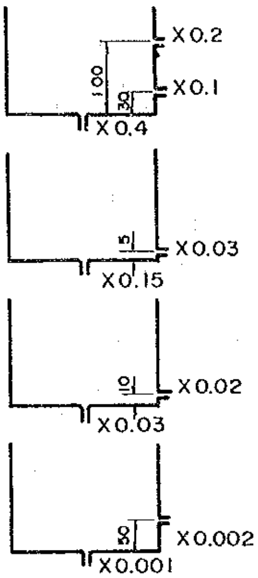
KARANGA RIV.

C.A. : 211 km



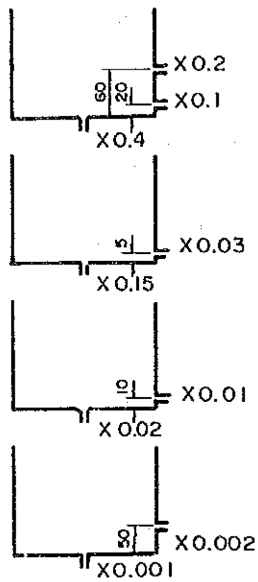
WERUWERU RIV.

C.A. : 85 km



KIKAFU RIV.

C.A. : 198 km



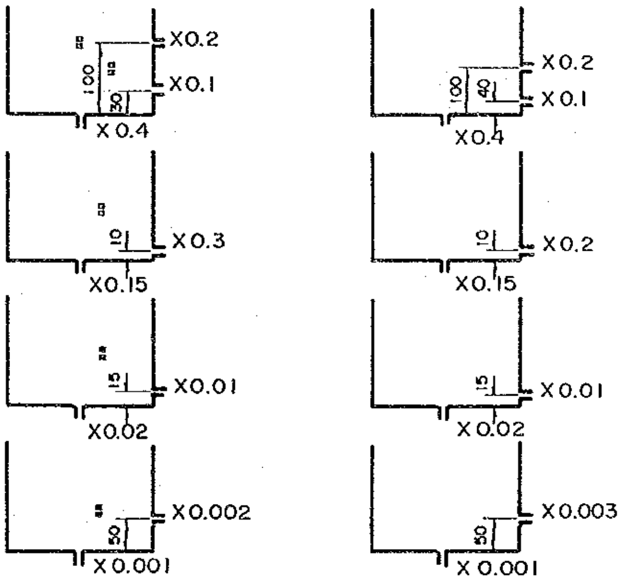
	C/R (mm)	A/E (mm)		C/R (mm)	A/E (mm)		C/R (mm)	A/E (mm)
JAN.	1.2	1.4	JAN.	1.5	1.6	JAN.	1.2	1.7
FEB.	1.3	1.4	FEB.	1.3	1.5	FEB.	1.5	1.6
MAR.	1.2	1.6	MAR.	1.3	1.8	MAR.	1.3	1.9
APR.	0.6	1.3	APR.	0.7	1.5	APR.	1.0	1.6
MAY.	1.0	1.1	MAY.	0.9	1.2	MAY.	1.6	1.3
JUN.	1.5	0.9	JUN.	1.2	1.0	JUN.	1.4	1.1
JUL.	1.0	0.8	JUL.	1.0	0.9	JUL.	1.2	1.0
AUG.	1.0	0.8	AUG.	1.0	0.9	AUG.	1.0	1.0
SEP.	1.0	1.0	SEP.	1.0	1.1	SEP.	1.0	1.2
OCT.	1.0	1.3	OCT.	1.0	1.4	OCT.	1.0	1.5
NOV.	1.0	1.4	NOV.	1.2	1.6	NOV.	1.4	1.7
DEC.	1.4	1.5	DEC.	1.8	1.6	DEC.	1.8	1.8

C/R;CONVERT RATE OF RAINFALL
A/R;AREAL RAINFALL

Fig. 3-10 TANK MODEL SIMULATION (1/2)
(KARANGA, WERU WERU, KIKAFU, KWARE, AND SANYA RIVERS)

KWARE RIV.(1DD10)　　　SANYA JUU(1DD13)

C.A. : 34 km　　　C.A. : 85 km



	C/R (mm)	A/E (mm)		C/R (mm)	A/E (mm)
JAN.	0.9	1.7	JAN.	1.0	1.7
FEB.	1.6	1.6	FEB.	0.6	1.6
MAR.	1.0	1.9	MAR.	1.0	1.9
APR.	0.7	1.6	APR.	0.4	1.6
MAY.	0.6	1.3	MAY.	0.3	1.3
JUN.	0.4	1.1	JUN.	0.2	1.1
JUL.	0.4	1.0	JUL.	0.2	1.0
AUG.	0.6	1.0	AUG.	0.4	1.0
SEP.	0.6	1.2	SEP.	0.4	1.2
OCT.	0.7	1.5	OCT.	0.5	1.5
NOV.	1.2	1.7	NOV.	1.0	1.7
DEC.	1.0	1.8	DEC.	1.1	1.8

C/R;CONVERT RATE OF RAINFALL
A/R;AREAL RAINFALL

Fig. 3-10　TANK MODEL SIMULATION (2/2)
(KARANGA, WERU WERU, KIKAFU, KWARE, AND SANYA RIVERS)

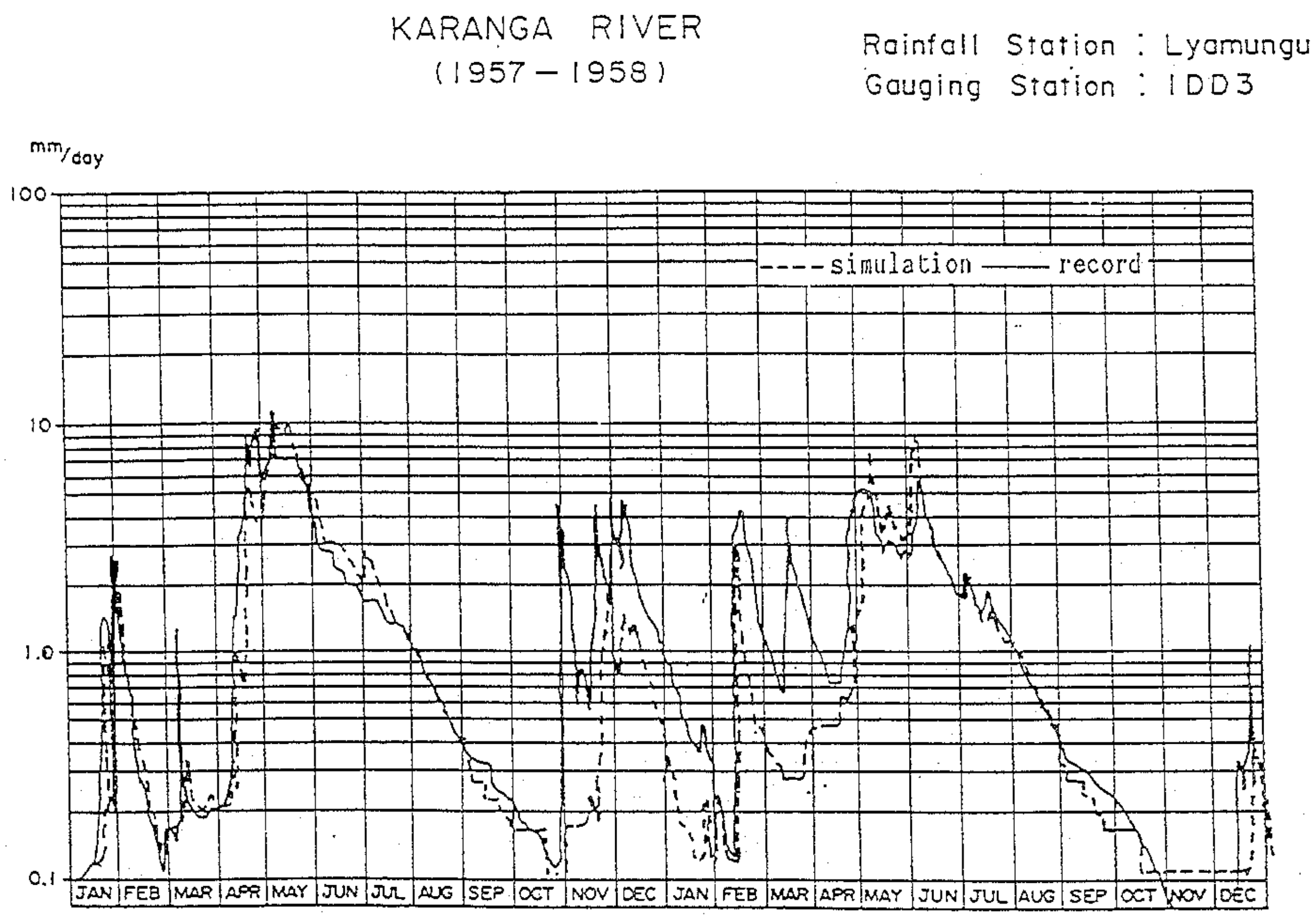


Fig. 3-11 SIMULATION RESULTS OF RIVER DISCHARGE (1/5)
(KARANGA RIVER)

WERUWERU RIVER
(1958 – 1959)

Rainfall Station : Lyamungu
Gauging Station : 1DD5A

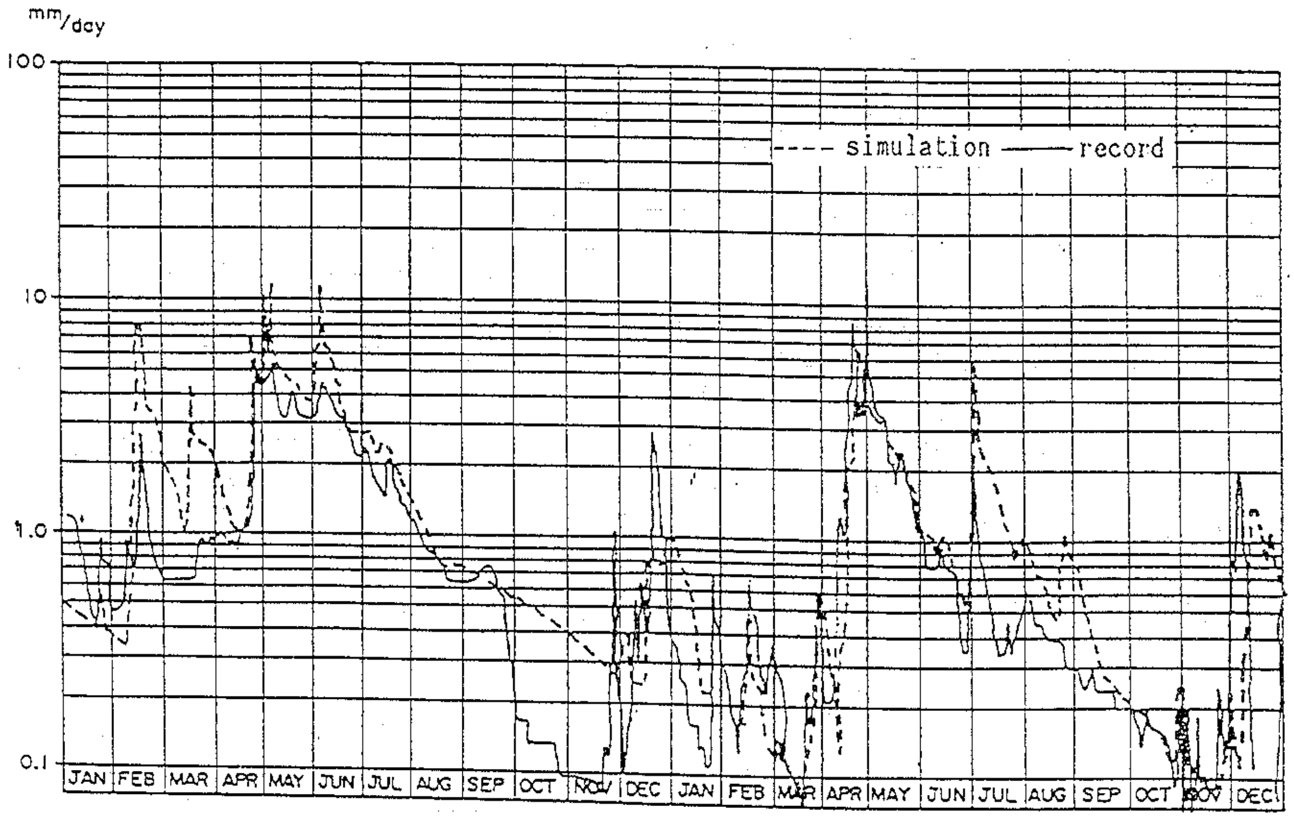


Fig. 3-11 SIMULATION RESULTS OF RIVER DISCHARGE (2/5)
(WERU WERU RIVER)

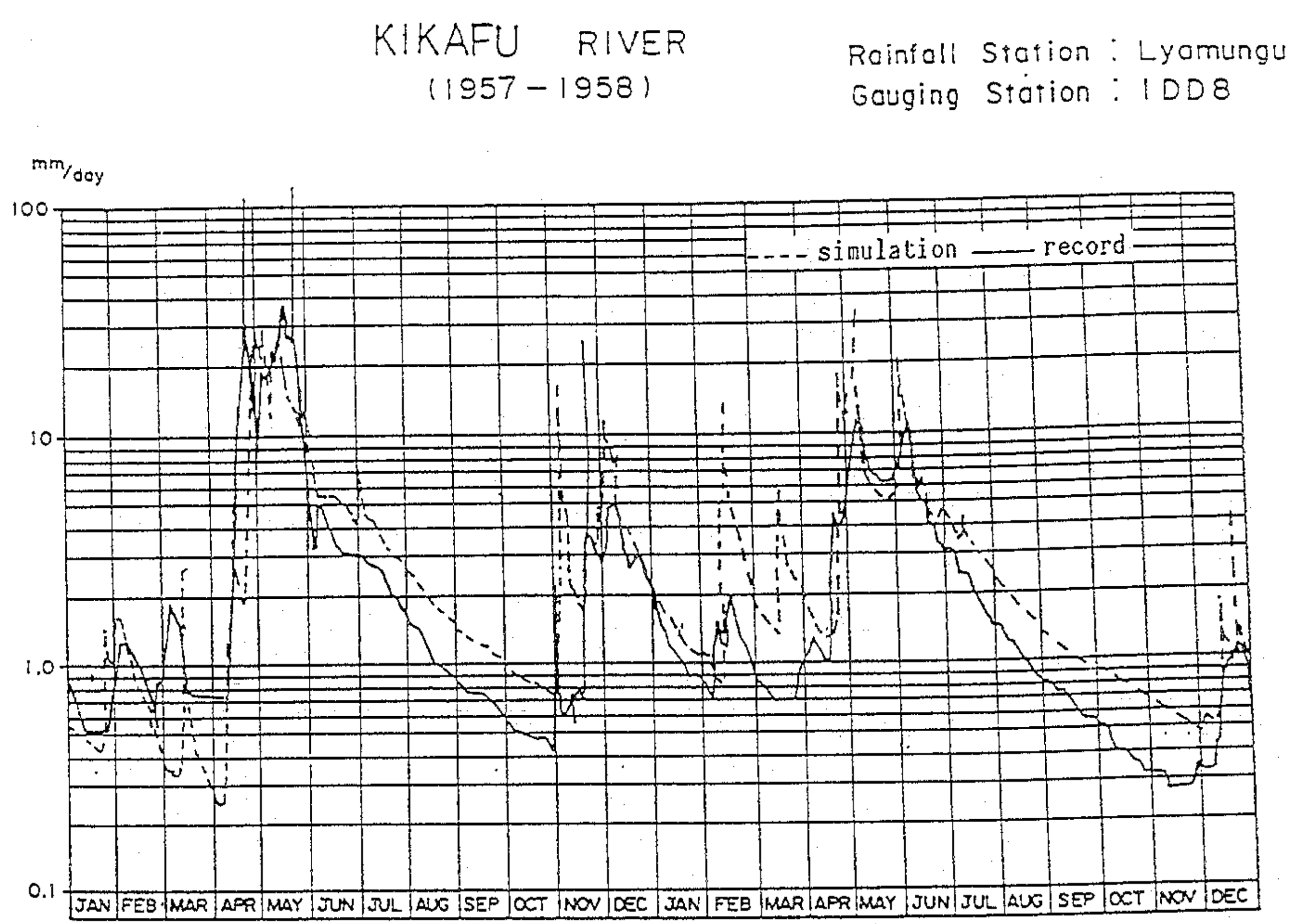


Fig. 3-11 SIMULATION RESULTS OF RIVER DISCHARGE (3/5)
(KIKAFU RIVER)

KWARE RIVER
(1956-1958)

Rainfall Station : Lyamungu
Gauging Station : IDDIO

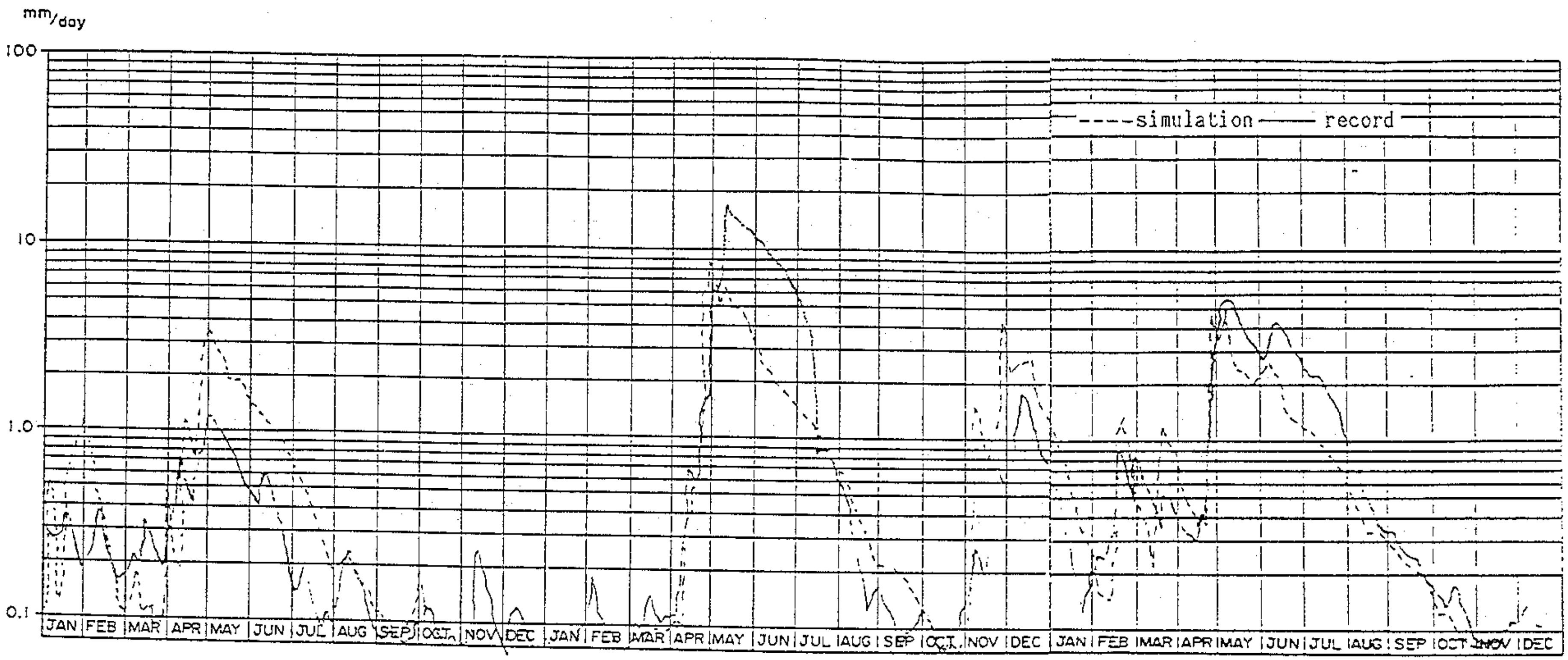


Fig. 3-11 SIMULATION RESULTS OF RIVER DISCHARGE (4/5)
(KWARE RIVER)

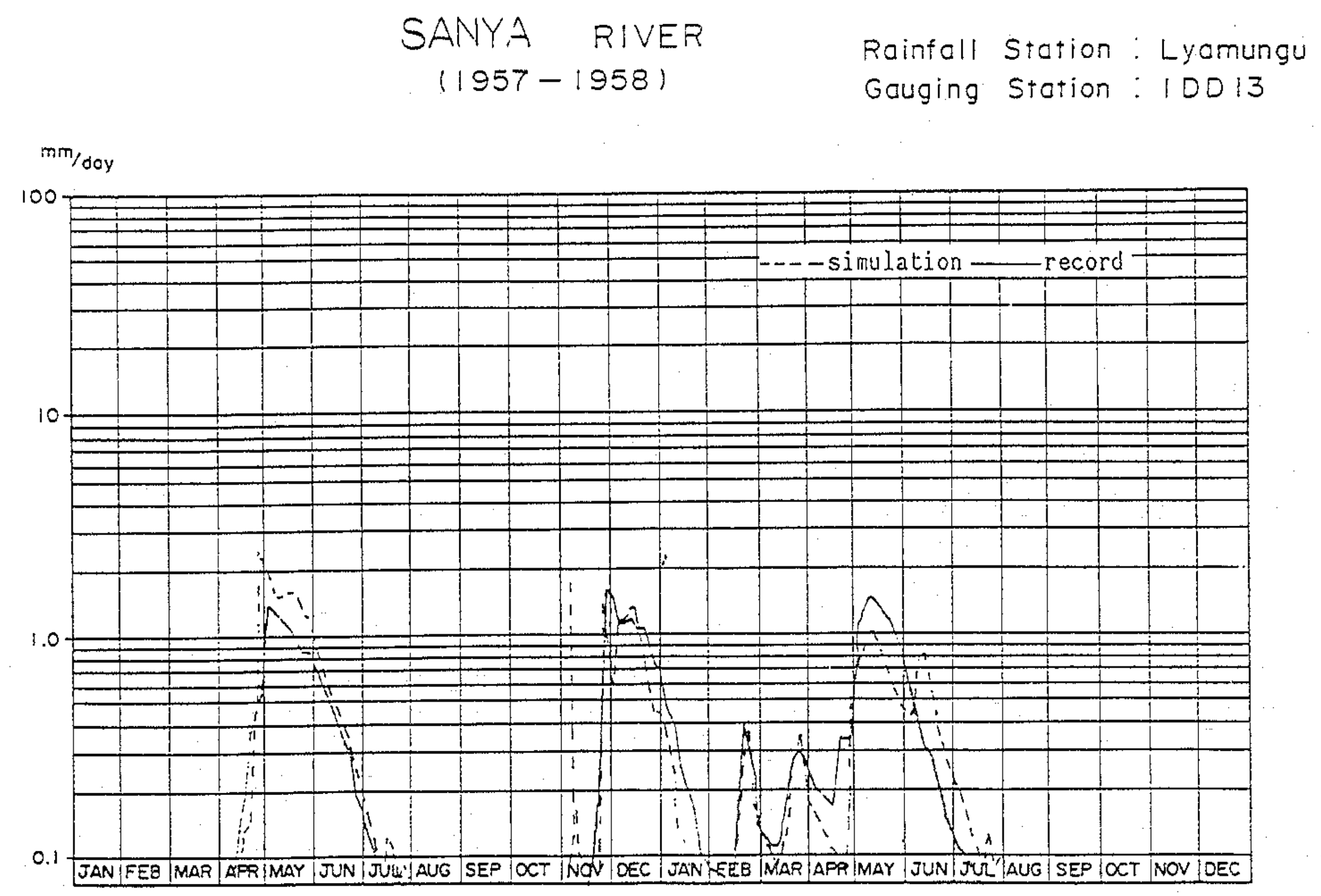


Fig. 3-11 SIMULATION RESULTS OF RIVER DISCHARGE (5/5)
(SANYA RIVER)

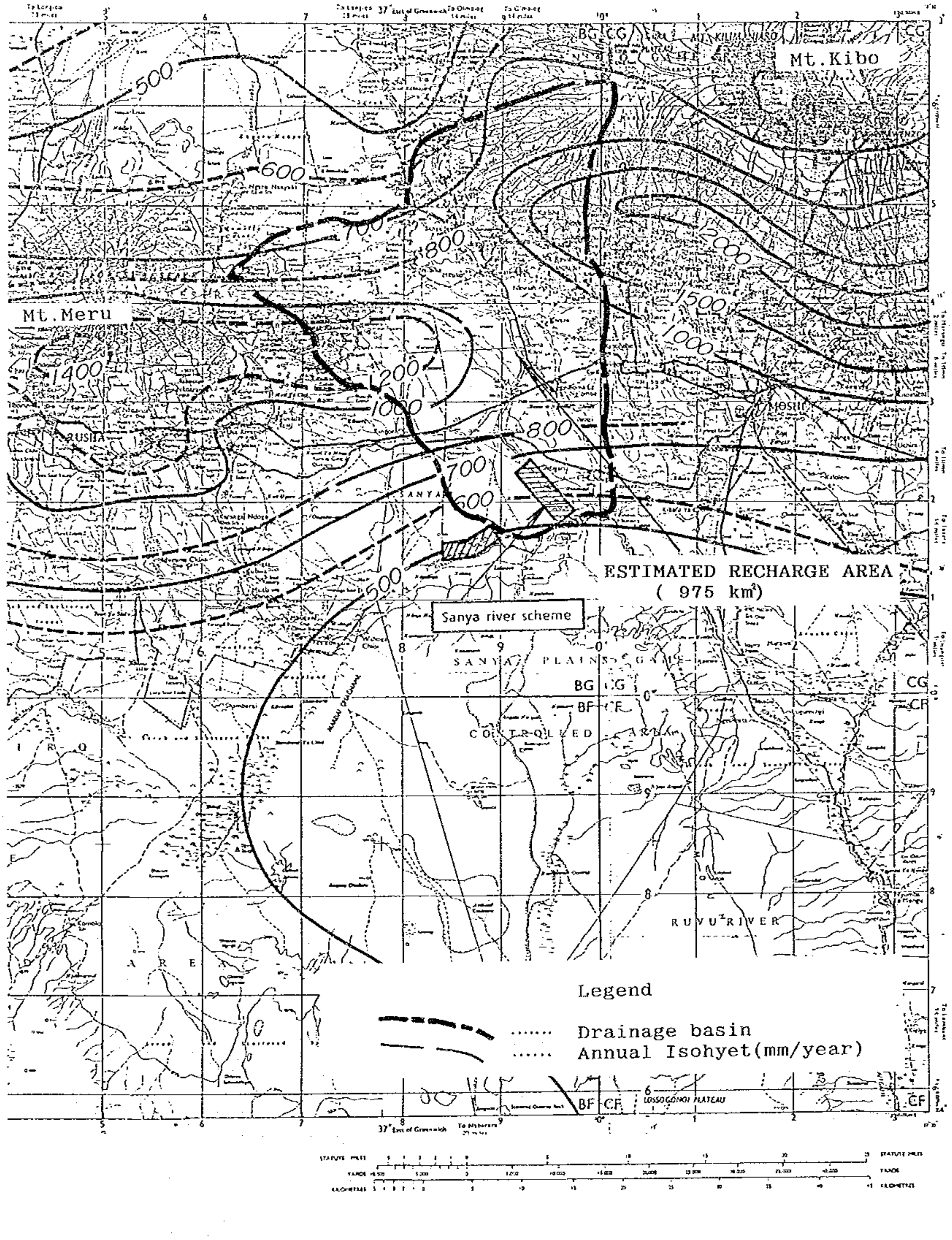


Fig. 4-1 ROUNDWATER RECHARGE AREA

ANNEX C

HYDROGEOLOGY

ANNEX C

HYDROGEOLOGY

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1. TOPOGRAPHY

1.1 Lower Hai Area

Lower Hai area is located at 700-1,200 m in elevation, and slopes gently from the north to the south.

The NE section of this zone corresponds to the foot of Mt. Kibo, which forms a part of the Kilimanjaro mountains, and its volcanic product has resulted in the formation of continuous, undulating plateaus. At the southern edge of Mt. Kibo is the point of origin of the Karanga, the Weru Weru and the Kikafu rivers, which form a very deep valley running in a NS direction.

From the center section to the southwest section of Lower Hai extends the Sanya Plain, which is wide and flat. This plain gets lower in elevation as its slopes lower on the SE side. This topography is rather diagonal, with the Sanya river flowing NNW-SSE, the Kikuletwa from west to east, and then the two joining together downstream. The Kikuletwa river then, further downstream, joins with the above-mentioned Weru Weru. Upstream of the confluence point, the Karanga and the Kikafu rivers flow into the Weru Weru river.

Between the two zones mentioned above, there is a plateau with many "mounded hills" which have been formed by mud flow spreading in a NNW-SSE direction. The Kware river crosses this plateau, and the Sanya river flows near the SSW border of the plateau. Both rivers flow in the SSE direction.

Rundugai area, found on the SE section of the Sanya Plain at about 850 m in elevation, is a flat zone adjacent to the south side of the plateau, which has an abundance of springs. The situation of these springs is closely related to the topography of the plateau and to the formation of the Kikuletwa basin, and the Kikuletwa basin formation derives from the Precambrian basement structure distributed further south than the southern tip of the survey zone.

1.2 Lower Rombo Area

Lower Rombo is found at the SSE foot of Mt. Mawenzi, which forms a part of the Kilimanjaro mountains, upon the sloping foot, and has an elevation of 1,000 - 1,700 m.

The eastern portion of this zone is a vast plain which continues on into the Republic of Kenya. Toward the west of this plain is a gently sloping basaltic lava plateau, and further to the west are volcanic lava mountains which grow gradually very steep.

On the ESE ridge of Mt. Kilimanjaro, there is a succession of numerous parasitic volcanoes, which is a characteristic topographic formation in Lower Rombo. Located in the the SE portion of this zone is Chala Lake, which is a crater lake. This lake is formed in the crater of approximately 3 km diameter of parasitic volcanoes.

2. GEOLOGY AND STRATIGRAPHY

2.1 Lower Hai Area

The geology of Lower Hai consists of Precambrian basement rock, Post-Paleocene, volcanic product, river deposit, lahar, sand and gravel bed and alluvium. This geology is shown in Fig. 2-1, and the geological section is shown in Fig. 2-2, and the stratigraphy is shown in Table 2-1.

Basement rock is only scattered in the southern portion of the survey zone, along the Kikuletwa river. However, it is widely exposed to the south of the zone, where it forms the Masai Steppe, a plateau-like mountain formation. In the northern portion, according to the Arusha geological map, these rock types can be found at the shallow portion of the borehole for groundwater at the NE foot of Mt. Meru. Thus, it can be structurally estimated that basement rock constitutes the geology of the underground shallow sections in Lower Hai.

The basement rock type found within the survey zone is principally crystallized limestone, and that found in the Masai Steppe is gneiss and granite.

Volcanic product is distributed in the NE section of Lower Hai. The volcanic product is composed of material from Mt. Meru as well as from Mts. Shira and Kibo, forming part of the Kilimanjaro mountains.

Among the volcanic product in Lower Hai, the oldest activity is from Mt. Shira. This is composed of trachitic basalt lavas and pyroclastic rocks and is very hard. The material originating from Mt. Meru, as well as from Mt. Kibo, is similar to that which originates from Mt. Shira. However, the latter contains a large amount of coarse, grained phenocryst of feldspar.

In the surrounding area, associated with the volcanic product, parasitic volcano product is also found. However, there is little seen within the Lower Hai area. Nonetheless, as this product consists principally of porous scolia, especially in areas with heavy rain, it represents a vital geological formation in the mechanism of groundwater recharging.

River deposit is found to be widely distributed westward of the stemmed portion of the dam site in the eastern section of the survey zone, where volcanic product and basement rock are distributed. This layer is comprised of unconsolidated tuffaceous sand, silt and mud, and interbedded with thin layers of tuff breccia. According to the boring results from this project, the thickness of the layer exceeds 70 m. The outcrop of this layer is limy and cemented, but in the shallow surface spots, there is mostly soft silt or mud.

Geologically-speaking, lahar is a portion of the make-up of volcanic product and it is one of the principal aquifers in Lower Hai.

Lahar, here, is separated into three parts by its distribution pattern as follows.

(1) Lahar 1: Originated from Mt. Meru
(2) Lahar 2: Mostly originated from Mt. Meru
(3) Lahar 3: Originated from Mt. Kibo

The quality of their lithology and texture are the same. Lahar 3 is distributed in the south-eastern zone of the Lower Hai area and is interfingered with river deposit. Lahar 2, located in the middle zone of the Lower Hai area, is also interfingered with river deposit.

Within the lahar in Lower Hai, there can be seen consolidated portions, with vertical and horizontal cracks, and unconsolidated portions. The consolidated portions, as they could be thought of as a component of volcanic product, are like tuff breccia containing compact basaltic fragments or welded tuff with lithofacies similar to basaltic breccia. The unconsolidated lithofacies are usually mud flow deposit. However, in Lower Hai, the unconsolidated lahar is composed of sub-angular granules and boulders, which hardly contain matrix and therefore make for a favorable aquifer. It is thought to gradually increase at the fine facies portion near the tip of the formation. Lahar 2 could be thought to add to the thickness of the layer to the east of the Sanya river, take away from the thickness of the layer to the west of the Sanya river and add to the thickness of the above-mentioned river deposit layer.

On the northern side of Mt. Ngrudoto, which is to the east of Mt. Meru, above Lahar 1, there are numerous ponds from which, in the upper area, the Biriri river, a principal branch of the Sanya, originates. This river runs from this point to the west, over Lahar 1, and finally joins in confluence with the Sanya.

Outwash is the so-called "fan deposit". It is made up of particles of every size, from fine to boulder, as well as, sand and round to sub-angular gravel, in strata form. In the areas of high topographic elevation (to the north), sub-angular gravel increases. Its relationship to alluvium and its distribution boundaries are not clear.

Alluvium consists of clay, fine sand and conglomerate, and is relatively widely distributed in the Sanya and Kikuletwa rivers. The lithofacies of alluvium resemble the outwash and river deposit which are distributed at lower positions, resulting in unclear boundaries. These could all be favorable aquifer because the 13 hand-dug wells in Mtakuja village located to the south of Kilimanjaro International Airport, KIA, in the survey zone have been dug into this layer.

2.2 Lower Rombo Area

The geology of Lower Rombo is comprised of Precambrian basement rock, volcanic deposit, terrace deposit, debris and fan deposit, talus deposit, alluvium and present riverbed deposit. This is shown in Fig. 2-3, with the geological section in Fig.2-4, and the geological stratigraphy for Lower Rombo in Table 2-1, along with that of Lower Hai.

Basement rock, about the size of hills, is distributed in the southern part of Lower Rombo; further to the south, it is found in a continuous spread, linking the Pare mountains. Basement rock in Lower Rombo, differing from that in Lower Hai, is crystalline schist. This schist strikes widely in a NNW-SSE direction, and dips to the NNE.

The volcanic deposit is related to the activity of Mt. Mawenzi, which is a component of Mt. Kilimanjaro. This formation is found from the central to the northern part of the survey zone. It derives from a lower position of lava plateaus and two alternations of lava and unconsolidated pyroclastic rocks. These are basaltic.

The lava which forms the lava plateau is extremely hard basaltic lava, covered with very shallow fan deposit and according to aerial photos, it is interpreted as terrace deposit.

Above this lava, alternations of lava and unconsolidated pyroclastic rocks are overlaid. The lava is from a few meters to about 50 meters in thickness and the unconsolidated pyroclastic rock is a few meters in thickness, irregularly sedimented and very porous. This rock condition can frequently be seen at roadsides and in very deep valleys.

Accompanying the volcanic deposit in the southern part of Lower Rombo, parasitic volcano deposit, terrace deposit, and debris deposit are widely distributed.

The parasitic volcano deposit makes up much of the volcanic cones which are composed of scolia and lava. The rain water infiltrates into the scolia and the recharged groundwater is supplied to the Miwaleni spring and to Lake Chala, as mentioned in the paragraph on hydrogeology.

The terrace deposit and the debris deposit are, to a great extent, of a brownish and muddy quality. Thus, these formations in Lower Rombo are not very good aquifers.

As for the fan deposit, it is in a thick state, located in a valley between two lava plateaus. On the upper part of these plateaus, there is brownish silt and on the lower part, there is an alternation of thin layers of large basaltic gravel and sand. This bed in Lower Rombo was confirmed as 40.30 m in depth from the surface by the JC4/89 borehole.

Talus deposit is found on a small scale in the southern portion of Lower Rombo. This formation consists of sand and gravel.

Alluvium and present riverbed deposit are found in the river areas. They range in size from gravel-sized to a few meters in diameter, and as there is hardly any matrix, permeability is very high. Therefore, there is almost no water supply to the rivers in Lower Rombo, except for during the rainy season and the period directly following it.

3 CONDITION OF GROUNDWATER USE

3.1 Springs

3.1.1 Lower Hai area

In Lower Hai, there is a large distribution of springs with the center being Rundugai spring (Fig. 3-1).

This zone adjoins the southern edge of a basement rock zone which is widely distributed to the south of the survey zone, corresponding to the SE section of Sanya Plain. It is 3 km wide, 15 km long and has lake deposit on the top layer, which becomes Moorish in the rainy season.

The amount of spring water ranges from simple dampness to rushing water. However, there is a tendency that, where the elevation is high, there is no spring water and where it is low, there is a quite a bit of water. The majority of the spring water eventually flows into the Kikuletwa. This discharge has been observed at the gauging station as 12 m^3/sec. It is believed that this flow amount is supplied by all the springs.

Considering the position and geological formations of these springs, it is estimated that groundwater is recharged principally from the Kware, Sanya and Kikuletwa basins. In the case of springs recharged from the Kware and Sanya basins, the distribution area and the thickness of Lahar are related. As for the springs recharged from the Kikuletwa basins the distribution and thickness of alluvium and outwash and basement rock in Masai Steppe are related. Additionally, the remarkable NE-SW lineal structure seen on the western edge of the Masai Steppe, is also thought to contribute to the groundwater supply coming from the distant southwest. There is also a possibility, which would require investigation, of water being supplied from the volcanic debris in the Kikafu river area.

As for the flow system of the springs, groundwater flows into this zone in the form of spring water. It is thought to be intercepted by basement rock or nearly impermeable volcanic debris, causing the water to flow.

3.1.2 Lower Rombo area

There are no remarkable springs found in this zone. There is merely seeping out in the forested belt at the upstream of the Muronbeya, Marue, Meru and Washi rivers and at the lava base from the valley walls in the Himo-Tarakea Road area. In the dry season, there is practically no spring water at all.

3.2 Existing Wells

3.2.1 Lower Hai area

(1) Shallow Wells (Hand-dug wells)

In Lower Hai, there are 6 wells in the Sanya Juu area and 13 wells in the Kikuletwa river area. The location of these is shown in Fig. 3-2, and the elevation, depth and water level are shown in Table 3-2.

The majority of the shallow wells in the Sanya Juu area were dug at the time of colonization and thus the only one used at this time is D19. These wells are found at around 1,300 m in elevation, with depths ranging from 1 to 5 m. This is thought to be unconfined groundwater which is retained in the "Lahar 2" surface bed.

The shallow wells in the area along the Kikuletwa river have depths ranging from 7 to 12 m, and water is mainly for domestic and livestock use. The water level is 10 m below ground surface and the elevation is 850 m. However, there is a small slope visible from west to east. This is thought to be free groundwater at the "Lahar 2" base bottom area.

(2) Deep Wells (Bored wells)

In the center of Lower Hai, there are only a few bored wells, which are mainly limited to those near the Kilimanjaro Airport (KIA). There are also some located in the surroundings of this area, in Kibohehe, Sanya Juu, and near Moshi.

The location and conditions of these wells are shown in Fig. 3-3 and Table 3-3, respectively. The aquifer depth predictions in Lower Hai and the static water level are shown as reference in Table 3-4.

From the deep wells in the Moshi area, water is collected from the two beds with depths of 70-100 m, and 20-50 m and 65-95 m. The pumping amount per well is around 3.5 m^3/hour.

The deep well at Kibohehe has a depth of 91.44 m. The elevation of this depth is close to the elevation of the river bottom of the Kikafu river, and the groundwater in this well is believed to be unconfined groundwater, related to flow in the river. The pumping amount of this well is 16 m^3/hour.

The deep well on the Sanya Plain is at a depth of 60-100 m, with a pumping amount at 2-14 m^3/hour.

There are 8 deep wells which were bored from 1968 to 1985 at the KIA. The depth of these is 90-160 m and the pumping amount per well is 38-95 m^3/hour.

3.2.2 Lower Rombo area

(1) Hand-dug wells

There are no shallow wells in Lower Rombo.

(2) Deep Wells (Bored wells)

In Lower Rombo, there are 4 bored wells (Fig. 3-4 and Table 3-5). The only records on these deep wells are those which are related to the Shoshoro and Chala Lake surroundings, and even for these, there is inadequate information on the location of the aquifers and the geology of the inner part of the holes.

There are records on 2 bored deep wells at Shoshoro, but, information related to the geology and the pumping amount is kept for only one of the wells.

It is believed that the results of the first well were not good, and that following this, two other wells were bored.

The boring depth of Well 7/65 at Shoshoro, which was in use up until March 1989, is 91 m and the static water level is at 68 m. The pumping amount is 5.6 m^3/hour and the specific capacity at this time is 3.85 m^3/hr/m.

The well in the Chala Lake area is not used presently. The depth of this deep well is around 160 m and the static water level is 132 m. The groundwater surface elevation is 828 m, which is close to the surface elevation of Chala Lake (855 m, judging from the map). The pumping amount is 6.0 m^3/hour, with the specific capacity at this time recorded as 4.8 m^3/hr/m.

The Uhare deep well was bored into basaltic rock volcanic debris, and water was found during the boring. However, in the additional boring up to 182 m, there was water disposal. This reason is considered that the boring depth reached porous layer.

4. ELECTRIC PROSPECTING

The purpose of electric prospecting is to decipher subsurface lithofacies of the project area.

4.1 Methods And Materials for Electric Prospecting

In this study, two types of electric prospecting were executed, horizontal electric profiling and vertical sounding. Electric prospecting was executed from November 1988 to January 1989 and in June 1989. The measuring equipment is based on the Wenner method. For the analysis of the vertical electric sounding, the Sundberg standard and auxiliary curves were used.

4.1.1 Vertical Sounding

The vertical sounding consisted of measuring the vertical resistivity change at each point. With the objective of understanding the underground geologic structures in this region, electric prospecting was conducted according to the following detail.

Vertical Sounding Content

Line	No.of Sites	Depth	Site Interval	Location
<Lower Hai>				
AA'(H)	6	120 m	500 m	Mungushi
BB'(H)	10	120 m	500 m	Sanya Chini
CC'(H)	28	120 m	500 m	Mtakuja/Tindigani
DD'(H)	11	120 m	500 m	Rundugai
<Lower Rombo>				
AA'(R)	11	120 m	300-500 m	Kirongo Chini
BB'(R)	15	120 m	300-500 m	Kirongo Chini
CC'(R)	15	120 m	300-500 m	Kirongo Chini
DD'(R)	4	120 m	1,200-2,000 m	Msaranga
EE'(R)	4	120 m	1,200-2,000 m	Msaranga
FF'(R)	8	120 m	200-300 m	Kiraeni

4.1.2 Horizontal Electric Profiling

With the purpose of understanding the horizontal resistivity change at constant depth, horizontal electric profiling was conducted in locations judged most desirable from the results of vertical sounding. The content of horizontal electric profiling is listed below.

Horizontal Profiling Content				
Line	No.of Sites	Depth	Site Interval	Location
<Lower Hai>				
EE'(H)	48	40,50,60 m	30,50 m	Sanya Chini
FF'(H)	58	40,50,60 m	50 m	Tindigani
GG'(H)	33	40,50,60 m	50 m	Mtakuja

4.2 Results of Electric Prospecting

4.2.1 Lower Hai area

The geological formation of Lower Hai is presumed to be composed of the following 7 layers.

Geologic Formation (Layers)	Specific Electrical Resistivity	Inferred Geology
	(ohm-m)	
A(H)	120-600	Dry surface, Deposit, Volcanic Rock
B(H)	110-120	Well Consolidated Pyroclastic Rock
C(H)	60-160	Lahar (dry part)
D(H)	30- 90	Precambrian or not well consolidated Pyroclastic Rock
E(H)	25- 70	Alternation of Lake Deposit and Lahar (L. Dep. < Lahar). River Bed Deposit or Outwash
F(H)	10- 30	Alternation of Lake Deposit and Lahar (L. Dep. > Lahar)
G(H)	5- 15	Lake Deposit (Argillaceous, Fine Sandy, Silty)

4.2.2 Lower Rombo area

The geologic formation of Lower Rombo is presumed to be composed of five layers as shown in the following table.

Geologic Formation (Layers)	Specific Electrical Resistivity	Inferred Geology
	(ohm-m)	
A(R)	90-1,700	Dry and Wet Surface Deposit
B(R)	500-2,400	Volcanic Rock
C(R)	70- 460	River Bed Deposit or Weathered Volcanic Rock
D(R)	60- 500	Volcanic rock (weathered or with fissures)
E(R)	20- 70	River Bed Deposit (sandy, silty)

4.3 Underground Geology

The underground geology interpreted from the results of electric prospecting is described in the following sub-sections.

4.3.1 Lower Hai area

The prospecting sites are shown in Fig. 4-1, the profile for the vertical sounding lines AA'(H)-DD'(H) is shown in Fig. 4-2, and the results from the horizontal profiling are shown in Fig. 4-3.

Below, in explaining the characteristics of the lines, "layer depth" signifies the depth of the bottom surface of the layer.

(1) Line AA'(H) (vertical sounding)

Line AA'(H) is located in the region between the Sanya River and the Kikuletwa River, on the northern side of the Arusha-Moshi Road, with Mungushi River as its center. The line crosses these rivers in an ENE-WSW direction.

Along Line AA'(H), layers A (H), D (H), E (H) and F (H) are found.

The A (H) layer of this line shows a value of 200-600 ohm-m. It is distributed at a 2-5 m depth from the earth's surface, and is estimated to be dried surface layer deposit.

The E (H) layer shows a value of 35-75 ohm-m, and is distributed to the west of site A-4 (the word "site" will be deleted) and below the A (H) layer. The layer is 5-14 m thick and 7-16 m deep, reaching maximum thickness and depth at point A-4. From the geology of the surface (of the earth), this layer is thought to indicate the presence of lahar and outwash.

The F (H) layer shows a value of 20-30 ohm-m, and can be seen beneath the E (H) layer everywhere along Line AA'(H). The thickness is 65-95 m and the depth is 70-110 m. Judging from the surrounding geology and the results concerning the other lines, this layer is thought to indicate the presence of lahar or sedimentary rock and to be comparatively rich in sand.

The D (H) layer can be found continuously beneath the F(H) layer. This layer shows a value of 45-90 ohm-m, and is thought to indicate the presence of pre-lahar volcanic deposits.

(2) Line BB'(H) (vertical sounding)

BB'(H) is located on the southern side of Arusha-Moshi Road, and crosses the Sanya River in an ENE-WSW direction.

Along Line BB'(H) are distributed the layers A (H), D (H), F (H), and G (H), and beneath these is distributed another D (H) layer.

The A (H) layer shows a value of 200-600 ohm-m, and is found at 2-7 m below the earth's surface. This is thought to indicate the presence of dried subsurface deposit.

The D (H) layer shows a value of 30-60 ohm-m and is distributed beneath the A (H) layer almost completely along this line. The thickness is 6-35 m and the distribution depth is 8-42 m. It is the thickest and deepest at B-3, located in the vicinity of the Sanya River, and reduces in thickness and depth as it moves away from the river. This layer shows alternating layers of lake deposit and lahar, and one portion shows former riverbed deposit or outwash.

The F (H) layer, with the center as B-2 (approx. 200 m east of Sanya River), is distributed beneath the D (H) layer, but is not found west of B-5. Layer 10-30 ohm-m is 40-60 m thick, but it disappears at B-3 (near Sanya River), and is deeper than 75 m at B-2 where bottom depth is unknown. With the exception of that at B-2, the distribution depth is 50-80 m. This layer is thought to indicate the presence of alternating layers of lake deposit and lahar, being comparatively rich in lake deposit.

The G (H) layer is widely distributed beneath the F (H) layer or the 10-20 ohm-m layer, west of Sanya River. It exists at points deeper than 10-50 m, but the bottom depth is unknown. Judging from the distribution location and depth of this layer, it seems to consist of lake deposit, and from the resistivity value, it seems to be rich in fine-grained sandy or silty materials.

The deeper D (H) layer is distributed separately, both on the east and west sides of Line BB'(H), and shows a value of 45-65 ohm-m. That on the east side is found at below 78 m of B-1, and that on the west side is found at below 28 m of B-9, and for both, the bottom depth is unknown. The geologic structure of this layer shows volcanic debris other than lahar or Precambrian rock.

(3) Line CC'(H) (vertical sounding)

Line CC'(H) is located 2 km south of Line BB'(H) and runs in a NE-SW direction, crossing the Sanya and Kikuletwa rivers.

Along Line CC'(H) the layers A (H), D (H), E (H), F (H), and G (H) are found, and below these are again found layers DH and G (H).

The A (H) layer shows a value of 90-370 ohm-m, and is distributed in the vicinity of C-12 and east of C-8 at up to a depth of 10 m. It is thought to indicate the presence of dried subsurface deposit.

The D (H) layer is distributed around Sanya River and shows a value of 48-60 ohm-m in this line. Maximum thickness is 60 m, the depth reaches 7-72 m, and the layer is the thickest and deepest in the Sanya River vicinity. Other than this, the layer is distributed on a small scale in the vicinity of C-19 and C-25 (vicinity of Kikuletwa River). Here, this layer is distributed directly below the subsurface to depths of 4-7 m. It is thought to indicate, in general, the presence of alternating layers of lake deposit and lahar, and to contain a portion of former riverbed deposit or outwash.

The E (H) layer shows a value of 20-50 ohm-m in the Kikuletwa basin (west of C-19), and is distributed as far as 20 m below the subsurface. This layer is the thickest between C-20 and C-21, with the middle portion (7 m-10 m depth) containing a low resistivity layer of 0.4-8 ohm-m.

The following describes this layer, based on its distribution location. The layer, if deeper than the G (H) layer, is thought to indicate the presence of riverbed deposit or outwash, while if shallower than the G (H) layer, is thought to show river-bed deposit (alluvium).

The E (H) layer contains a 5-30 ohm-m layer which shows a value of 0.4-8 ohm-m. It is thought to be of a silty or clayey quality.

The F (H) layer on Line CC'(H) shows a value of 9-33 ohm-m, and is widely distributed from below the D (H) layer in the vicinity of Sanya River to below the E (H) layer in the vicinity of Kikuletwa River. In the interval between C-5 and C-10, this layer contains the below-mentioned G (H) layer and exists below it as well. The shallower F (H) layer has a thickness of 20-40 m in the Sanya River vicinity, becoming gradually thinner west of C-6. The thickness of the deeper F (H) layer is over 100 m, and the bottom depth is unknown. The portion of the F (H) layer of high resistivity value, judging from the distribution location and the depth, is thought to indicate the presence of alternating layers of lake deposit and lahar or colluvial deposit. That of low resistivity value shows lake deposit rich in fine-grained facies.

The G (H) layer is distributed west of C-5, and is not found in the vicinity of Sanya River. Between C-6 and C-10, this layer is contained within the F (H) layer, as mentioned above. The thickness of this layer in general is 5-70 m and the depth is 10-100 m, but in the vicinity of C-6 and C-26, the bottom depth is unknown. This layer is thick near the Sanya River and near the Kikuletwa River and thought to be thinner at all other locations.

Judging from its distribution pattern and depth, this layer is thought to indicate the presence of alternating layers of lake deposit and lahar, and judging from the resistivity value, there seems to be a portion rich in fine-grained facies (fine-grained sandy or silty materials). West of C-16, as this layer shows a value higher than 10 ohm-m, it is thought to be rich in silty fine-grained facies or clay.

The D (H) layer on Line CC'(H) shows resistivity values in a wide range of 22-135 ohm-m, and it is found below the F (H) layer in the Sanya River vicinity, while in other zones it is found below the G (H) layer. The D (H) layer is thought to indicate the presence of volcanic deposit prior to lahar or weathered muddy quality Precambrian rock.

(4) Line DD'(H) (vertical sounding)

Line DD'(H) is located 3 km northwest of Rundugai and, crossing Kware River, runs in an ENE-WSW direction.

Along Line DD'(H) the layers A (H), B (H), C (H), D (H), E (H), and F (H) are found.

The A (H) layer shows a value of 120-500 ohm-m west of D-5, and is found at a depth of 2-8 m. This layer indicates the presence of dried subsurface deposit.

The F (H) layer shows a value of 15-30 ohm-m, and west of D-5, it is distributed below the A (H) layer, while east of D-5 it is distributed from the surface. The thickness of this layer is 15-50 m and the depth is generally 55 m, but the depth is unknown in the vicinity of D-8. The middle portion of this layer contains a 60-160 ohm-m layer, and in the vicinity of D-5 the bottom portion contains an 8 ohm-m layer to a small degree. Judging from the surrounding subsurface geology, this layer is thought to indicate the presence of alternating layers of lake deposit and lahar or of lahar rich in fine-grained facies.

The C (H) layer is found contained within relatively shallower portions of the F (H) layer. The thickness is approximately 4-25 m, and this layer is thought to be lahar of low water content (welded or dried).

The D (H) layer shows a value of 80-50 ohm-m, and is found under the F (H) layer throughout the entire region, but west of D-4, it is found at a depth of over 40 m and the bottom depth is unknown. East of D-3, the thickness is 5-85 m and the depth is 5-110 m, with both the thickness and the depth decreasing in an eastward direction. From the subsurface geologic conditions, this layer is thought to indicate the presence of volcanic deposit distributed beneath lahar, and as the resistivity value is low, the component of this layer is most likely pyroclastic rock, which is of relatively low consolidation.

The B (H) layer is found east of D-3. The layer thickness is 55-85 m and the depth is about 90 m, but at D-3 the bottom depth is unknown. This layer is thought to be lava or pyroclastic rock of good consolidation.

The E (H) layer in the east of D-2 and deeper than 90 m, shows a value of 25-70 ohm-m. From the subsurface geology, this layer is thought to be pyroclastic rock of relatively low consolidation, but this resistivity value geologically resembles that of the volcanic deposit or Precambrian rock of Line CC'(H).

(5) Line EE'(H) (horizontal profiling)

Line EE'(H), with B-4 as the reference point, extends to the 1,450 m site upstream Sanya River (NW direction), and to the 500 m site (C-28) downstream (SE direction), with a total length of 1,950 m.

Within 200 m NW of B-4, resistivity value is scattered around 0-70 ohm-m.The resistivity value tends to be higher at deep points (60 m) than at shallow points (40 m). This high value layer seems to indicate conglomerate or lahar.

Between 200 m and 1,100 m from B-4, a resistivity value of 10-20 ohm-m can be observed. Judging from the JC2/89 boring test site, this seems to reflect lake-bed deposit principally composed of clayey silt.

Between 1,100 m and 1,450 m from B-4, the same resistivity values as those found in the former can be observed. This is also thought to be lake-bed deposit,but as the value is fairly high at 20-30 ohm-m, it could possibly be lake-bed deposit of principally sandy bed or alternating layers of lake-bed deposit and lahar.

In the SE direction, between B-4 and 350 m point, the layer content is thought to be lake-bed deposit of a principally clayey silt base, as the same pattern seen between 200 m and 1,100 m in the NW direction can also be seen here.

Between 350 m and 500 m SE of B-4, the apparent resistivity distribution is convergent and resembles the zone in the vertical sounding where the ohm-m contour line changes from descending to horizontal. Judging this against the results from the vertical sounding, geologically it resembles the region of lake-bed deposit and lahar or of basement rock (lava or Precambrian). In other words, it is a zone with a shallow distribution depth for the basement rock layer.

(6) Line FF'(H) (horizontal profiling)

Line FF'(H) extends from C-27, 650 m northeast and 2,100 m southwest, for a total length of 2,750 m crossing the Sanya River in a NE-SW direction. In the NE direction from C-27, the apparent resistivity value is 30-60 ohm-m and is generally fairly high. At 200 m from C-27, an ascending curve distribution is suggested by the resistivity values, which are high at 60 m and low at 40 m. Judging from the results of the JC2/89 test boring, this pattern illustrates alternating layers of lake-bed deposit and lahar. On the other hand, in the SW direction from C-27, the overall apparent resistivity value is the same at 10-30 ohm-m, which resembles the zones of Line EE'(H) between 200 m and 1,100 m NW, and between 0 m and 350 m SE. This is thought to show alternating layers of lake-bed deposit and lahar which grow thicker in this direction.

(7) Line GG'(H) (horizontal profiling)

Line GG'(H) has a point of origin which is 1 km from C-23 upstream of Kikuletwa River, crossing it in a south-north direction. From Kikuletwa River, it runs 950 m (N) and 650 m (S), for a total length of 1,600 m. Between the point of origin and 300 m, the apparent resistivity value is 20-30 ohm-m, and between 250 m and 400 m from the point of origin, the resistivity value is somewhat higher than the former. This is thought to illustrate distribution of fairly consolidated bed in deep areas. Judging from the geological condition of the surface, this is thought to be Precambrian basement rock. A similar pattern is observed between 650 m and 850 m, and between 1,000 m and 1,600 m from the point of origin.

The apparent resistivity value is fairly low at 10-20 ohm-m at a distance between 450 m and 650 m, and between 850 m and 1,000 m from the point of origin. The resistivity value at 60 m is lower than that at 40 m (descending curve), or the measured value is the same at the above-mentioned depths (horizontal curve). This is thought to be riverbed deposit or lahar enclosed in lake-bed deposit.

4.3.2 Lower Rombo area

The execution sites for electric prospecting are shown in Fig. 4-4 and the analytic result profile for each of the lines AA'(R)-FF'(R) is shown in Fig.4-5.

Lines AA'(R), BB'(R) and CC'(R) are established consecutively from east to west, in a NNE-SSW direction across the lower reaches of Muronbeya River. In addition, between the Marue and Motare rivers, Lines DD'(R) and EE'(R), are established on the SSW extensions of Lines AA'(R) and BB'(R), respectively. The electric prospecting was conducted in an area extending 4 km EW and 8 km SN.

Further, on both margins of the Marue river, Line FF'(R) is established in a NNE-SSW direction. In measuring operations, A-7 and A-7-2 (200 m east of A-7) were remeasured, and measuring was carried out in order to check Marangu and Shoshoro where bored wells were found to exist.

(1) Line AA'(R)

Line AA'(R) contains layers A (R), B (R), C (R) and E (R). Within the B (R) layer from A-0 to A-2, there is a layer of an approximate 250-500 ohm-m resistivity. The D (R) layer crosses the above layers between A-7 and A-8.

The A (R) layer on this line shows a value of 50-163 ohm-m, indicating presence of surface layer deposit.

The E (R) layer shows a value of 28-48 ohm-m, and is distributed at a depth of 26-32 m between A-6 and A-7. This layer is thought to indicate sandy or silty fine-grained riverbed deposit.

The C (R) layer shows a value of 223-360 ohm-m, and is distributed at a depth of 23-28 m near A-0 and between A-9 and A-10. Judging from the distribution pattern and the resistivity value, this layer seems to be weathered volcanic facies or riverbed deposit.

The B (R) layer shows a value of 570-1,610 ohm-m, and is distributed at a depth exceeding 23-28 m. The wide variation in the resistivity value may indicate a heterogeneous distribution of lava and pyroclastic rock. The resistivity value of the 250-500 ohm-m layer, which is within this layer, indicates presence of fine-grained pyroclastic rock.

The D (R) layer between A-7 and A-9 shows a value of 342-360 ohm-m and is found at a depth of 7-32 m. From these distribution conditions, this layer seems to be sand and gravel bed enclosed between two lava plateau slopes or cracked volcanic rock facies. At A-7, the results from JC4/89 boring confirm that lava is the sole component found between depth of 40.30 m and 55.25 m.

(2) Line BB'(R)

This line contains layers A (R), B (R), C (R) and E (R). The D (R) layer crosses the above layer at B-8.

The A (R) layer shows a value of 92-870 ohm-m, indicating presence of surface layer deposit.

The E (R) layer shows a value of 40-64 ohm-m and is distributed at a depth of 7-24 m between B-8 and B-9. The E (R) layer is also seen on a small scale between B-0 and B-2, and between B-13 and B-14. This layer appears to be sandy or silty fine-grained riverbed deposit.

The C (R) layer shows a value of 144-252 ohm-m and is distributed between B0 and B-7, and between B-9 and B-14 at a depth of 13-54 m. It is divided into 2 layers, one of 100 ohm-m and one of 200 ohm-m. This layer is thought to be weathered volcanic facies or riverbed deposit.

The 500-2,400 ohm-m layer shows a value of 515-2,040 ohm-m and is distributed at a depth of 13-54 m. It shows a distribution of lava and pyroclastic rock. It is distributed throughout the area from B-0 to B-14, and resembles Line AA'(R) in its wide variation in resistivity value.

The D (R) layer in the vicinity of B-8 shows a value of 416 ohm-m, and is distributed at a depth exceeding 24 m. The distribution conditions show sedimented sand and gravel bed enclosed between 2 lava plateau slopes or cracked volcanic rock.

(3) Line CC'(R)

This line contains layers A (R), B (R), C (R), and E (R). The D (R) layer crosses the above layers between C-9 and C-11.

The A (R) layer shows a value of 164-1,700 ohm-m, indicating presence of surface layer deposit.

The E (R) layer shows a value of 20-31 ohm-m and is distributed at a depth of 7-31 m from C-10 to C-13. This is sandy or silty fine-grained riverbed deposit.

The C (R) layer shows a value of 72-348 ohm-m and is distributed at a depth of 2-13 m down to 75 m from C-0 to C-10, and between C-13 and C-14. From the distribution pattern and the resistivity value, this layer appears to be weathered volcanic facies or riverbed deposit.

The B (R) layer shows a value of 500-2,400 ohm-m and is distributed at a depth of 14-75 m. The varied resistivity value indicates a heterogeneous distribution of lava and volcanic pyroclastic rock.

The D (R) layer between C-9 and C-11 shows a value of 210-380 ohm-m and is distributed at a depth of 5-32 m. From the distribution pattern, this layer seems to be sand and gravel bed sedimented between numerous lava plateau slopes or cracked volcanic facies.

(4) Line DD'(R)

This line contains layers A (R), B (R), C (R), and E (R). The D (R) layer crosses the above layers at D-1.

The A (R) layer shows a value of 400-701 ohm-m, indicating presence of surface layer deposit.

The C (R) layer shows a value of 92-229 ohm-m and is distributed from D-0 to D-3 at a depth of 3-32 m. At D-3, the C (R) layer continues to a depth of 120 m. This is thought to be weathered volcanic facies or riverbed deposit.

The B (R) layer shows a value of 473-1,129 ohm-m and is distributed at a depth of 20-32 m.

The D (R) layer distributed near D-1 shows a value of 243 ohm-m and is found at a depth exceeding 58 m. This layer is thought to be sedimented sandy conglomerate between two lava plateaus or cracked volcanic facies.

(5) Line EE'(R)

This line contains layers A (R), B (R), C (R), and E (R). The D (R) layer crosses the above layers at E-1.

The A (R) layer shows a value of 130-900 ohm-m, indicating presence of surface layer deposit.

The C (R) layer shows a value of 104-195 ohm-m and is distributed between E-0 and E-3 at a depth of 1.5-50 m. This layer is weathered volcanic facies or riverbed deposit.

The B (R) layer shows a value of 245-460 ohm-m and is distributed at a depth exceeding 8 m.

The D (R) layer found near E-1 shows a value of 60-94 ohm-m and is distributed at a depth exceeding 23 m. From the distribution pattern, this layer is either sand and gravel bed sedimented between two lava plateau slopes or cracked volcanic facies.

(6) Line FF'(R), Marangu and Shoshoro

This line contains layers A (R), B (R), C (R) and E (R).

The A (R) layer shows a value of 100-130 ohm-m, indicating presence of surface layer deposit.

The E (R) layer shows a value of 24-47 ohm-m and is distributed at a depth of 3.5-17 m from F-0 to Shoshoro. This is fine-grained riverbed deposit as sand or silt.

The C (R) layer shows a value of 90-200 ohm-m and is distributed at a depth of 3.5-48 m from F-7 to Shoshoro. This is weathered volcanic rock or riverbed deposit, but the results of the bored well JC3/89 at F-3 show lava at a depth ranging from 14.4 m to 21.25 m.

The B (R) layer shows a value of 500-810 ohm-m, with a portion of it showing a value of 238-450 ohm-m or of over 4,000 ohm-m. The distribution depth exceeds 3 m. The variation in the resistivity of this layer indicates heterogeneous distribution of lava and pyroclastic rock.

4.4 Supplemental Survey in Phase-2

4.4.1 Sanya river water basin

The supplementary study for the vertical sounding was carried out in Phase-2 of the field survey. This included the establishment and the survey of a 1 Km extension, named L0, of Line CC'(H), which had been established and surveyed in Phase 1, in a NE direction, and then the establishment of ten lines parallel to this line, numbering up to L10 (Fig. 4-6).

The interval between the lines from L0 to L6 is 500 m, from L7 to L10 is 750 m, between L6 and L7 is 1,000 m, and that between electric prospecting points is 500 m, totalling 60 points in all. Prospecting depth is 100 m.

The Wenner Method was used, and the analysis was conducted using standard and auxiliary curves.

The results from the analysis of the vertical sounding are shown in Fig. 4-7. Based on these results are the conditions of specific electrical resistivity at the subsurface depths of 30 m and 40 m, which are shown in Fig. 4-8. In order to estimate the structures of the layer equivalent to basement rock, the conditions of specific electrical resistivity at the subsurface depth of 80 m, shown in Fig. 4-8 were consulted.

The specific electrical resistivity layers for the Sanya River basin, based on the specific electrical resistivityand geology, are classified into 8 layers, identified as layers A (S) to H (S).

They have the following specific electrical resistivity values.

A (S)	over 100	ohm-m
B (S)	40-70	ohm-m
C (S)	20-30	ohm-m
D (S)	10	ohm-m
E (S)	30-45	ohm-m
F (S)	over 100	ohm-m
G (S)	40-70	ohm-m
H (S)	over 100	ohm-m

From these results and those from the subsurface study, these specific electrical resistivity layers are equivalent to the following lithofacies layers.

A (S)	Basement
B (S)	Gravel, Sand, Lahar
C (S)	Lake Deposit
D (S)	Silt, Clay
E (S)	Lahar, Lake Deposit
F (S)	Lahar
G (S)	Outwash
H (S)	Dried Sub-surface Deposit, Volcanic Deposit

The conditions of the underground specific electrical resistivity of the Sanya River basin are clear along lines L1, L0 and L3 (Fig.4-7).

The underground conditions of the Sanya River basin show a range consisting of the Layers A (S), B (S) and C (S), with Layer B (S) absent in some places. Layer C (S) is eroded in a channel-like formation, and in its place, Layer E(S) has sedimented. However, the distribution of Layer E (S), according to the results of this study, is limited to the south of Line L3.

Layer B (S) is found directly above the layer equivalent to basement rock (Layer A (S)) and also recognized above Layer C (S) (Line L4). However, it is possible that the majority of what is above Layer B (S) is Layer G (S). It is necessary to carry out periodic profiling on this relationship, based on the geology of the study site.

To the south of line L6, above Layer C (S) or E (S), there is local distribution of a thin layer of Layer D (S) (Fig.4-7). However, to the north of the line, from Line L7 to L10, Layer D (S) is extremely thick.

After the sedimentation of Layer D (S), above this at depths shallower than 25 m, Layer G (S) is sedimented. As Layer G (S) shows the same specific electrical resistivity as Layer B (S), where Layers C (S) E (S) or D (S) are absent, the distinction between G (S) and B (S) is difficult. The specific electric resistivity value of the upper limits of Layer G (S) resembles that of the lower limits of the below-mentioned Layer H (S), thus making the distinction between layers G (S) and H (S) difficult.

Above Layer G (S) there is a distribution of layers of relatively high specific electric resistivity value. Among these, Layer F (S) is distributed down to a relatively deep level, and Layer H (S) at a shallow level. From the results of the subsurface study, these layers are thought to indicate the presence of lithofacies which would become aquifer of good condition. Therefore, it is important to understand the relationship between the depth of the layer and surrounding groundwater level.

According to the above results, in the groundwater prospecting for the Sanya River basin, it is important to trace Layers B (S) and E (S). An additional important objective is investigation of Layer F (S), G (S) and H (S), according to the relationship with the surrounding groundwater level.

4.4.2 Kikuletwa river basin

The supplementary study for the vertical sounding was carried out in Phase-2 of the field survey. The established and surveyed base line, identified as L11, runs in a SN direction through the C21 site of line CC'(H) which was established and surveyed in Phase-1. Parallel to this line, numbering up until L13 to the west, there were three more lines established and surveyed (Fig. 4-9). The interval between the lines is 1 Km, and the interval between the sites is 500 m, totalling 11 sites in all. The Wenner Method and standard and auxiliary curves were used for the analysis.

The results from the vertical sounding are shown in Fig. 4-10., and based on these results, the conditions of specific electric resistivity layers at depths of 30 m and 40 m are shown in Fig. 4-11. In this same figure, the conditions for the layer at a depth of 80 m is shown in order to estimate the layer equivalent with basement rock structure.

Using the same electrical resistivity layers classification as for the Sanya River water system, the following layers were found in the Kikuletwa River Basin: A (S), C (S), D (S), E (S), F (S), G (S), and H (S).

These layers are found as Layers A (S), C (S), D (S) and E (S) in this order, from deep to shallow, and above these Layers F (S), G (S) and H (S) are distributed on a small scale. However, Layer D (S) is not found west of L13 (Fig. 4-10).

The depth of the aquifer of JC1/89 corresponds to the boundary of Layers C (S) and D (S) and to the midway depth of Layer C (S), and the lower part of the former aquifer, in JC1/89, has partial alteration or fissured metamorphic rock. In this way, the layer equivalent to basement rock in Lower Hai, as they show a tendency to be generally low in specific electric resistivity, additional data should be collected for making comparisons between the observed resistivity values and layer classification resistivity values.

5. HYDROGEOLOGICAL STRUCTURE

5.1 Lower Hai Area

The main aquifers in the Lower Hai area are the lahar and the river deposit. These layers were deposited in the palaeo-lake surrounded by basement rock composed of Masai steppe and the Kibo volcanic deposit (Fig. 5-1 and 5-2).

As the lahar intermittently flowed and was deposited in the palaeo-lake, alternating beds of lahar and river deposit were formed in the Sanya plain. The groundwater is recharged in the mountain area and flows through the lahar along with the palaeo-geomorphic surface.

The groundwater, then, flows into the river deposit under the Sanya plain.

The direction and amount of the groundwater flow seem to be affected by palaeo-geomorphic surface originated in the basement structure (Fig.5-2).

5.2 Lower Rombo Area

In the Lower Rombo, aquifer is expected in the volcanic rocks from Mt. Mawenzi and in the alluvial deposit. Since volcanic rocks partly include porous volcanic layer, this may become aquifers in the plateau.

However, the distribution , continuity and hydrogeologic property of the volcanic rocks are not yet studied. According to the results of the drilling and pumping test, exploitable groundwater was not found in the alluvial deposit during the dry season.

6. TEST DRILLING AND PUMPING TEST

6.1 Test Drilling

After the geological survey and electric prospecting were carried out in Phase-1, points C21 and C3 of the electrical prospecting were chosen as the boring points in Lower Hai area and points F3 and A7 were chosen in Lower Rombo area. The diameter of the drilled holes was fixed at 270 mm and that of the completed screen holes was fixed at 150 mm.

6.1.1 Lower Hai area

(1) JC1/89 (KL.BH 32/89)

The inner conditions of the hole JC1/89 are described in Fig. 6-1.

1) Drilling point: Mtakuja, Elec. pros. point C21
2) Drilling depth: 45.60 m
3) Inner conditions of the hole

a) 0.00 - 17.80 m: Alluvium and outwash

This is formed from a sandy gravel bed, with basal gravel found at 16.70-17.80 m and a calcareous sand bed at 6.30-9.80 m.

From the results of the electric logging and the conditions of the lost circulation and the mud solution, the major discharge portion of the groundwater was estimated to be from gravel beds at a depth of 7.5 m, and 11.0 m, and from a basal gravel bed at 16.70-17.80 m.

b) 17.80 - 27.90 m: Weathered basement rock

This is a sandy bed associated with a soil which is reddish brown in color and highly viscous, and with gneiss gravel.

c) 27.90 - 45.60 m: Basement rock

This zone is gneiss associated with richly fissured parts or altered portions in 35.30-43.10 m.

During drilling, discharge of groundwater was found at each point exceeding 35.3 m in depth, and when the drilling reached 44 m in depth, the level of mud solution dropped to 6-10 m below the surface of the earth.

4) Screens

Considering the results from the electric logging in the hole, the inner geology and the conditions during drilling, the decision was made to place the screens were at 7.10-18.10 m and at 32.50-43.50 m.

As for the electric logging, the AM intervals were established at 0.25 m and 1.00 m for resistivity. In addition to his, the self-potential method was also employed.

5) Groundwater conditions

The groundwater conditions for this hole are shown in the data on existing boreholes in Lower Hai, in Table 3-2. Particulars on the pumping tests are stated in the respective section related to pumping tests.

(2) JC2/89 (KL. BH 33/89)

The inner conditions of the hole for JC2/89 are described below and in Fig. 6-2.

1) Drilling point: Tindigani, Elec. pros. point C3
2) Drilling depth: 93.80 m
3) *Inner conditions of the hole (Fig. 6-2)*

This is formed of alternating soft clayey sand bed and hard strata. The clayey sand beds and the hard strata are correlated to lake deposit and lahar, respectively.

The interval at 0.00 to 24.00 m is composed of only lahar, and the interval between 24.00-93.80 m consists of an alternation of lake deposit accompanied with a thin bed of lahar. The depth of this lahar varies at 48.60-51.60 m, 60.10-63.10 m, 65.10-66.10 m, and 83.10-83.60 m.

From the conditions of lost circulation during the drilling, a major aquifer was estimated at around 38.8 m, although signs of recharging water were recorded in various places during drilling time.

4) Screens

Considering the results from the electric logging, the geology of the hole and the conditions during drilling, the decision was made to place the screens at depths of 19.00-24.50 m, 35.50-52.00 m and 61.50-67.00 m.

As for the electric logging, only the resistivity was recorded at 5.00-83.00 m. The AM interval at this time was 0.25 m.

5) Groundwater conditions

The groundwater conditions for this hole are shown in the data on the existing boreholes in Lower Hai, in Table 3-2. The particulars on pumping tests are stated in the respective section on pumping tests.

6.1.2 Lower Rombo area

(1) JC3/89 (KL. BH undecided)

The inner conditions of the hole JC3/89 are described below and in Table 3-5.

1) Drilling point: Kiraeni, Elec. pros. point F3
2) Drilling depth: 21.25 m
3) Inner conditions of the hole (Fig. 6-3)

At 0.00-3.50 m is unconsolidated, brownish silt. At 3.50-14.40 m is found unconsolidated brownish silt which includes hard gravel. In particular, at 3.50-4.40 m, there is big gravel, at 10.40-11.9 m, there is a gravel layer, and at 13.90-14.4 m, there is basal conglomerate.

4) Screens

Considering the results from the electric logging in the hole, the inner geology and the conditions during drilling, the decision was made to place screens at 9.80-15.30 m.

As for the electric logging, the AM intervals were established at 0.25 m and 1.00 m for the resistivity. Additionally, the self-potential method was also employed.

5) Groundwater conditions

After the screen was set in the well, development of well was carried out using 50 m^3 of clean water. Afterwards, the water level gradually dropped and subsequent to removing the submergible pump, the bottom of the well was reached(Fig.6-3). Consequently, no pumping tests could be carried out in this well.

(2) JC4/89 (KL. BH undecided)

The inner conditions of the hole JC4/89 are described below and in Table 3-5.

1) Drilling point: Masekeni, Elec. pros. point A7
2) Drilling depth: 55.25 m
3) Inner conditions of the hole (Fig. 6-4)

At 0.00-17.70 m, there is unconsolidated, reddish brown silt which includes sand.

At 17.70-40.30 m is found the same type of layer which includes some portions of hard gravel. In particular, there is large-sized gravel at 17.70-22.20 m, there is gravel at 28.75-34.45 m and there are boulders of 0.5-1.2 m in diameter.

4) Screens

Considering the results from the electric logging in the hole, the inner geology and the conditions during drilling, the decision was made to place the screens at 41.00-52.00 m.

As for the electric logging, the AM intervals were established at 0.25 m and 1.00 m, for resistivity. The self-potential method was also employed.

5) Groundwater conditions

During the drilling of the well, lost circulation occurred when 38.25 m was reached. This was followed by continued lost circulation. At the time of completion of the drilling, the mud solution level was confirmed at 42.98 m. However, just seconds after the start of the pumping, a weak airlift led to drawdown. Because of this, no pumping test was carried out at this well.

6.2 Pumping Tests

For JC1/89 and JC2/89 wells which are expected to get groundwater, step-drawdown tests and constant pumping tests were carried out by airlift method.

As for the airlift pipe, a tripipe formula was chosen, including the casing, because air causes waves to appear on the surface of the water. Further, the water level was measured during pumping in the discharge pipe and the casing.

The interval between the above-mentioned casing pipe and discharge pipe is small and, as a commercial water level measuring device could not be used, a hand-made water level measurement device was employed. Because there was no apparatus affixed to prevent water from dropping from the upper portion, the lowering of the water level inside the well during pumping became a problem, as described below.

As for the discharge volume, the time necessary to fill a 200 liter drum can was measured and the conversion calculation to discharge was performed using that value. As the pumping was done by the airlift method, there was an abundance of air bubbles in the water. Consequently, the discharge volume should be more than the exact volume.

6.2.1 JC1/89 (KL. BH 32/89)

(1) Drilling depth	:	45.6 m
(2) Static water level on the testing day	:	5.0 m
(3) Screen depth	:	7.1-18.1 m 32.5-43.5 m

(4) Step-drawdown test

The pumping, within the limitations of the airlift capabilities used at the time of the testing, was converted into three steps (Fig. 6-5).

The yields for these tests were 3.4 lit/sec (0.20 m^3/min), 4.4 lit/sec (0.26 m^3/min), and 5.7 lit/sec (0.34 m^3/min).

In Fig.6-5, the line linking the points is of a 45° slope and straight. Average specific capacity is calculated by pumping volume and drawdown as 1.06 lit/sec/m (31 m^3/day/m).

(3) Constant pumping test

During the testing, the breakdown in the compressor was repaired and the pumping capacity was brought up to 8.9 lit/sec (0.53 m^3/min) as shown in Fig. 6-6.

In the constant pumping testing, this capacity was kept up for a 330 min period (5 hrs 30 mins, Fig. 6-6).

In Fig.6-6, when the water level during pumping fell below the first aquifer level, an unreasonably small drawdown occurred. This is due to the structure of the above-mentioned water level measuring equipment. In other words, there is no apparatus affixed for the prevention of water dropping from the upper portion. Consequently, when the water level goes below the level of the first aquifer during testing, water drops from the upper portion cause short-circuit of the equipment. Because of this, before the sensor on the equipment touches the surface of water, it is perceived as if it had just touched water.

From the above, the pattern on the same map following the first 60 minutes of the pumping shows that at around 8 m in drawdown (water level is 13.7 m in elevation), there is an aquifer containing a relatively good amount of groundwater.

(4) Transmissivity (T) and Strativity (S) Trial Calculation

The trial calculation shown below was done using a simplified formula derived from Jacob's nonequilibrium formula.

$$T = 2.3Q/4\pi\Delta s \qquad (6.1)$$
$$S = 2.25Tt_0/r_0^2 \qquad (6.2)^{*1}$$

Where,
- Q : pumping capacity (m^3/min)
- s : difference of s in the logarithm cycle in Fig. 6-6
- t_0 : value of t at s=0 in Fig.6-6
- r_0 : the distance between discharge well and a certain point (here it is the radius of the casing.)

Thus,

$s = 3.205$
$t_0 = 7.749 \times 10^{-3}$ min
$r_0 = 0.150/2 = 0.075$ m

By this,

$T = 0.0305$ m^2/min (43.9 m^2/day)
$S = 0.0945$

The values for T and S are substituted in the following formula and a basic formula is found.

$$s = \frac{2.3Q}{4T} \log \frac{2.2Tt}{r^2S} \qquad (6.3)$$
$$s = 6.00Q\ (\log t - 2 \log r - 0.139) \qquad (6.4)$$

Using equation 6.4, the pumping capacity, drawdown, pumping time and distance are estimated.

In Fig.6-7, the relationship of "time (t) and drawdown (s)" for JC1/89, during constant pumping is illustrated by curves when the yield is at 5.0 lit/sec (0.3 m^3/min), 8.9 lit/sec (0.5 m^3/min), 10 lit/sec

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*1 Strativity is the calculation derived from a testing for both the pumping well and the observation well. In the drawdown testing for individual wells, usually S is not estimated. However, trial calculations are sometimes performed, as shown in this report.

(0.6 m^3/min) and 15 lit/sec (0.9 m^3/min). In Fig.6-8, the relationship of the "distance from the discharge well (r) and drawdown (s) at that point", during constant pumping at each fixed yield is shown. In these figures, r, when the drawdown is at 0 m, is the so-called "influential radius".

6.2.2 JC2/89 (KL. BH 33/89)

(1)	Drilling depth	:	93.80 m
(2)	Static water level on testing day	:	2.5 m
(3)	Screen depth	:	19.0-24.5 m
			35.5-52.0 m
			61.5-67.0 m

(4) Step-drawdown test

At JC2/89, the yield was converted into five steps (Fig. 6-9), from 5.9 lit/sec (0.3 m^3/min) to 22.2 lit/sec (1.3 m^3/min).

The curve of the drawdown, when the yield is at 5.9-14.0 lit/sec (0.3-0.84 m^3/min), shows about a 45 degree angle between the curve and the axis of the abscissa. However, when the yield exceeds this amount, the curve bends in an unusual direction and changes into a curve which is gentler sloping than a 45° curve.

This shows that when the water level drops (the water pressure decreases), discharge from the lower aquifer increases.

Average specific capacity is calculated by the relationship between pumping volume and drawdown as 9.3 lit/sec/m (803 m^3/day/m).

(5) Constant pumping test

At the highest yield by the airlift, 22.2 lit/sec (1.3 m^3/min), continuous pumping was carried out for 300 mins (5 hrs).

This hole differs from JC1/89 in that the water level does not decrease as far as the level of the first aquifer. Consequently, as there were no water drops falling into the casing from the screen, the water level measurement was carried out smoothly (Fig. 6-10).

(6) Transmissivity (T) and Strativity (S)

Just as for JC1/89, the value of

Q = 1.332 m^3/min
s = 0.350
t = 3.1×10^{-4} min
r = 0.075 m

was substituted in the Jacob simplified formula, and

$T = 0.6969\ m^2/min$
$S = 0.1240$

was found, and the following basic formula was established.

$$s = 0.2628Q\ (\log t - 2 \log r + 1.257) \qquad (6.5)$$

Using this JC2.1 formula, the consumable discharge volume of groundwater from JC2/89 is estimated.

In Fig.6-11, the relationship of "time (t) and drawdown (s)" of JC2/89, during constant pumping, is illustrated by curves when the yield is at 22.2 lit/sec (1.3 m^3/min), 40 lit/sec (2.4 m^3/min), 60 lit/sec (3.6 m^3/min), 80 lit/sec (4.8 m^3/min) and 100 lit/sec (6.0 m^3/min). In Fig. 6-12, the relationship between "distance from the discharge well (r) and the drawdown (s) at that point", during constant pumping under each of the fixed yield conditions is shown.

In these figures, when the drawdown is at 0 m, "r" is the so-called "influential radius".

7. GROUNDWATER DEVELOPMENT

Based on the results of hydrogeological study which included drilling and pumping tests, it is confirmed that groundwater development is possible in the Lower Hai area. This chapter outlines the groundwater development programme in the Hai area.

7.1 Estimated Well Discharge from Pumping Test

7.1.1 JC 1/89

The aquifer at this point is composed of alluvial gravel layer, and weathered and fractured portions of gneiss. According to the pumping test results, specific capacity is 91 m^3/day/m, transmissivity is 43.9 m^2/day, storage coefficient is 0.0945. Therefore, when the radius of well is 0.075 m, pumping capacity is theoretically determined from Equation (6.4) as follows.

$$Q = S / 6.0 \times (\log t - 2 \log 0.075 - 0.139) \qquad (7.1)$$

Permissible drawdown(s) and Pumping time(t) will be applied to estimate well discharge (Q).

Pumping time is assumed to be 10 days. The dynamic water level should be maintained at less than 17.8 m, higher than the bottom of the alluvial gravel layer. Static water level is 5 m. Therefore, permissible drawdown will be 17.8 - 5.0 = 12.8 m.

The above assumptions yield the well discharge as follows:

$$Q = 12.8/6.0 \times (\log 144{,}000 - 2 \log 0.075 - 0.139)$$
$$= 0.3 \text{ m}^3/\text{min}$$
$$= 5 \text{ lit/sec}$$

7.1.2 JC 2/89

The aquifer at this test drilling point is composed of lahar and lake deposit. According to pumping test results, the specific capacity is 803 m^3/day/m, the transmissivity is 1,003 m^2/day, and the storage coefficient is 0.124. Therefore, when the radius of well is 0.075 m, theoretically, the well discharge is calculated by the following formula:

$$Q = s/0.2628 \times (\log t - 2 \log 0.075 + 1.257) \qquad (7.2)$$

Here, pumping rate by air lift pump is 22.2 lit/sec with a drawdown of 2.3 m. Because the specific capacity of this well is very large, a large well discharge is expected at this point.

When pumping time is assumed as 10 days and well discharge is 30 lit/sec, 50 lit/sec and 70 lit/sec, drawdown is calculated as follows.

Pumping Rate (lit/sec)	Drawdown (m)
30	3.6
50	6.0
70	8.4

According to these results, theoretical drawdown will be only 8 m with 70 lit/sec of pumping rate and it is estimated that more than 100 lit/sec can be pumped up by submersible motor pump.

7.2 Target Area and Planned Pumping Capacity

The results of the JC2/89 test drilling and electrical prospecting indicate that the geological condition in the vicinity of the Sanya River, target area for groundwater development, is similar to that of the drilling point, as shown in Fig. 7-1.

From the pumping test results, pumping capacity per well is conservatively expected to be 30 lit/sec to 70 lit/sec and set at 50 lit/sec as an average design capacity in the Sanya river in and around JC2/89 shown in Fig.7-1 as groundwater-promising area.

7.3 Groundwater Collection Method

Generally, groundwater is collected using an infiltration gallery, a shallow well or a deep well and pumping equipment, such as a volute type pump, a submersible pump,etc. In the rare case of an infiltration gallery and shallow well being used, no pumping equipment is required. However, in Lower Hai, pumping equipment is required for groundwater development.

In the case of pumps which are installed on the ground level, such as the volute and the centrifugal types, the lowest dynamic water level is set at 7~8 m. Operation and maintenance costs are relatively low for this type of pump. However, when the water level goes down beyond this limit, pumping capacity decreases and eventually stops. The price of a submersible pump is basically higher than the other types of pumps mentioned. However, the dynamic water level limit can go beyond 7-8 m below the ground.

The same type of pump should be installed in order to ensure economical and simple operation and maintenance.

Considering these matters and the geological condition in the Lower Hai area, the submersible motor pump is recommended. Total head is 20 m. Drilling diameter of the well is 500 mm, casing diameter is 350 mm and drilling length per one tubewell is about 70 m. Profile of typical tubewells is shown in Fig. 7-3.

The yield of each well will vary with the geological condition, and the pumping capacity shall be designed after the pumping test.

7.4 Investigation Following Project Implementation

The aquifer in Lower Hai consists of altered or fissured basement rock and the alluvium which covers it (Kikuletwa zone), former river sedimented sand, former lake sedimented silt and clay, and alternation of the lake deposit and lahar which flow on and off (Sanya zone). Where this is the case, lahar forms much desired aquifer.

For groundwater development, it is necessary to understand the local distribution of hydrogeological structures in order to effectively select drilling sites.

For this reason, the Lower Hai groundwater development plan must incorporate detailed electrical prospecting and drilling investigation at a few points prior to drilling of production wells.

Additionally, it is necessary to carry out pumping tests after completion of the well drilling, in order to understand both the yield capacity and aquifer's coefficient at each well, as well as to define the objective cultivation area for each well.

7.5 Influence of Groundwater Development

In the vicinity of the project area, the influence of groundwater development on the many springs is studied from the viewpoint of water balance. Total amount of water volume to be pumped up by this project is estimated at 14.0×10^6 m^3 on the assumption that the irrigation area is 600 ha and irrigation water requirement is 1.0 lit/sec/ha during the dry season of six months and 0.5 lit/sec/ha during the rainy season of six months.

On the other hand, the water balance of the Sanya river basin (975 km^2) related to the hydrological investigation results is as follows:

Groundwater Recharge

Basin	Area (km^2)	Rainfall (mm/year)	Run off (MCM)	Evapotranspiration (mm/year)	Recharge (m^3/year)
Sanya River	975	750	17.4	400	324×10^6

Note: refer to Section 4.2 of Annex B

The ratio of the annual pumping volume for the project area to the total amount of recharge volume of the Sanya river basin is only 4.3 %. Therefore, considering that some amount of the irrigation water will return to the groundwater, little adverse effect is expected from this project.

Table 2-1 STRATIGRAPHY OF LOWER HAI AND LOWER ROMBO AREA

AGE	LOWER HAI AREA			LOWER ROMBO AREA
Quarternary	alluvium talus deposit outwash	alluvium talus deposit outwash	alluvium talus deposit outwash	current river deposit alluvium terrace deposit fan deposit debris flow deposit
	lahar 2	lahar 1	lahar 3	
		lake deposit	lake deposit	Colluvial deposit talus deposit from parasitic cone
	parasitic volcano deposit	parasitic volcano deposit	parasitic volcano deposit	parasitic volcano deposit
			KIBO VOLCANO Kibo volcanic rock	
				MAWENZI VOLCANO Mawenzi volcanic rock
?	MERU VOLCANO	SHIRA VOLCANO		
Neogene		Shira volcanic rock		
Precambrian	USAGARAN precambrian (basement rock)			

Table 3-1 CONDITIONS OF SPRINGS

Measuring Point No.	Altitude (m)	pH	EC (μmho/cm^2)	Temperature (°C)	Current Amount (m^3/sec)	Location
S-1	850	7.59	410	24.9	-	Branch of Makuna River
S-2	850	7.73	480	26.3	-	Branch of Makuna River
S-3	845	-	-	-	-	Branch of Makuna River
S-4	845	-	-	-	-	Branch of Makuna River
S-5	845	-	-	-	-	-
S-6	845	-	-	-	-	Kware River
S-7	835	-	-	-	-	Kware River
S-8	835	-	-	-	-	Branch of Kware River
S-9	835	-	-	-	-	Branch of Kikure River
S-10	835	-	-	-	-	Branch of Kikule River
S-11	840	-	-	-	-	-
S-12	840	7.23	1,573	28.9	approximately 2(t/m)	Kikuletwa River
S-13	845	-	-	-	-	Kikuletwa River
S-14	850	-	-	-	-	Bran. of Kikule River
S-15	850	7.26	1,695	28.6	-	Kikuletwa River
S-16	855	-	-	-	-	-

Table 3-2 CONDITIONS OF DUG-WELLS IN LOWER HAI

D.W.No.	A.t.	D.p.	W.l.	G.L.	W.d.	Location
	m	m	m	m	m	
Kikuletwa River						
D- 1	865	11.00	10.54	854.46	0.46	Majengo (Kikule.)
D- 2	865	11.70	11.22	853.78	0.48	Majengo (Kikule.)
D- 3	865	11.10	10.00	855.00	0.15	Majengo (Kikule.)
D- 4	865	10.08	9.96	855.04	0.12	Majengo (Kikule.)
D- 5	865	9.58	8.47	856.53	1.11	Majengo (Kikule.)
D- 6	865	7.05	7.05	857.95	0.00	R.b. of Kikule.
D- 7	875	11.77	10.83	864.17	0.94	Majengo (Kikule.)
D- 8	865	9.85	9.70	855.15	0.15	Majengo (Kikule.)
D- 9	865	9.60	9.19	855.81	0.41	Majengo (Kikule.)
D-10	865	8.40	8.38	856.62	0.02	Majengo (Kikule.)
D-11	865	7.71	7.61	857.39	0.10	Majengo (Kikule.)
D-12	860	6.70	6.68	858.32	0.02	Mutakuja(Kikule.)
D-13	860	7.34	7.04	852.96	0.30	Mutakuja(Kikule.)
Sanya Juu						
D-14	1,370	4.13	2.92	1,367.08	1.21	Kilingi Est.
D-15	1,370	5.15	3.52	1,366.48	1.63	Kilingi Est.
D-16	1,370	1.20	0.94	1,369.06	0.26	Kilingi Est.
D-17	1,370	1.40	1.19	1,368.81	0.21	Kilingi Est.
D-18	1,370	3.63	3.15	1,366.85	0.48	Kilingi Est.
D-19	1,340	4.00	1.16	1,338.84	2.84	Kilingi Est.

D.w.No. : Dug well No.
A.t. : Altitude
D.p. : Depth
W.l. : Water level
G.L. Groundwater level
W.d. :

Kikule. : Kikuletwa river
R.b. : River bed
Est. : Estate

Table 3-3 CONDITIONS OF BORE-HOLE WELLS IN LOWER HAI

B.H.No.	D.p.	S.S.	S.W.l.	Y.d.	D.d.	S.c.	Location
KL.BH-	m	m	m	m^3/h	m	$m^3/h/m$	
24/85	93.00	24.00-28.80 75.90-88.50	18.75	4.62	15.00	0.31	West of Majengo
42/82	69.00	-	-	6.66	-	-	North of Hoshi
61/82	108.00	28.50-42.90 66.90-76.50	62.40	5.00	-	-	(Kibo Poltry)
38/80	76.20	30.00-49.20 65.40-70.20	49.50	4.23	0.60	7.05	North of Hoshi
92/83	99.00	70.80-80.40 83.40-93.00	5.45	10.28	17.50	0.59	North of Hoshi
150/87	90.00	22.20-27.12 43.32-48.24 64.44-69.36	51.00	3.50	15.40	0.23	North of Hoshi
146/80		-	0.60?	-	-	-	South of Hoshi
38/81	96.00	-	8.75	28.64	28.25	1.01	South of Hoshi
75/81	91.44	-	-	16.00	3.38	4.73	Kibohehe
23/82	-	-	-	-	-	-	(Kikafu River)
a	-	-	-	useless	-	-	Kilingi Est.
10/49	99.13	-	-	-	-	-	Sanya Juu
13/49	75.64	-	-	14.11	-	-	Sanya Juu
b	-	-	-	useless	-	-	Pyrita Est.
c	-	-	-	useless	-	-	Pyrita Est.
d	-	-	-	0.30	-	-	Kifaru Est.
e	-	-	-	no pump	-	-	Sanya Plan.
38/87	62.32	-	13.25	2.00	-	-	Sanya Plan.
82/69	91.44	-	30.68	38.65	23.84	1.62	Northward of
104/70	90.00	-	48.90	8.13	-	-	K.airport (KIA)
21/68	-	-	-	-	-	-	K.airport (KIA)
19/70	156.20	-	-	95.55	-	-	K.airport (KIA)
28/70	89.80	-	27.90	50.00	-	-	K.airport (KIA)
71/71	-	-	-	-	-	-	K.airport (KIA)
78/71	107.10	-	57.60	11.50	-	-	K.airport (KIA)
100/85	48.80	-	30.50	-	-	-	K.airport (KIA)
JC1/89	45.60	7.10-18.10 32.50-43.50	4.60	+32.76	13.50	2.43	Kikuretwa R. Utakuja
JC2/89	93.8	19.00-24.50 35.00-52.00 61.50-67.00	3.41	+90.00	1.36	66176	Sanya River Tindigani

B.h.No. : Bore hole number
D.p. : Depth
S.s. : Situation of screen
S.W.l : Static watter level
Y.d. : Yield
D.d. : Draw down
S.c. : Specific capacity

Plan. : Plantation
Est. : Estate
KIA : Kirimanjalo airport
R. : River

* JC1/89 → KL.BH 32/89
* JC2/89 → KL.BH 33/89

Table 3-4 INFERRED DEPTH OF AQUIFER AND STATIC WATER LEVEL

Location		Condition of Groundwater	Location of Aquifer	Static Water Level
Moshi city	:	Un-confined	-	-
		Confined	20-50 m (EL.920-800 m) 65-95 m (EL.880-840 m)	5-20 m and 5-65 m (EL.770-950m)
Kibohehe	:	Un-confined	-	-
		Confined	91 m (EL.850 m)	-
Sanya Juu	:	Un-confined	3.5-5 m (EL.1,350-1,370 m)	3.5-5 m (EL.1,350-1,370m)
Near D19*	:	Confined	60-99 m (EL.1,160-1,300 m)	About 50 m (about 1,300 m)
KIA	:	Un-confined	-	-
		Confined	90-160 m (EL.740-790 m)	25-60 m (EL.830-890m)
Along Kikuletwa River	:	Un-confined	7-11 m (EL.850-865 m)	7-11 m (EL.830-865m)
		Confined	-	27-31 m (EL.830-845m)

Note: * D-19: Dug Well No.

Table 3-5 CONDITIONS OF BORE-HOLE WELLS IN LOWER ROMBO
in Lower Rombo

B.H.No.	D.D.	S.S.	S.W.l.	Y.d.	D.d.	S.c.	Location
KL.BH-	m	m	m	m^3/h	m	$m^3/h/m$	
5/87	182.00	-	-	-	-	-	Uhare (Tarakea)
7/65	91.44	-	68.27	5.60	1.46	3.85	Shoshoro
9/64	-	-	-	-	-	-	Shoshoro
8/64	160.01	-	131.97	6.00	2.13	4.48	Chara
JC3/89	21.25	9.80-15.30	<15.49>	-	-	-	Kiraeni
JC4/89	55.25	41.00-52.00	< - >	-	-	-	Masekeni

B.h.No. : Bore hole number
D.P. : Depth
S.s. : Situation of screen
S.W.l : Static watter level
Y.d. : Yield
D.d. : Draw down
S.c. : Specific capacity

Plan. : Plantation
Est. : Estate
KIA : Kirimanjalo airport
R. : River

* JC3/89 → KL.BH (undecided)
* JC4/89 → KL.BH (undecided)

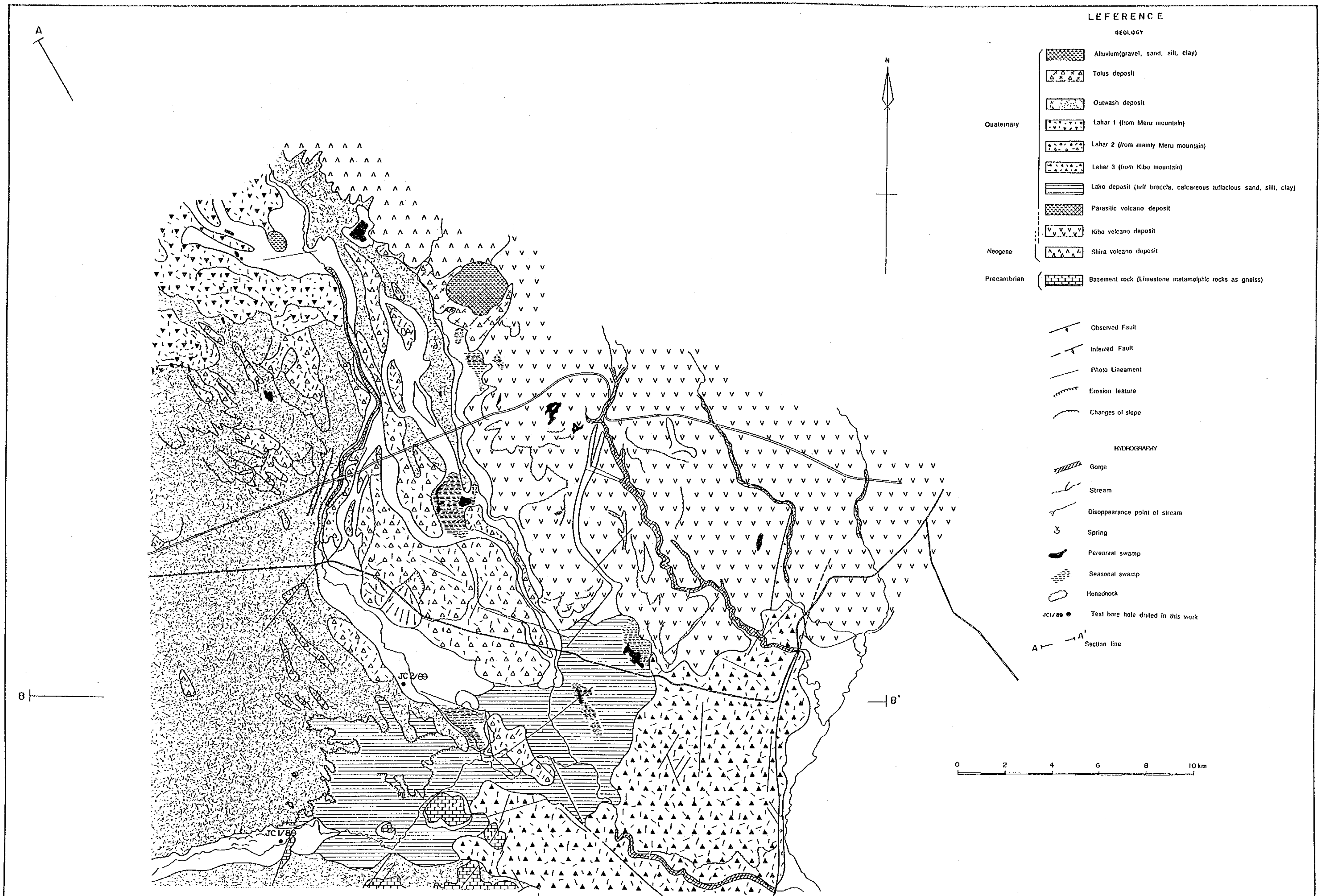


Fig. 2-1 GEOLOGICAL MAP (LOWER HAI)

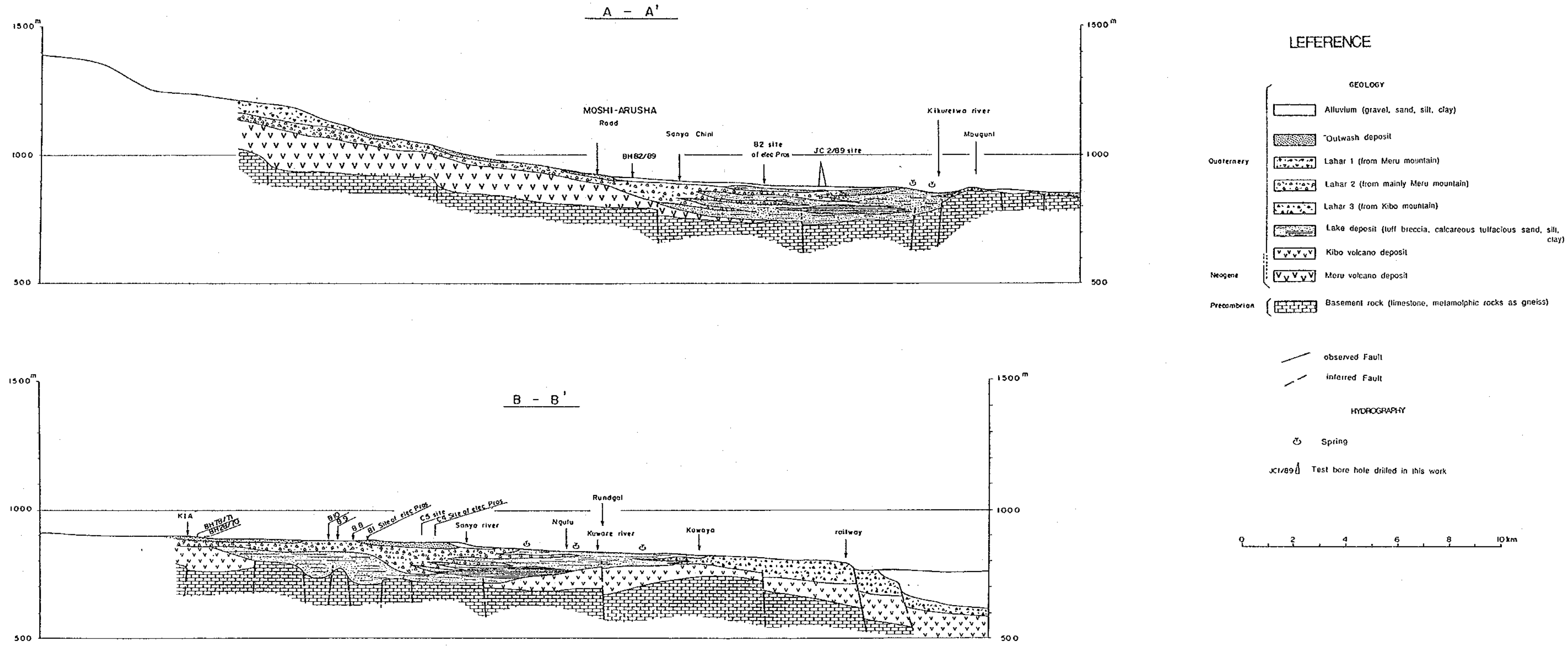


Fig. 2-2 GEOLOGICAL SECTION (LOWER HAI)

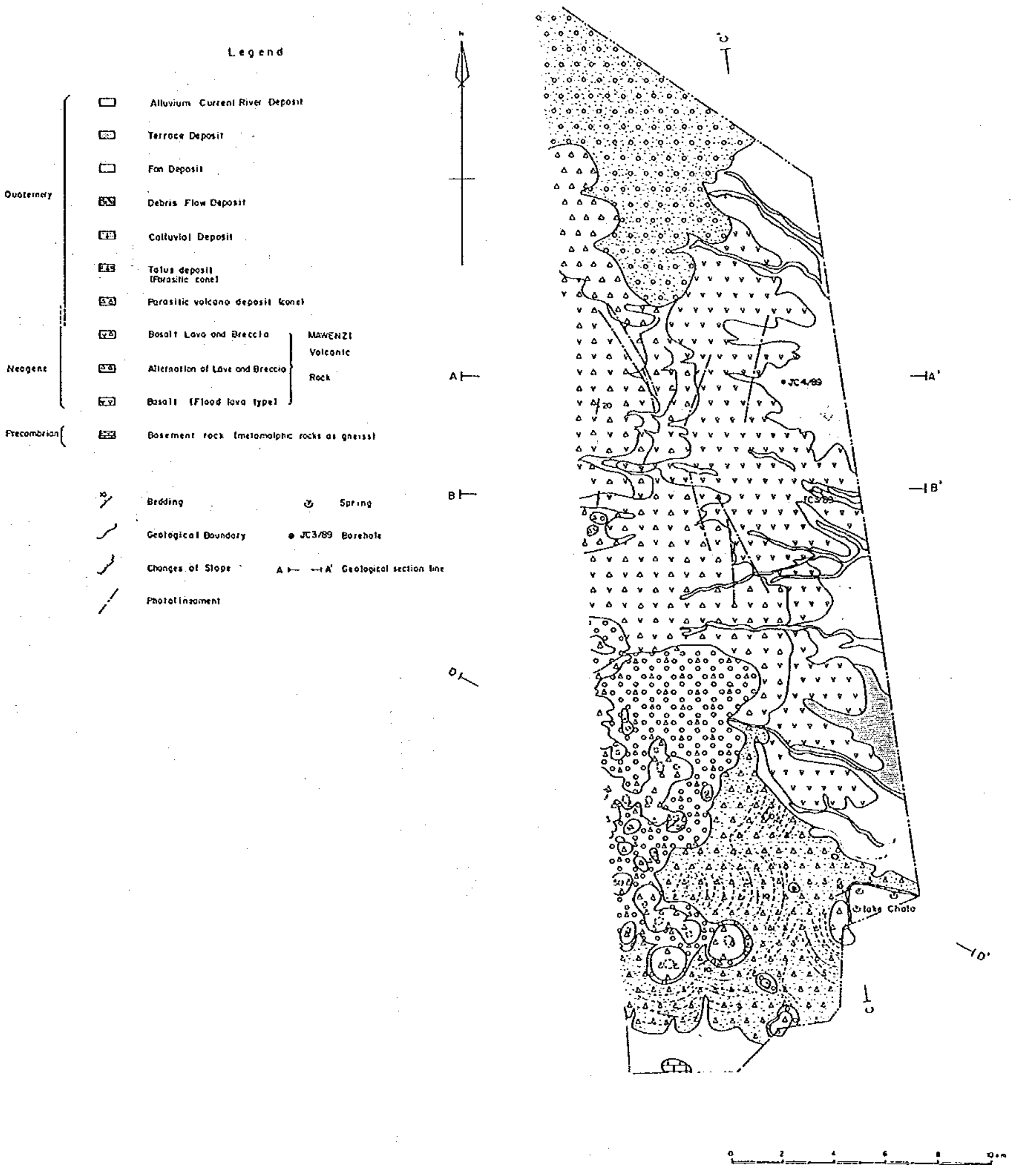


Fig. 2-3 GEOLOGICAL MAP (LOWER ROMBO)

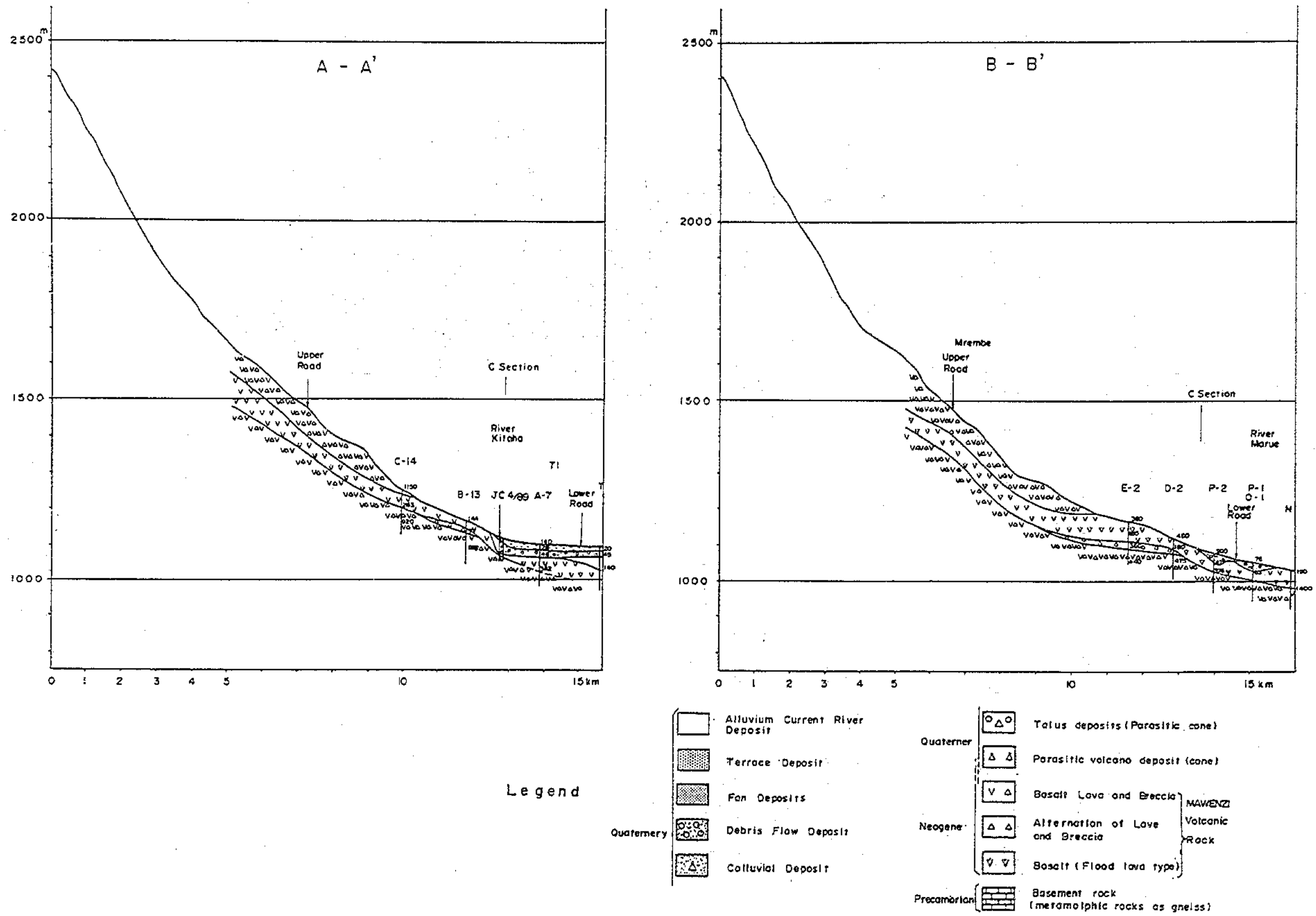


Fig. 2-4 GEOLOGICAL SECTION (LOWER ROMBO)(1/2)

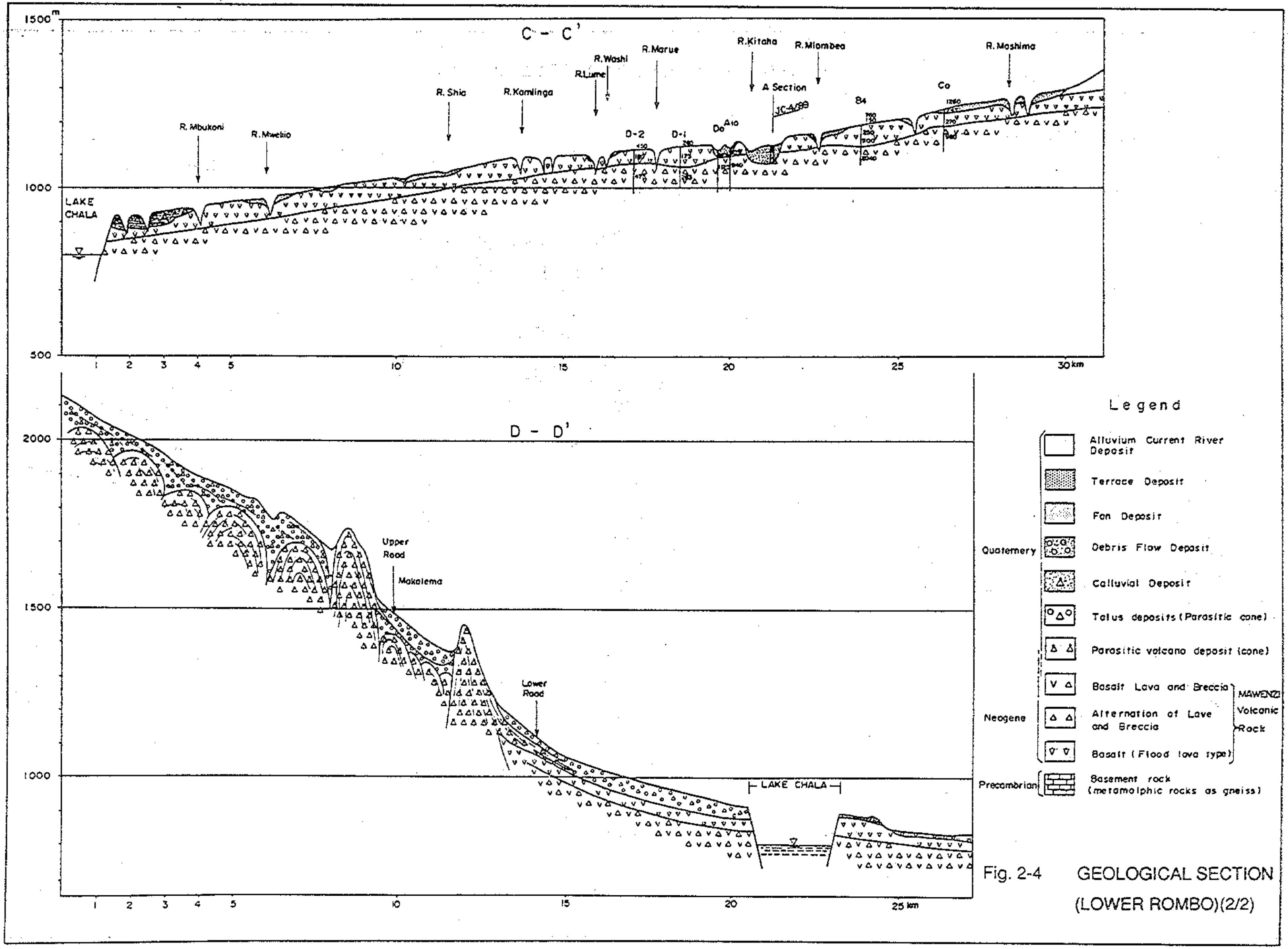


Fig. 2-4 GEOLOGICAL SECTION (LOWER ROMBO)(2/2)

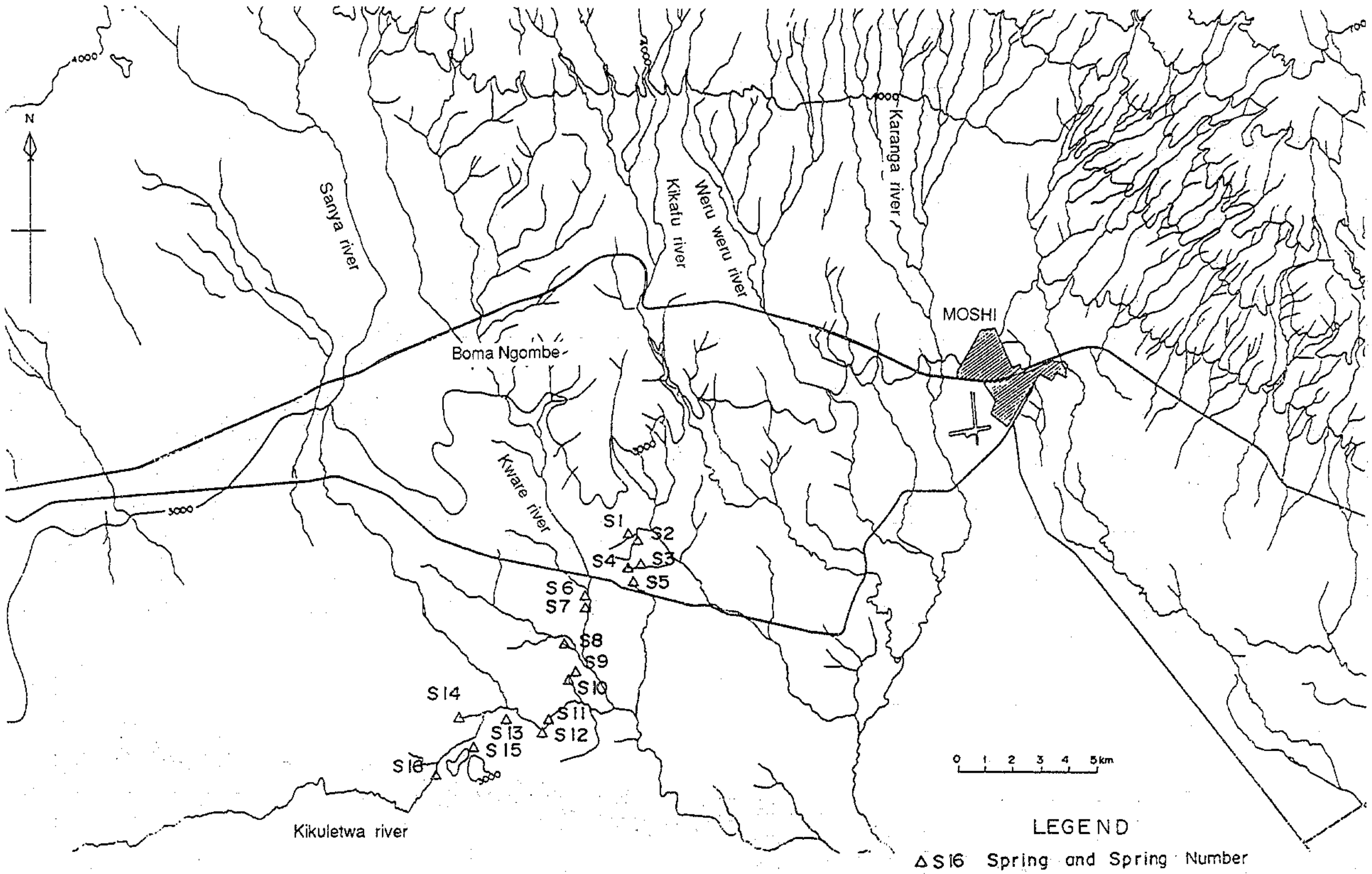


Fig. 3-1 DISTRIBUTION OF SPRINGS (LOWER HAI)

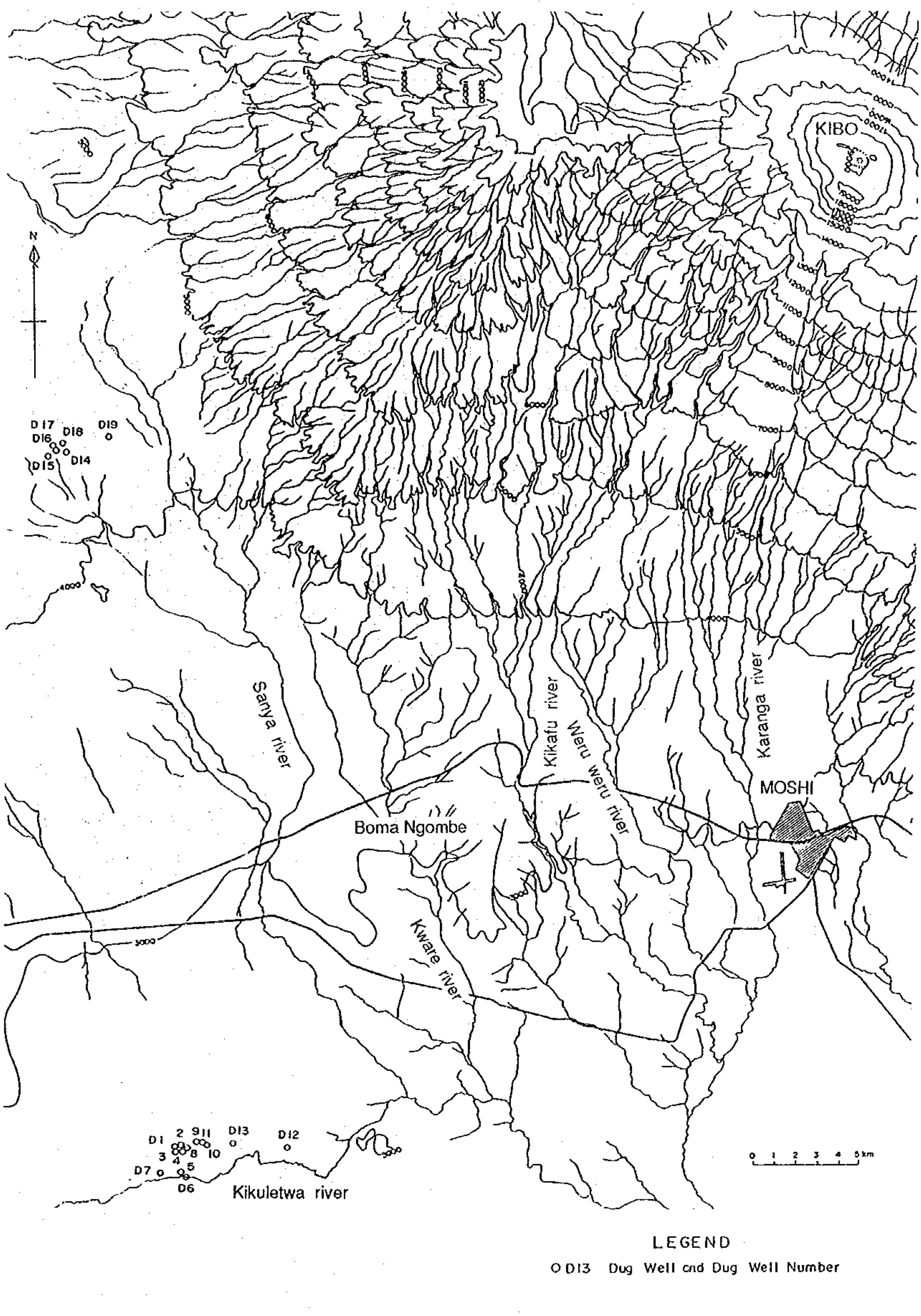
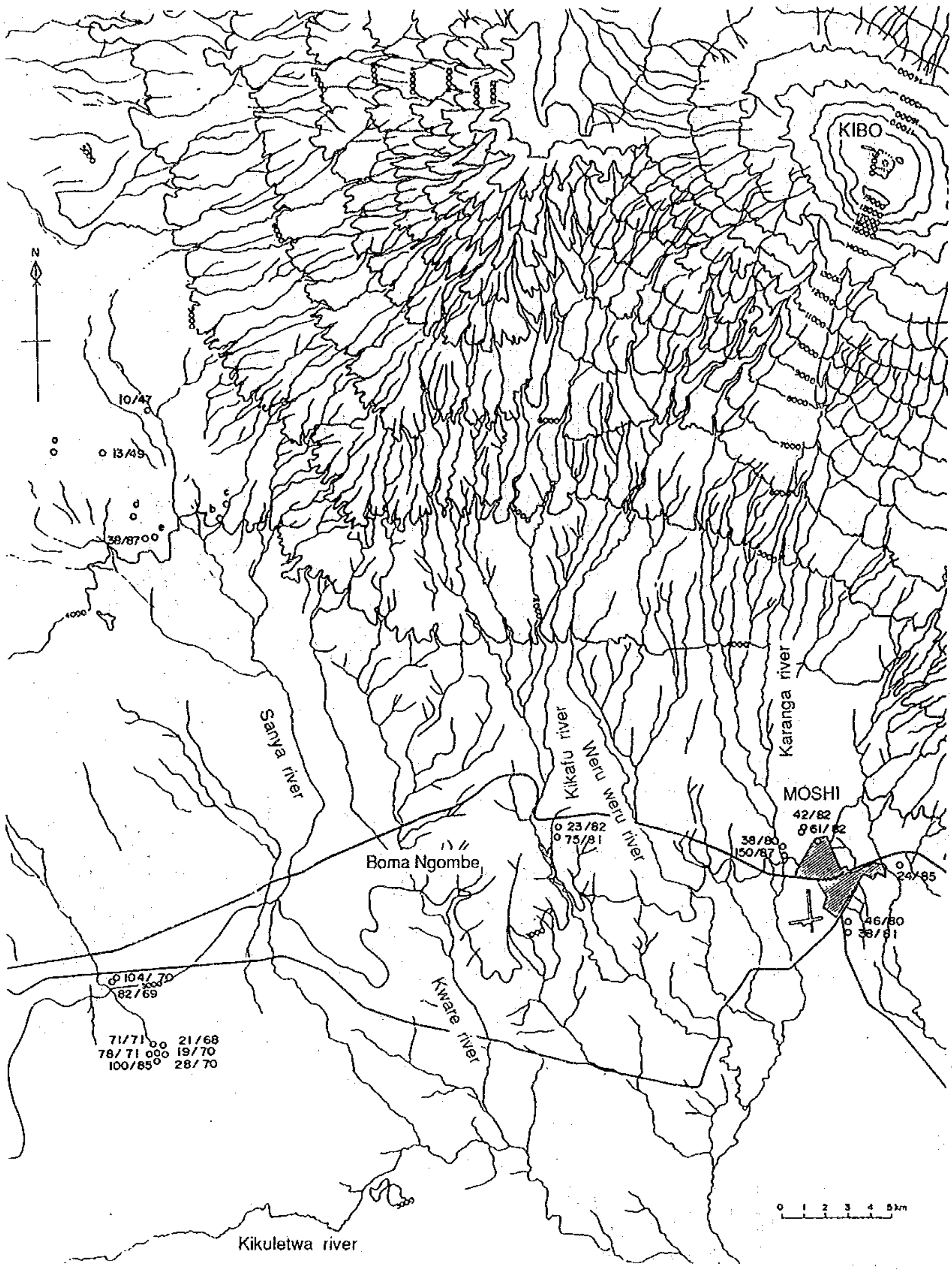


Fig. 3-2 DISTRIBUTION OF DUG-WELLS (LOWER HAI)



LEGEND
O 23/82 Bore Hole and Bore Hole Number

Fig. 3-3 DISTRIBUTION OF BORE-HOLE WELLS (LOWER HAI)

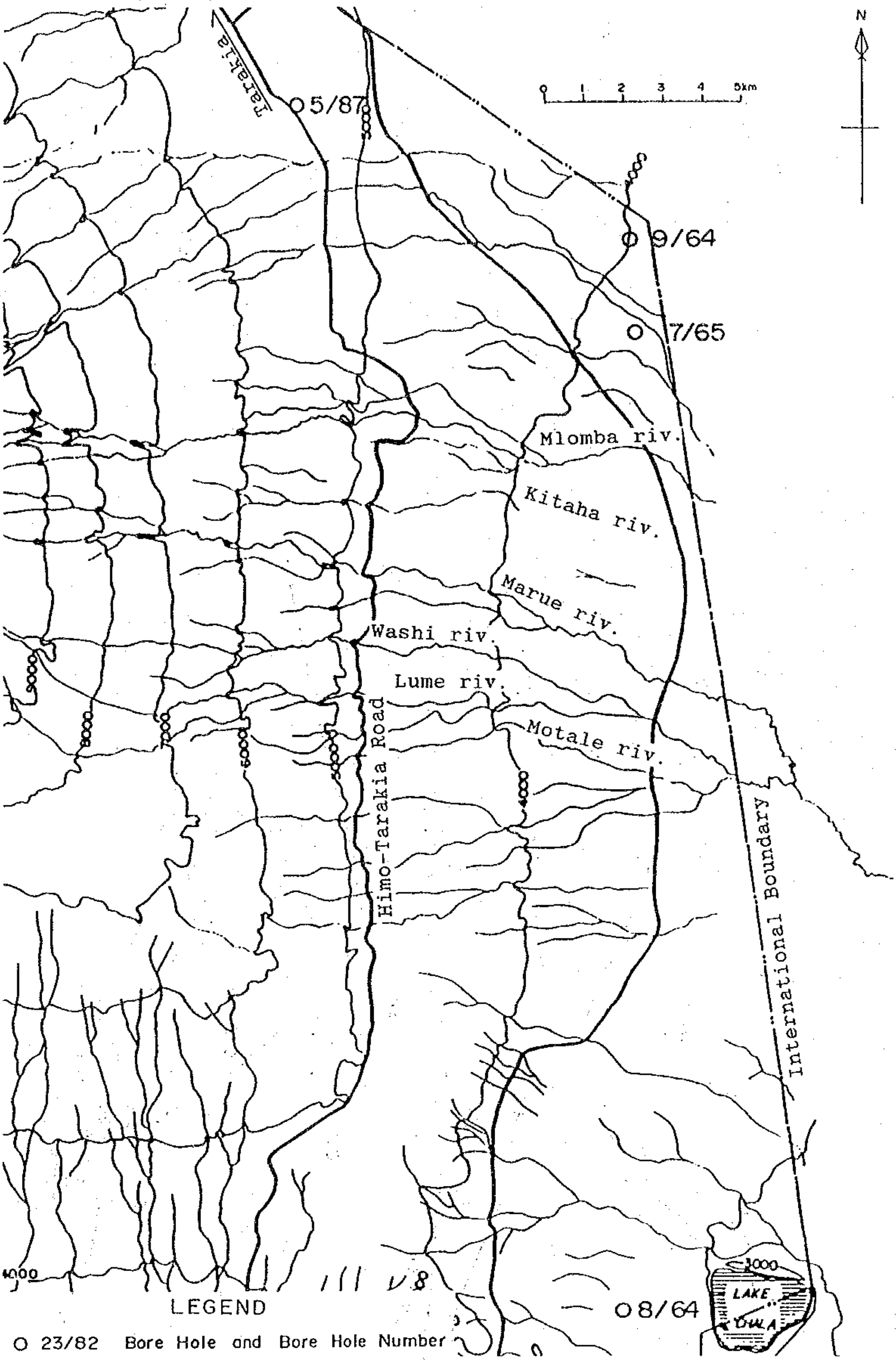


Fig. 3-4 DISTRIBUTION OF BORE-HOLE WELLS (LOWER ROMBO) AND ITS CIRCUMFERENCE

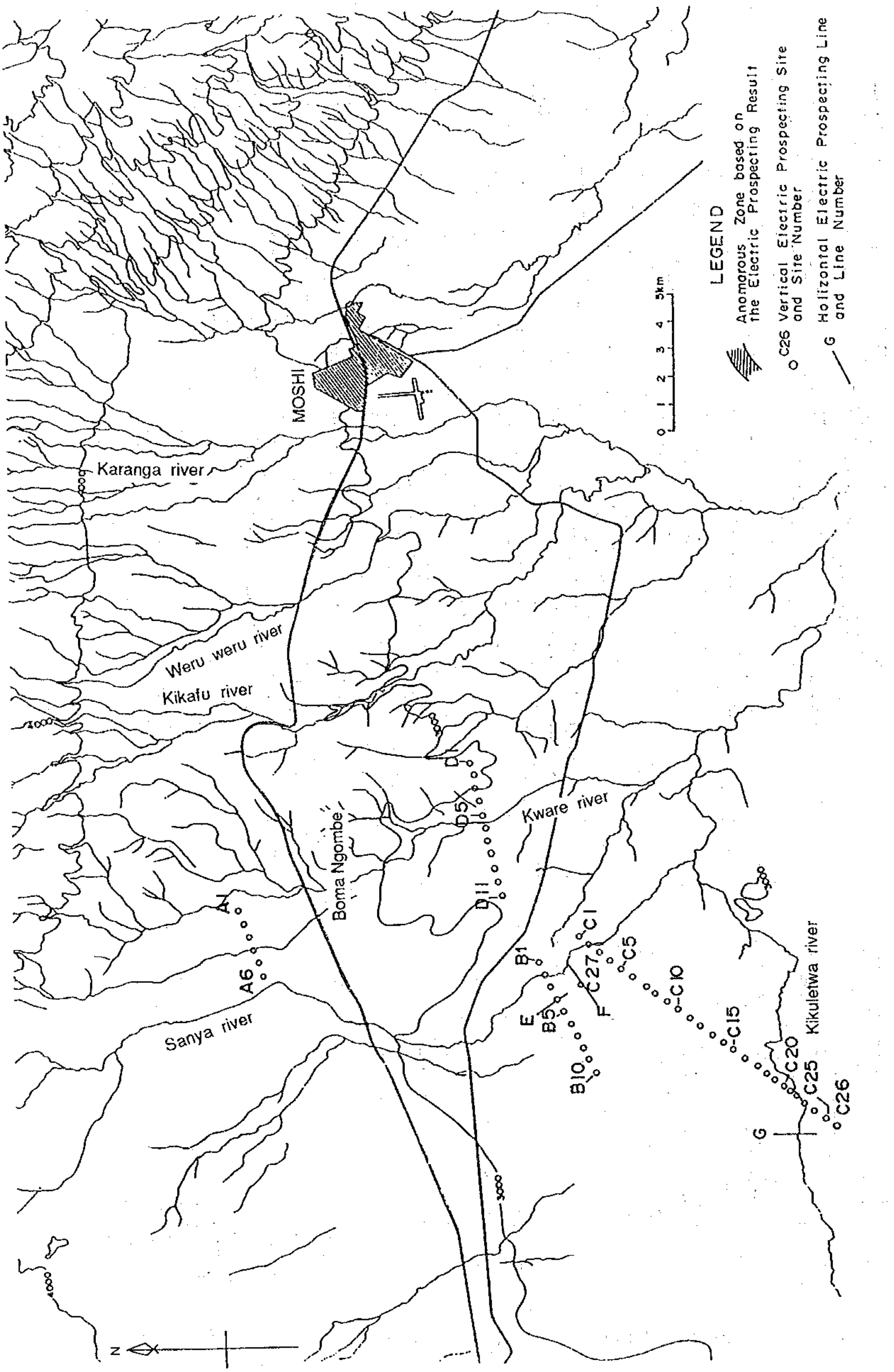
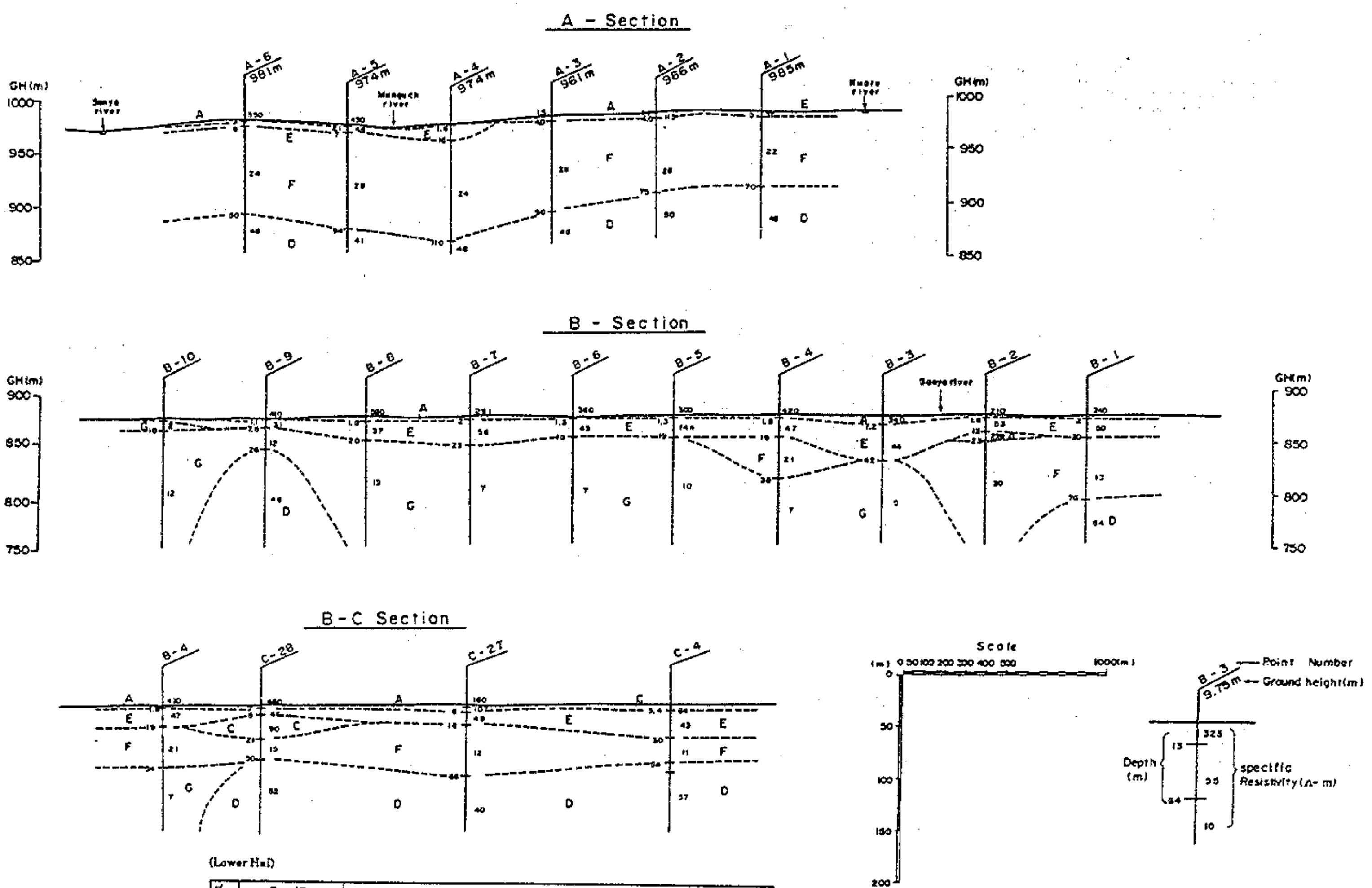


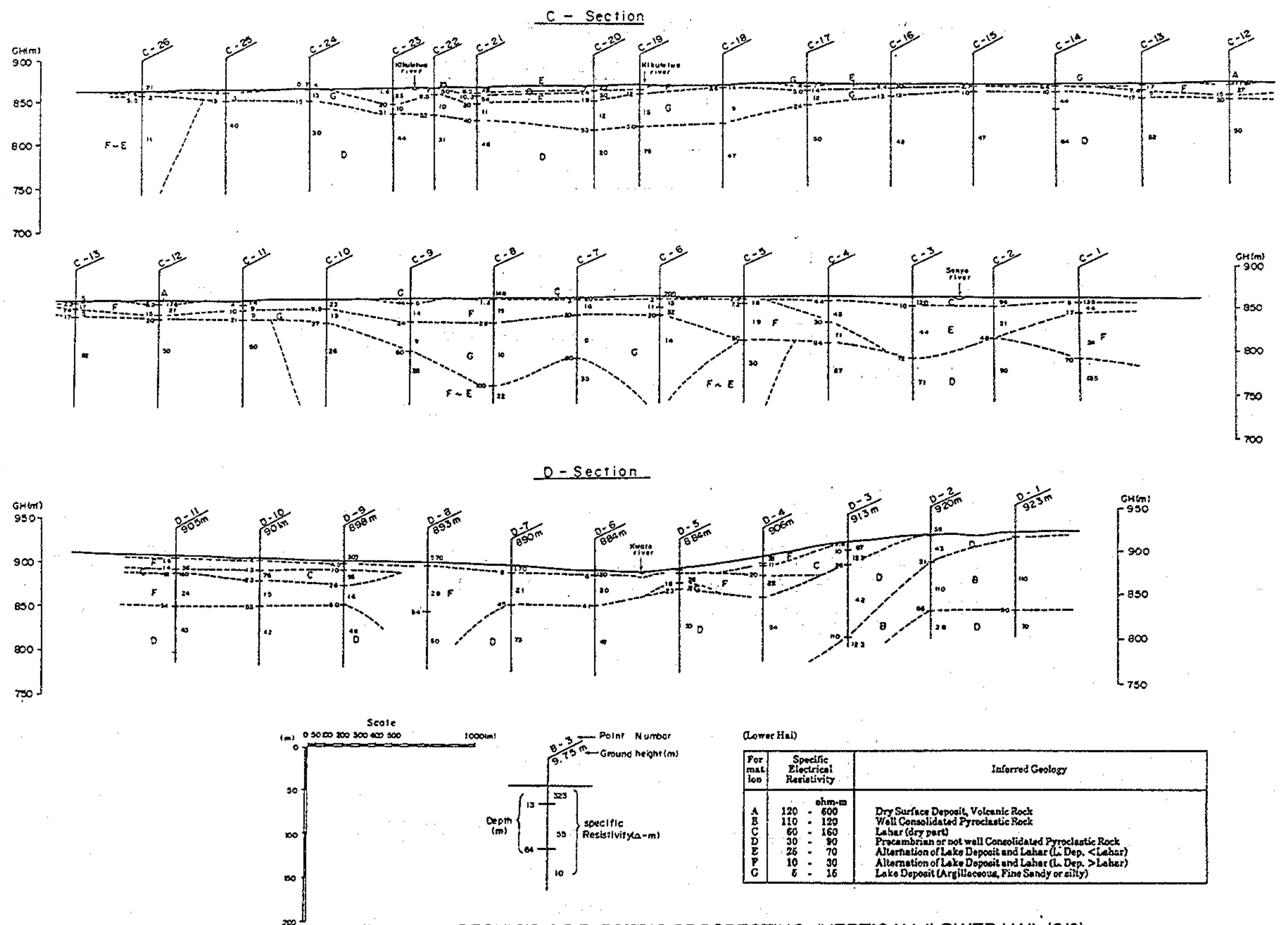
Fig. 4-1 ELECTRIC PROSPECTING SITE (LOWER HAI)



Formation	Specific Electrical Resistivity (ohm-m)	Inferred Geology
A	120 - 600	Dry Surface Deposit, Volcanic Rock
B	110 - 120	Well Consolidated Pyroclastic Rock
C	60 - 160	Lahar (dry part)
D	30 - 90	Precambrian or not well Consolidated Pyroclastic Rock
E	25 - 70	Alternation of Lake Deposit and Lahar (L. Dep. <Lahar)
F	10 - 30	Alternation of Lake Deposit and Lahar (L. Dep. >Lahar)
G	5 - 15	Lake Deposit (Argillaceous, Fine Sandy or silty)

Fig. 4-2 RESULTS OF ELECTRIC PROSPECTING (VERTICAL) (LOWER HAI) (1/2)

C - 52



(Lower Hai)

For mat ion	Specific Electrical Resistivity (ohm-m)	Inferred Geology
A	120 - 600	Dry Surface Deposit, Volcanic Rock
B	110 - 120	Well Consolidated Pyroclastic Rock
C	60 - 160	Lahar (dry part)
D	30 - 90	Precambrian or not well Consolidated Pyroclastic Rock
E	25 - 70	Alternation of Lake Deposit and Lahar (L. Dep. <Lahar)
F	10 - 30	Alternation of Lake Deposit and Lahar (L. Dep. >Lahar)
G	5 - 15	Lake Deposit (Argillaceous, Fine Sandy or silty)

Fig. 4-2 RESULTS OF ELECTRIC PROSPECTING (VERTICAL) (LOWER HAI) (2/2)

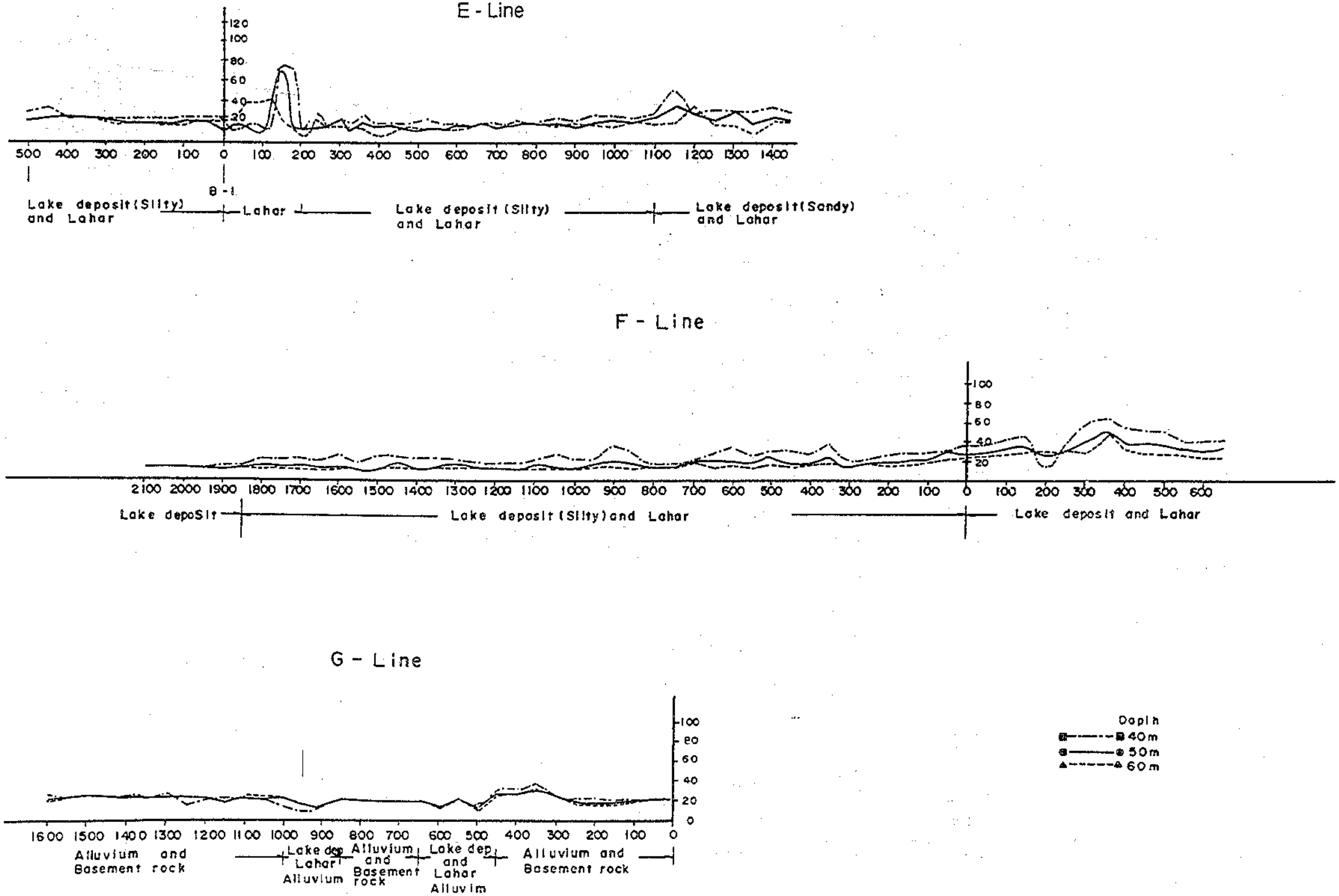


Fig. 4-3 RESULTS OF ELECTRIC PROSPECTING (HORIZONTAL) (LOWER HAI)

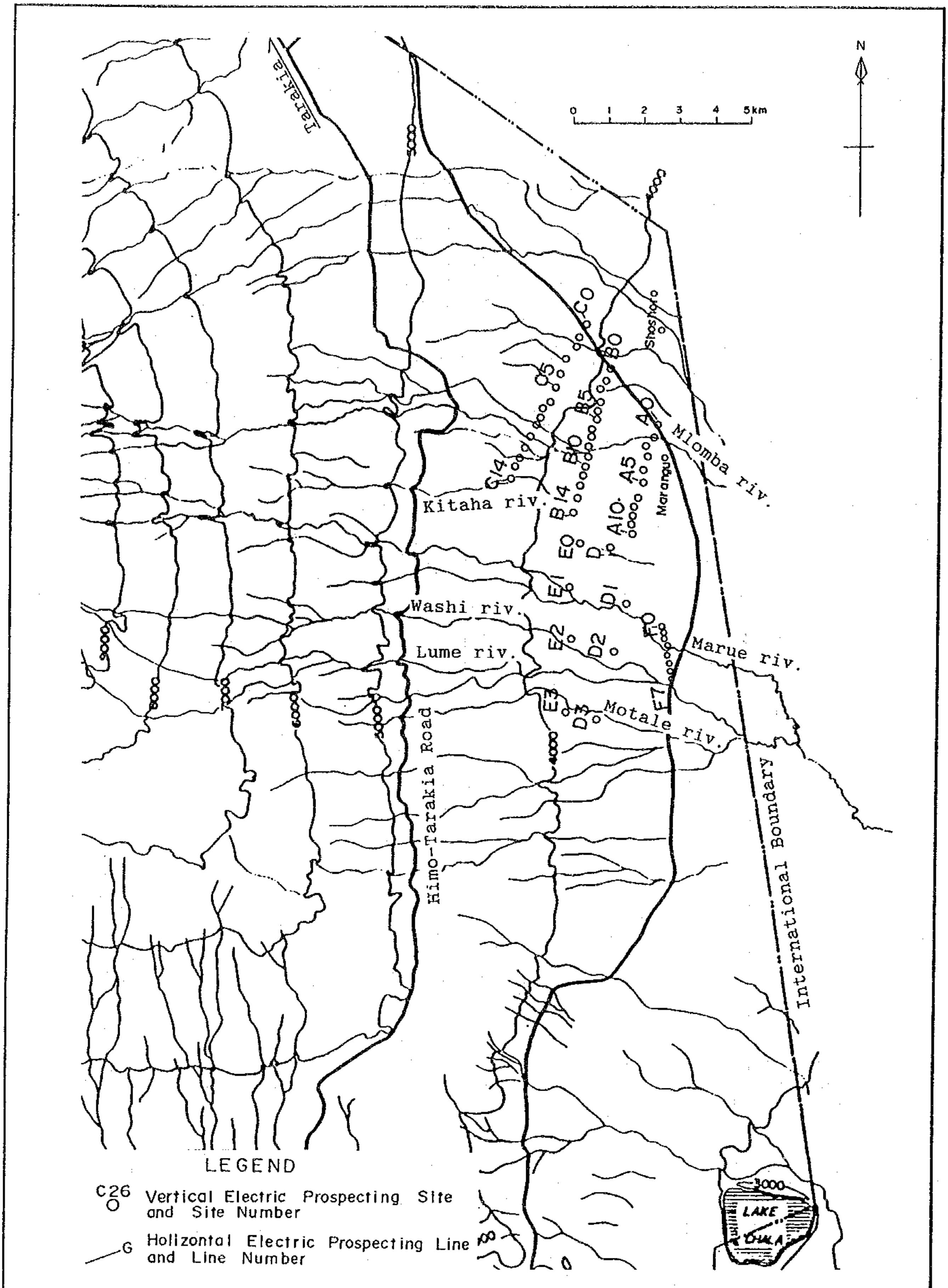
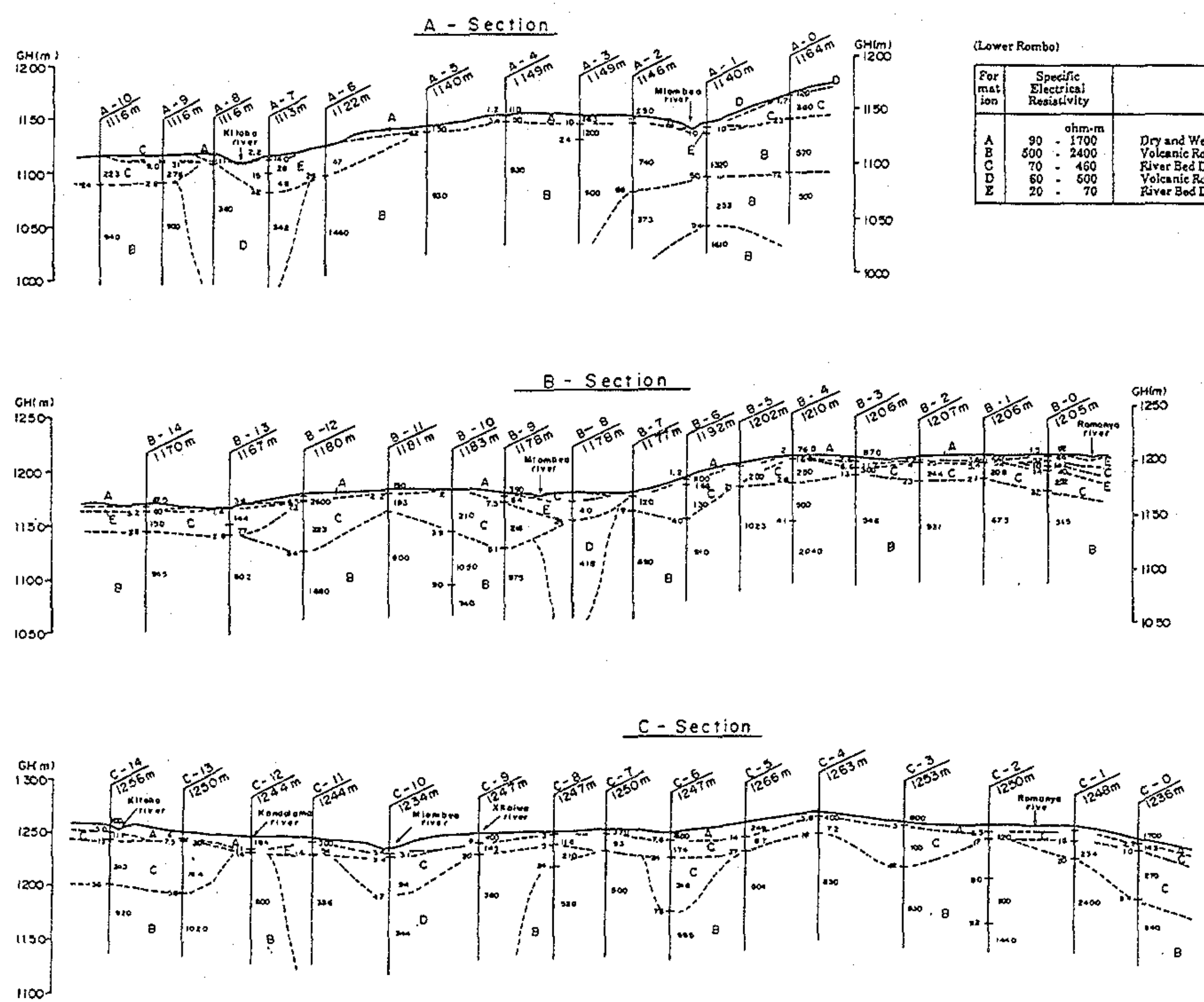


Fig. 4-4 ELECTRIC PROSPECTING SITE (LOWER ROMBO)



(Lower Rombo)

Formation	Specific Electrical Resistivity (ohm-m)	Inferred Geology
A	90 - 1700	Dry and Wet Surface Deposit
B	500 - 2400	Volcanic Rock
C	70 - 460	River Bed Deposit or Weathered Volcanic Rock
D	60 - 500	Volcanic Rock (weathered or with fissures)
E	20 - 70	River Bed Deposit (sandy, silty)

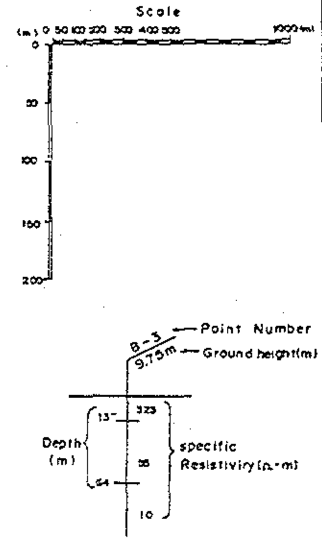
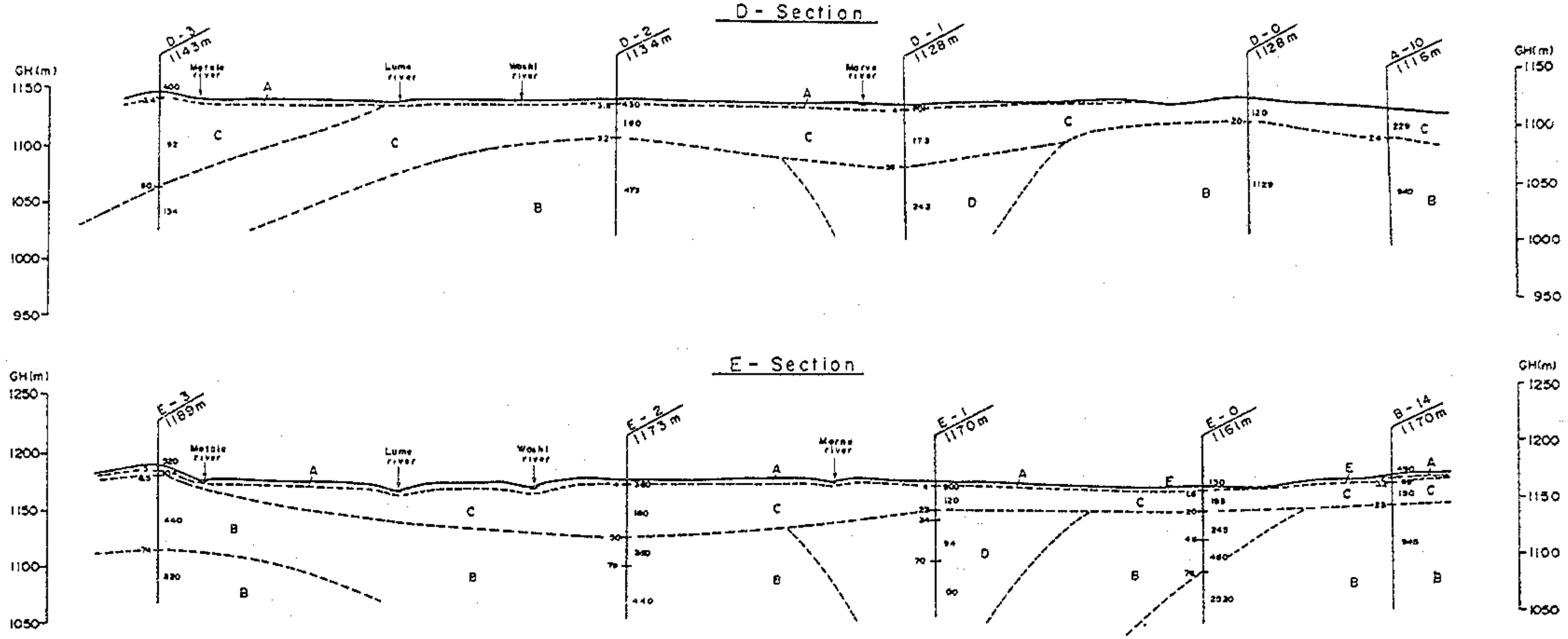
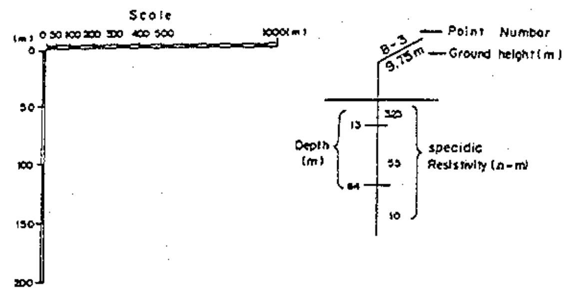


Fig. 4-5 RESULTS OF ELECTRIC PROSPECTING, (VERTICAL) (LOWER ROMBO) (1/3)





(Lower Rombo)

For mat ion	Specific Electrical Resistivity	Inferred Geology
	ohm-m	
A	90 - 1700	Dry and Wet Surface Deposit
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C	70 - 460	River Bed Deposit or Weathered Volcanic Rock
D	60 - 600	Volcanic Rock (weathered or with fissures)
E	20 - 70	River Bed Deposit (sandy, silty)

Fig. 4-5 RESULTS OF ELECTRIC PROSPECTING, (VERTICAL) (LOWER ROMBO) (2/3)

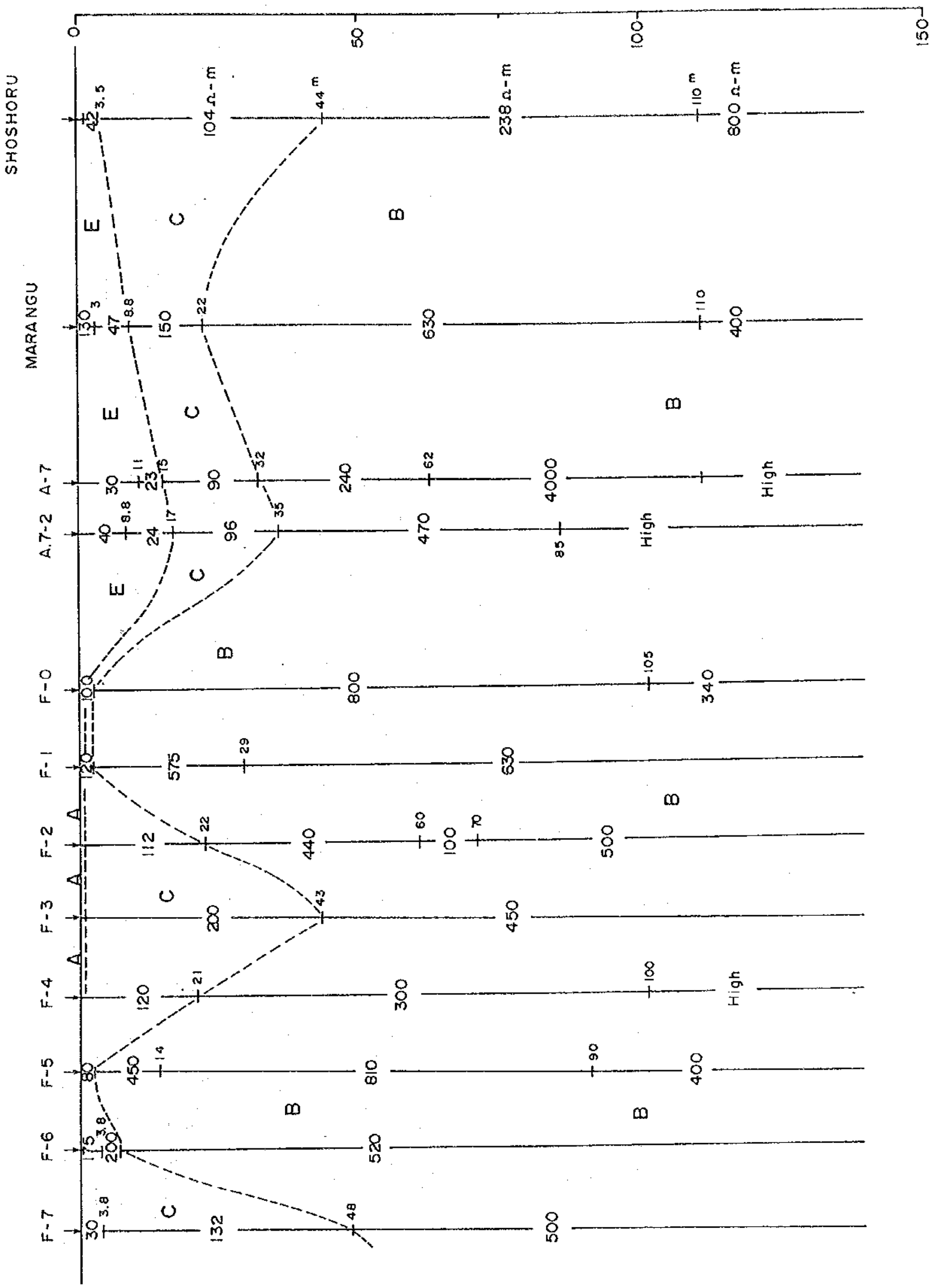

Fig. 4-5 RESULTS OF ELECTRIC PROSPECTING, (VERTICAL)(LOWER ROMBO) (3/3)

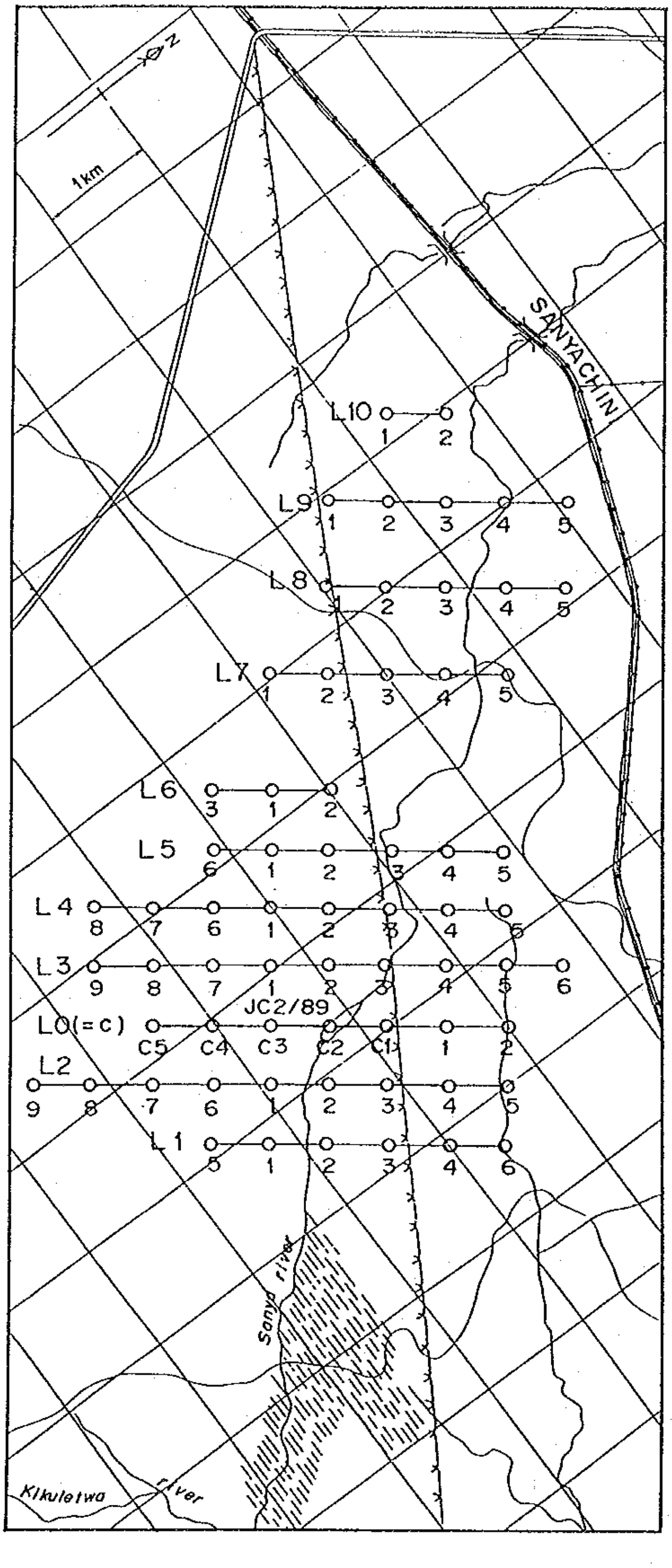

Fig. 4-6 SITES OF ELECTRIC PROSPECTING IN SANYA AREA

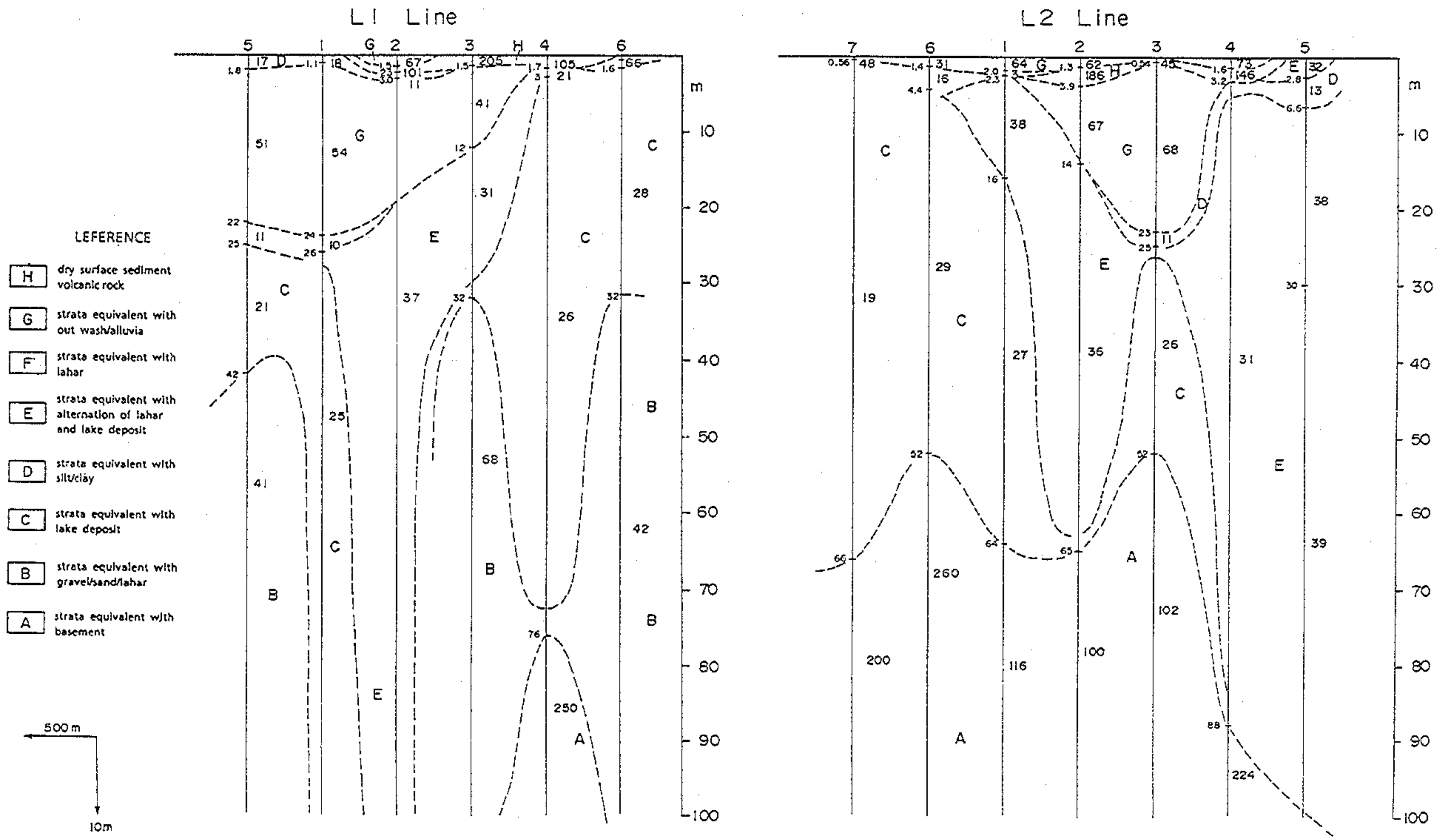

Fig. 4-7 ELECTRIC PROSPECTING SECTION IN SANYA RIVER AREA (1/6)

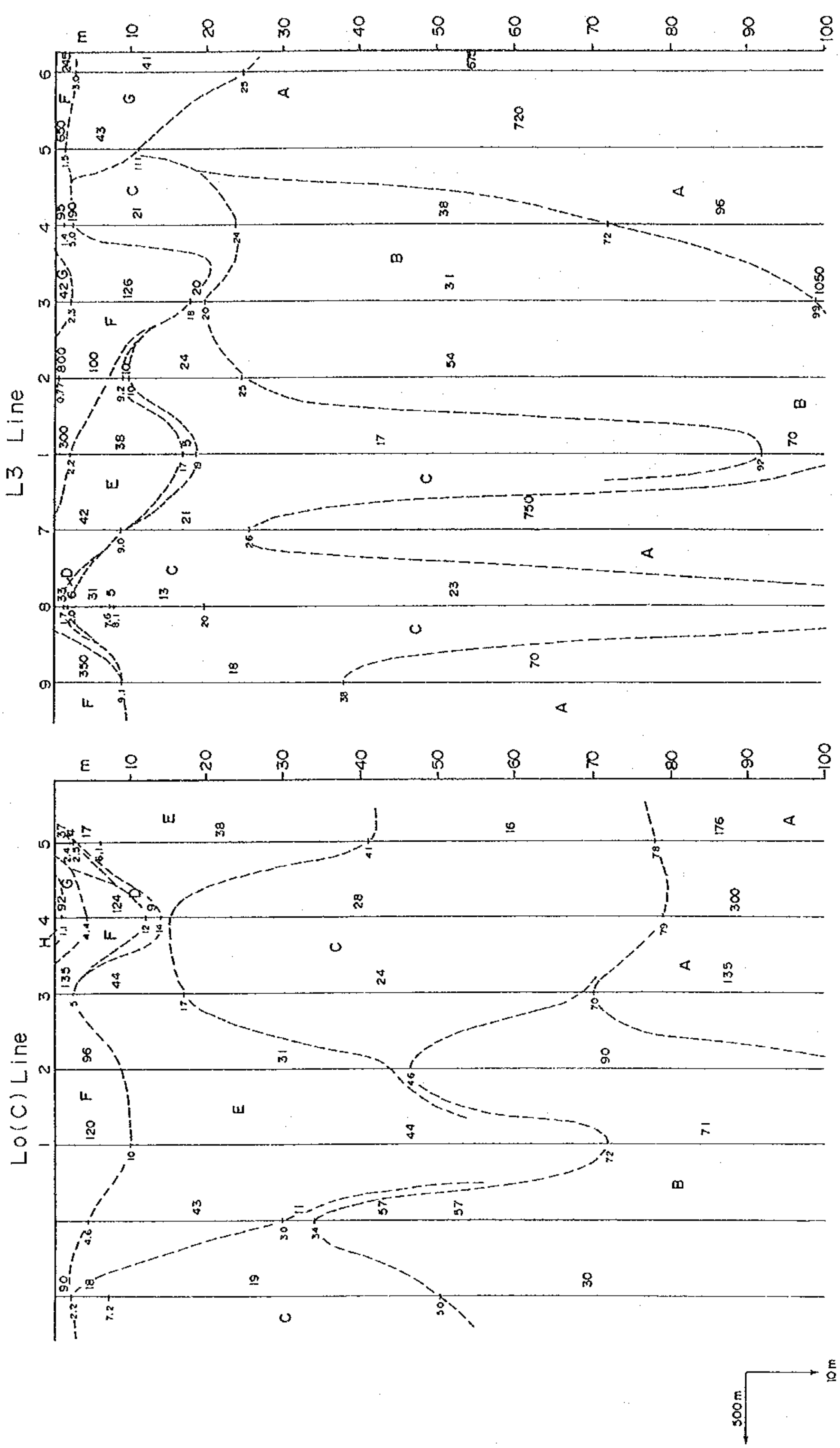

Fig. 4-7 ELECTRIC PROSPECTING SECTION IN SANYA RIVER AREA (2/6)

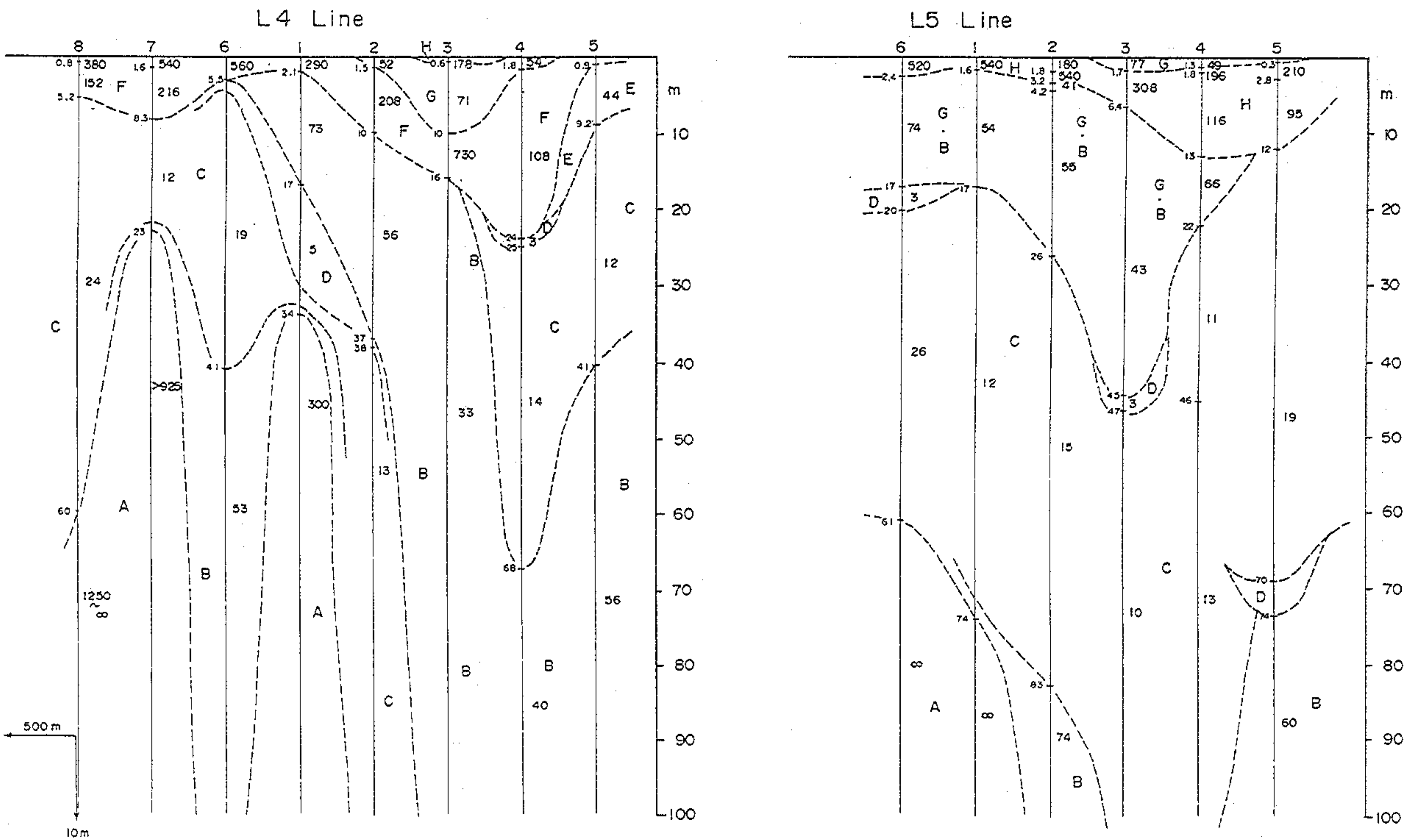

Fig. 4-7 ELECTRIC PROSPECTING SECTION IN SANYA RIVER AREA (3/6)

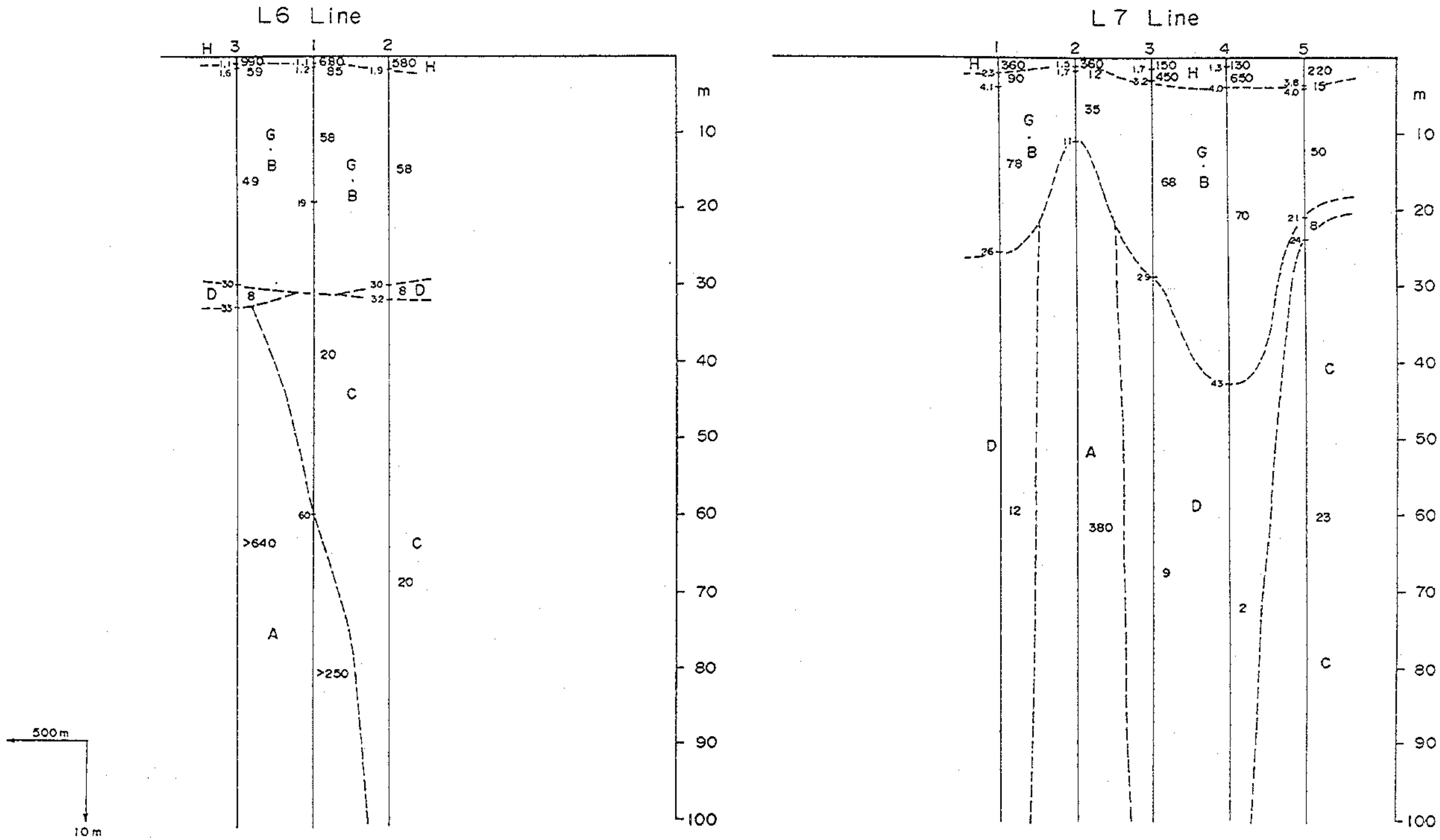

Fig. 4-7 ELECTRIC PROSPECTING SECTION IN SANYA RIVER AREA (4/6)

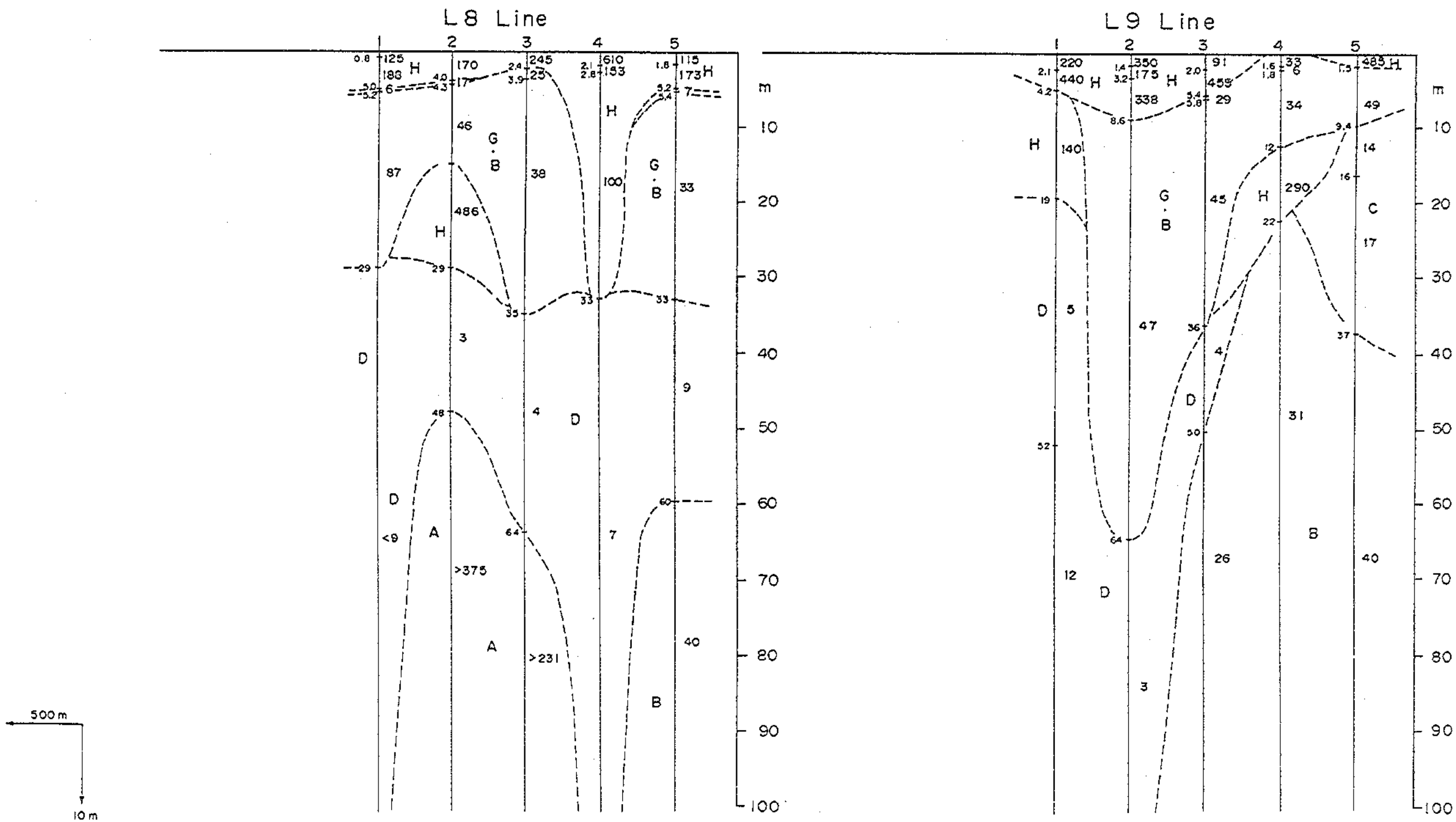

Fig. 4-7 ELECTRIC PROSPECTING SECTION IN SANYA RIVER AREA (5/6)

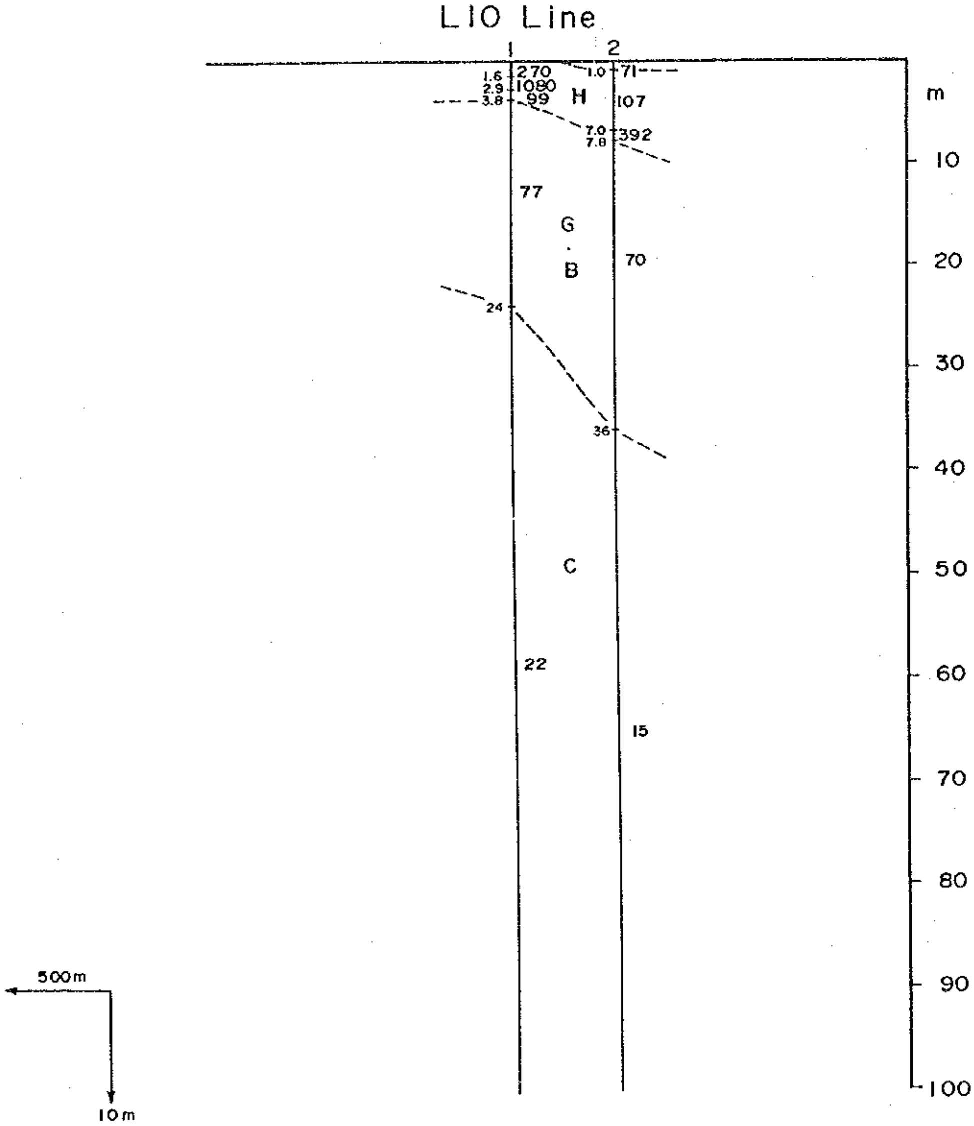

Fig. 4-7 ELECTRIC PROSPECTING SECTION IN SANYA RIVER AREA (6/6)

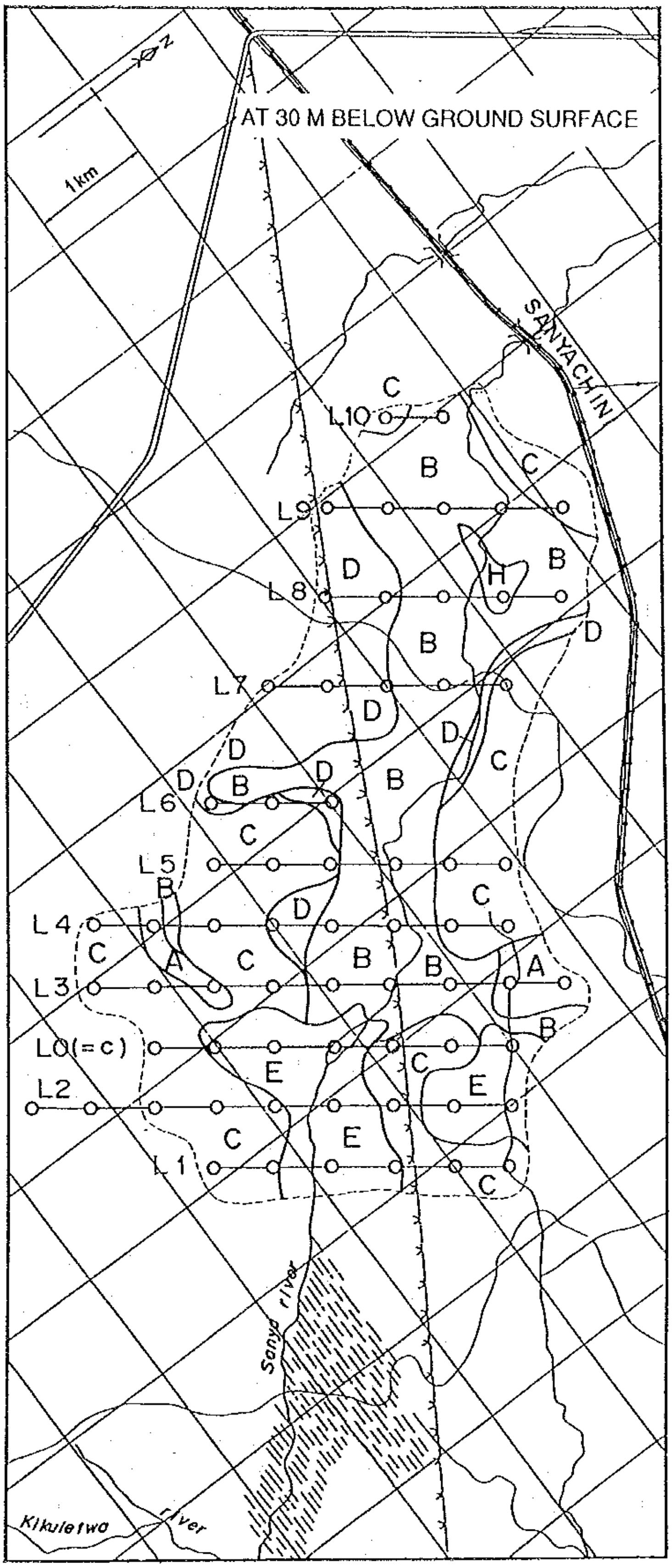

Fig. 4-8 RESULTS OF ELECTRIC PROSPECTING IN SANYA RIVER AREA (1/3)

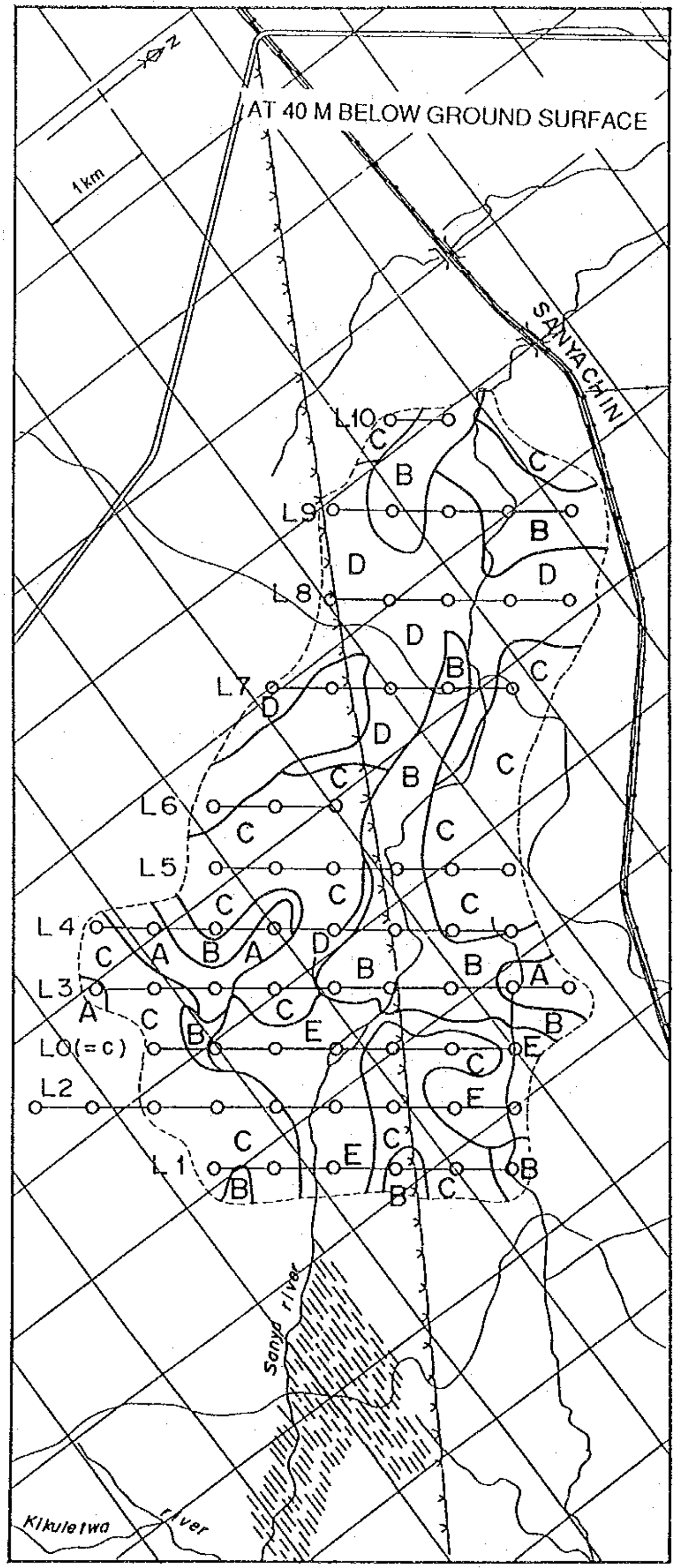

Fig. 4-8 RESULTS OF ELECTRIC PROSPECTING IN SANYA RIVER AREA (2/3)

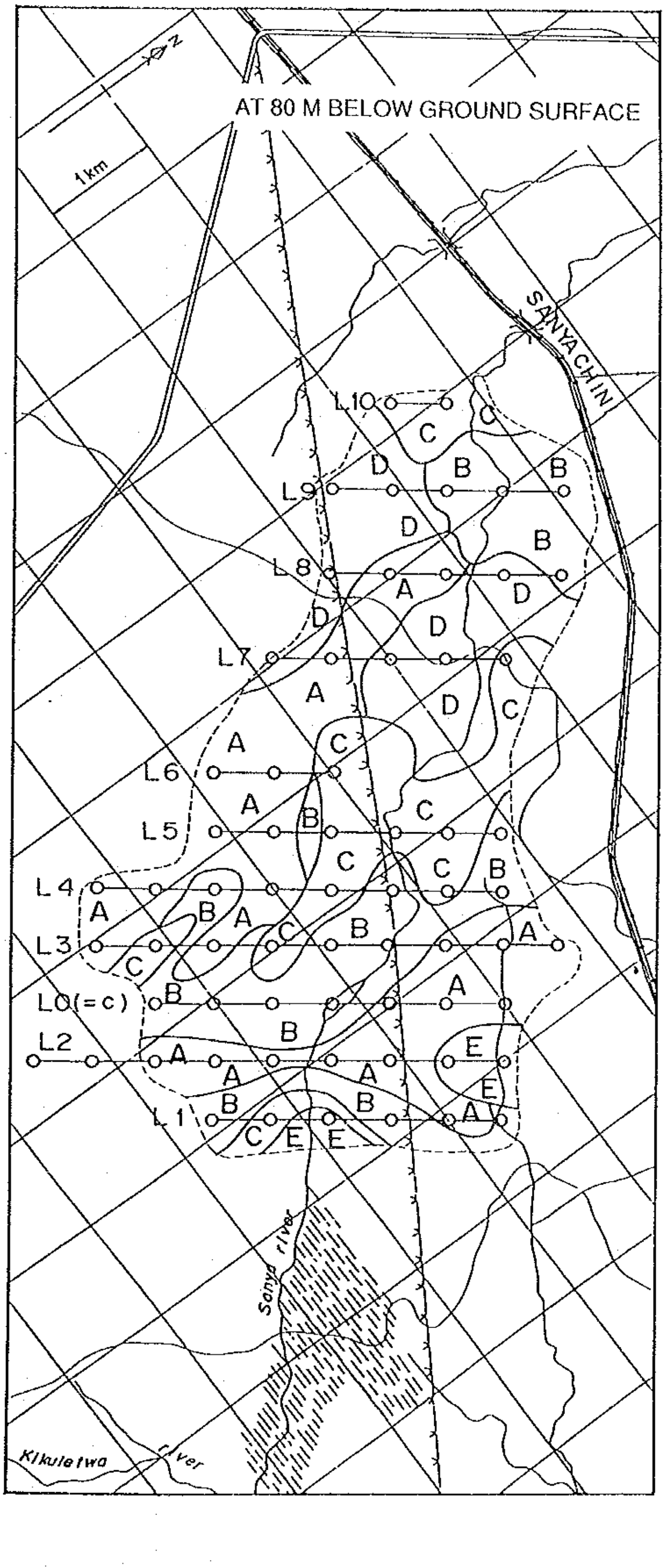

Fig. 4-8 RESULTS OF ELECTRIC PROSPECTING IN SANYA RIVER AREA (3/3)

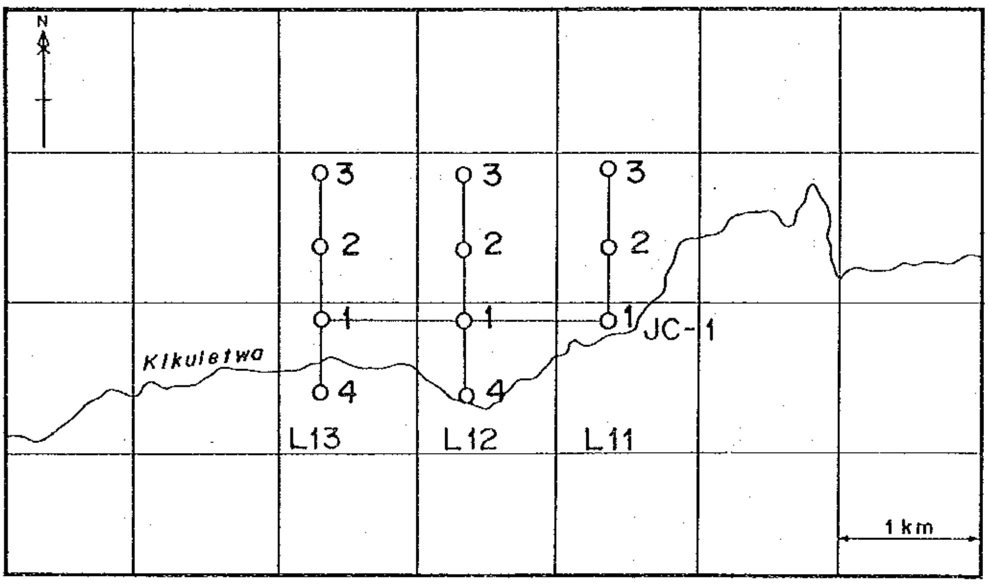

Fig. 4-9 SITE OF ELECTRIC PROSPECTING IN KIKULETWA RIVER AREA

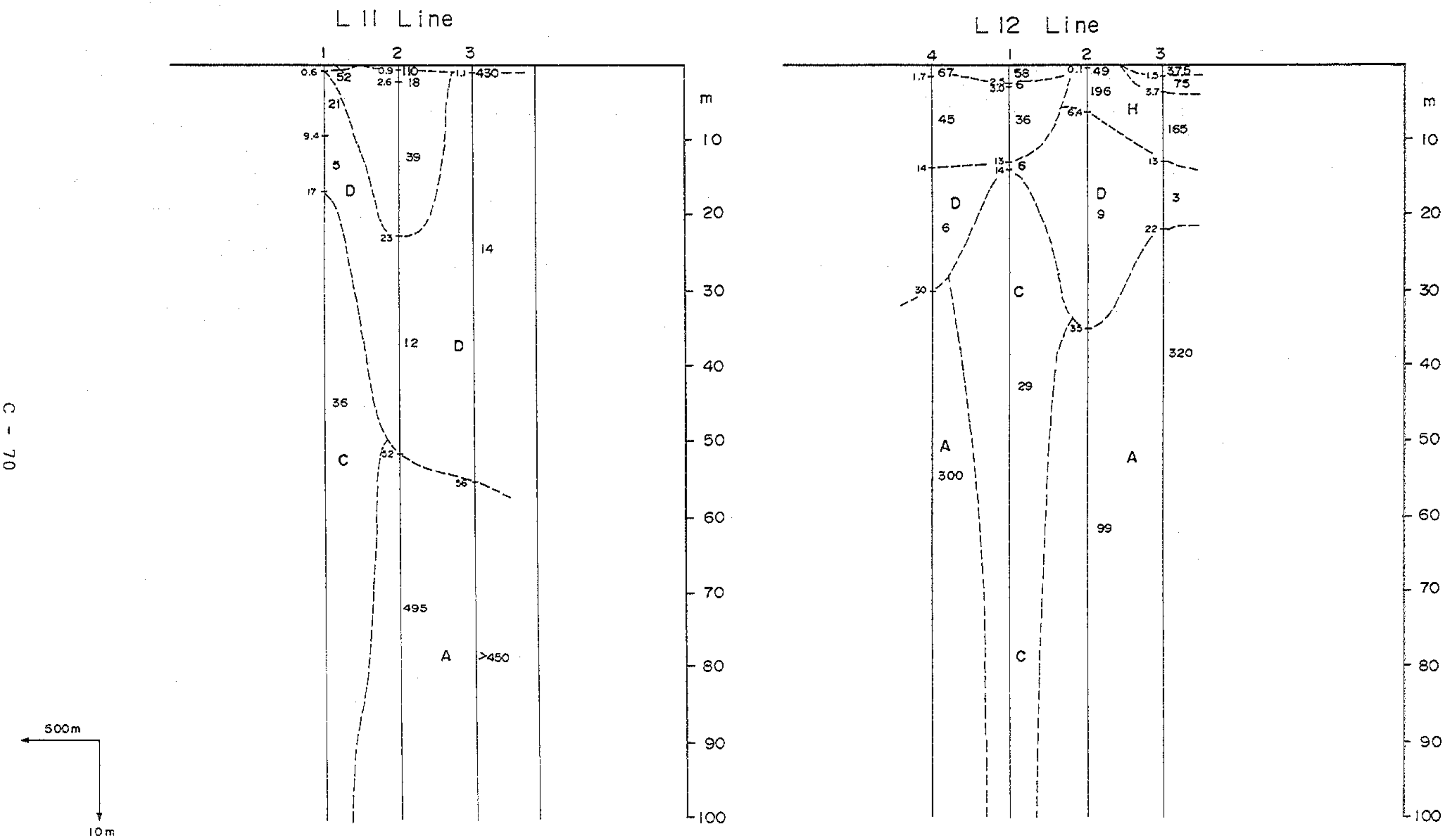

Fig. 4-10 ELECTRIC PROSPECTING SECTION IN KIKULETWA RIVER AREA (1/2)

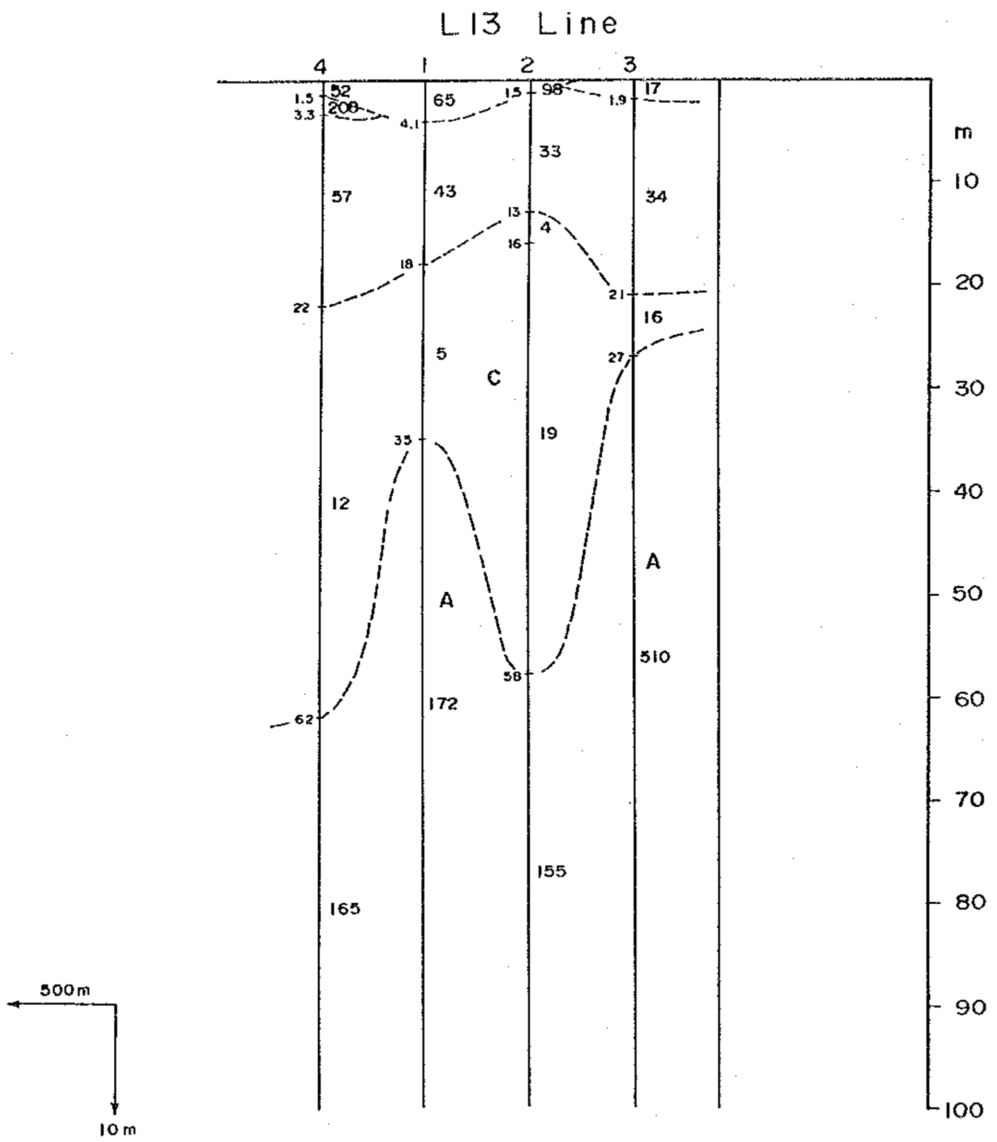

Fig. 4-10 ELECTRIC PROSPECTING SECTION IN KIKULETWA RIVER AREA (2/2)

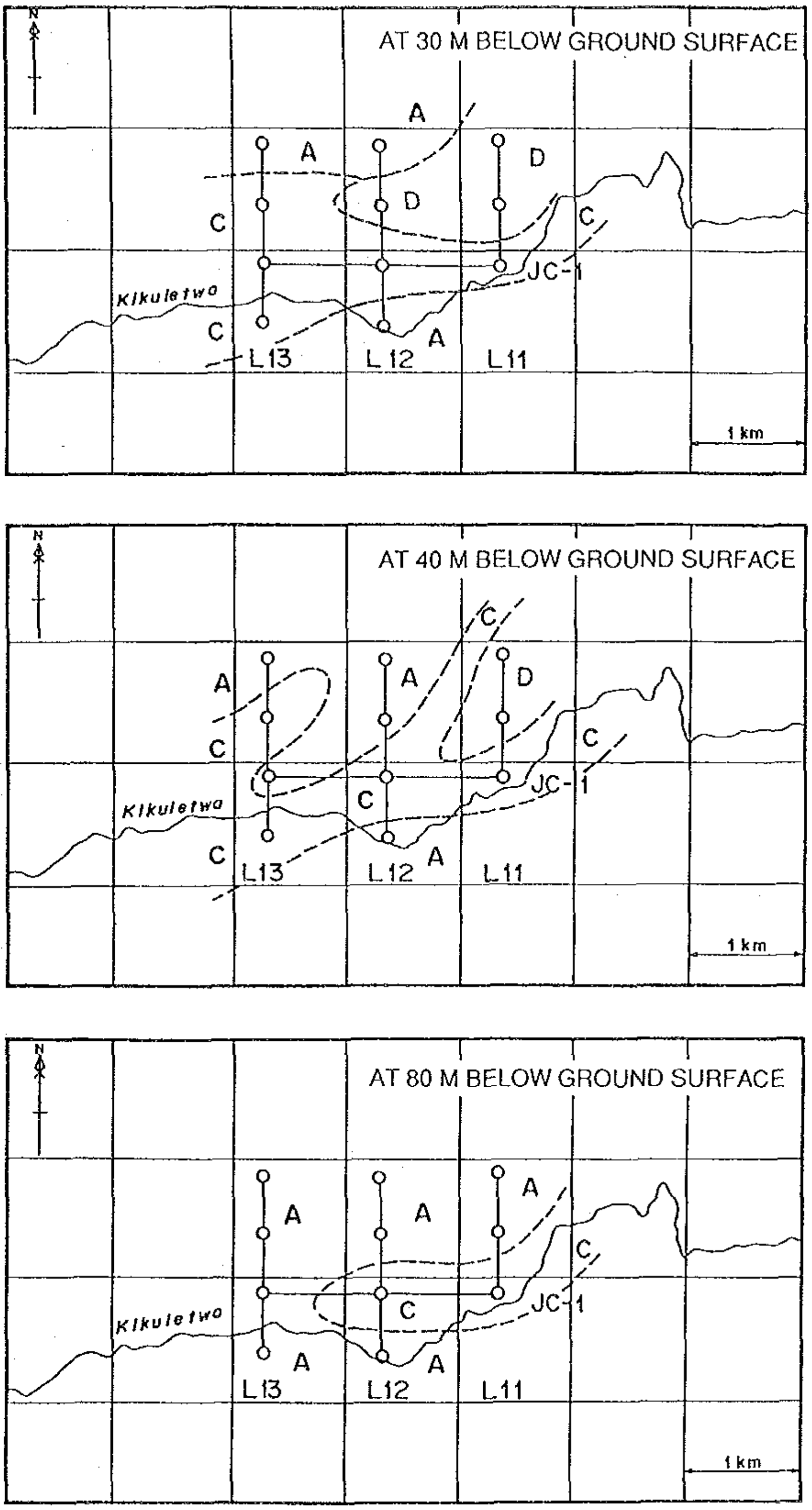

Fig. 4-11 RESULTS OF ELECTRIC PROSPECTING IN KIKULETWA RIVER AREA